DEVELOPMENT OF AN IT-BASED TOOL FOR PORTFOLIO ASSESSMENT AND MANAGEMENT FOR CONSTRUCTION COMPANIES

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ABSTRACT

DEVELOPMENT OF AN IT-BASED TOOL FOR PORTFOLIO ASSESSMENT AND MANAGEMENT FOR CONSTRUCTION COMPANIES

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Development in the construction industry has leaded most of the construction companies to undertake more complex projects than before, which are generally executed concurrently. Therefore, project management routines of the companies may not support effective management of multi-projects. Project portfolio management approach has been suggested to meet requirements for coordinating multi-projects to meet strategic objectives under limited resources. Since project portfolio management requires a comprehensive multi-criteria evaluation process, tools and methods to facilitate decision-making at the portfolio level are needed; however, there have been limited studies responding to this need in the construction industry. This study aims development of a practical decision support tool for construction companies to enable them manage their projects as a part of a portfolio and conduct analysis at the portfolio level. A tool (COPPMAN) has been generated based on the requirements identified through literature survey on project portfolio management and explorative studies with construction company professionals in Turkey. It is capable of capturing and utilizing project knowledge, conducting analysis of portfolios considering interdependencies, enabling selection of the best portfolio considering strategic objectives of the company and facilitating decision-making by providing visual representations of alternative scenarios. The tool has been validated by usability testing and case study with a portfolio of real projects in a construction company. COPPMAN may be beneficial in adoption of portfolio management perspective for especially medium and large-sized construction companies resulting in competitive advantage in international markets by effective management of multi-projects.

Keywords: Construction Projects, Decision Support System, Project Portfolio Management, Project Dependencies, Risk Assessment, Strategic Management

ÖZ

İNŞAAT ŞİRKETLERİ İÇİN BİLGİSAYAR DESTEKLİ BİR PORTFÖY DEĞERLENDİRME VE YÖNETİM ARACININ GELİŞTİRİLMESİ

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İnşaat sektöründeki gelişme, inşaat şirketlerinin çoğunun genellikle eş-zamanlı olarak yürütülen, eskisinden daha karmaşık projeler üstlenmesini sağlamıştır. Bu nedenle, şirketlerin proje yönetimi alışkanlıkları, çoklu-projelerin etkili yönetimini desteklemeyebilir. Proje portföy yönetimi yaklaşımı, sınırlı kaynaklar altında stratejik hedeflerin gerçekleştirilmesinde başarılı olmak için aynı hedeflere hizmet eden farklı projeleri koordine ve kontrol etme gereksinimlerini karşılamak için önerilmiştir. Proje portföy yönetimi kapsamlı bir çok-kriterli değerlendirme süreci gerektirdiğinden, portföy seviyesinde karar vermeyi kolaylaştıracak araçlar ve yöntemler gereklidir; ancak, inşaat sektöründe bu ihtiyaca cevap veren sınırlı çalışma yapılmıştır. Bu çalışma, inşaat şirketleri için projelerini bir portföyün parçası olarak yönetebilmelerini ve portföy düzeyinde analiz yapabilmelerini sağlayacak kullanışlı bir karar destek aracının geliştirilmesini amaçlamaktadır. Proje portföy yönetimi ile ilgili literatür taraması ve Türkiye temelli inşaat şirketi çalışanları ile yapılan keşif çalışmaları sonucunda belirlenen gereksinimler doğrultusunda bir araç (COPPMAN) geliştirilmiştir. Araç, proje bilgisini kaydetme ve kullanma, ilişkileri göz önünde bulundurarak portföylerin analizini yapma, şirketin stratejik hedefleri göz önünde bulundurularak en iyi portföyün seçilmesini sağlama ve alternatif senaryoların görsel sunumunu sağlayarak karar vermeyi kolaylaştırabilme yeteneğine sahiptir. Aracın kullanılabilirlik testi ve bir inşaat firmasında gerçek proje portföyü ile vaka çalışması ile geçerliliği sınanmıştır. COPPMAN özellikle orta ve büyük ölçekli inşaat şirketlerin çoklu-projelerin efektif yönetilmesini sağlayarak uluslararası pazarda rekabet avantajı kazanmasını sağlayacak portföy yönetimi perspektifini benimsemesinde faydalı olabilir.

Anahtar Kelimeler: İnşaat Projeleri, Karar Destek Sistemi, Proje İlişkileri, Proje Portföy Yönetimi, Risk Değerlendirmesi, Stratejik Yönetim

To My Family

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

2D	Two-Dimensional
AEC	Architecture, Engineering and Construction
AHP	Analytical Hierarchy Process
AOI	Area of Interest
AOL	American Online, Inc.
AVI	Audio Video Interleaved
CASOS	Computational Analysis of Social and Organizational Systems
CEO	Chief Executive Officer
CII	Construction Industry Institute
CIS	Commonwealth of Independent States
COPPMAN	COnstruction Project Portfolio MANagement
DEA	Data Envelopment Analysis
diMs	Design Interface Management System
DST4P3	Decision Support Tool for Project Portfolio Prototyping
EBSPM	Evidence-Based Software Portfolio Management
EPC	Engineering, Procurement and Construction
EPPM	Enterprise Project Portfolio Management
ESC	Escape Key
EV-Gantt	Earned Value Gantt Chart
FD	Financial Dependency
FDP	Force-Directed Placement Algorithm
GAO	General Accounting Office
IRR	Internal Rate of Return
IPPM	Innovation Project Portfolio Management
ISO/IEC	International Organization for Standardization/International Electrotechnical Commission
IT	Information Technology

JPEG	Joint Photographic Experts Group
KM	Knowledge Manager
LD	Learning Dependency
LinCTool	Learning in Construction Tool
LL	Lessons Learned
NA	Not Applicable
NPV	Net Present Value
OD	Outcome Dependency
OPM	Organizational Project Management
PDF	Portable Document Format
PM	Portfolio Management
PMI	Project Management Institute
PMO	Project Management Office
PP	Payback Period
PPA	Post Project Appraisal
PPM	Project Portfolio Management
PPST	Project Portfolio Selection Tool
RD	Resource Dependency
REDIS	Renovation Decision Support
ROI	Return on Investment
SOM	Self-Organizing Maps
SPSS	Statistical Package for the Social Sciences
SRS	System Requirements Specification
TBL	Triple Bottom Line
TUBITAK	Scientific and Technological Research Council of Turkey
URL	Uniform Resource Locator
V3PM	Value Based Process Project Portfolio Management
VPM	Visual Project Mapping

CHAPTER 1

INTRODUCTION

“Portfolio Management” as a process and a perspective has been first utilized in the finance sector with the intent of managing risks of individual investments by treating them as a portfolio, namely as a mix of investments. The boundaries of the concept of portfolio management widened with other considerations such as strategic decision-making and resource allocation for individuals/enterprises which require a holistic analysis on the initiatives to be undertaken and their effective management. Application of this perspective to the project-based industries has recently been adopted with the intent of management of projects as portfolios, namely set of projects, rather than individual initiatives as it has been conventionally made. Its application in project-based industries has been limited with Information Technology projects and Innovation projects. Its use in project-based industries is widely appreciated when the advances provided with its link with achievement of strategic objectives is taken into account. Traditional project management (or single-project management) has been structured to meet requirements of projects’ scope, time, cost, quality, risks and such. However, portfolio management has the potential to extend the capability of management through combining the operational and business strategies. By this way, portfolio management can act as a bridge between corporate strategies and projects, which may result in not only effective management of projects in the portfolio but also achievement of enterprise strategy (Clegg et al., 2018; Wu et al., 2013). In the light of these, with portfolio management perspective, main focus can be shifted to top-down approach by “which projects to choose” rather than down-top focus adopted by “how to manage projects” view of the traditional project management (Sun et al., 2010). Thus, portfolio management enables companies to make project selection in line with their strategic objectives and to manage their projects in line with these goals. The projects take place in the portfolio with the contribution to the company strategy and the existing resources are allocated among the projects in the direction of the strategies. This leads to a project portfolio that is strategically appropriate and makes more efficient allocation of the limited resources between these projects. As a summary, portfolio management has the potential of creating competitive advantage within project-based sectors with its potential benefits in linking the corporate strategy with the resources and projects, improved decision-making and effective management of multi-projects (Costantino et al., 2015; Hadjinicolaou and Dumrak, 2017; Padovani and Carvalho, 2016). This holistic view and integrated approach of project portfolio management require comprehensive evaluations and decision-making with multi-criteria analyses. Therefore, there is a need for portfolio management tools and techniques to serve on various purposes in this area. As one of the project-based industries, the construction industry also needs adoption of portfolio management solutions to respond the needs of simultaneous management of multi-projects. From the construction sector standpoint, portfolio management-oriented studies have been very limited. Considering the complex, variable, multi-partied and condition-sensitive nature of construction projects, prospect of a portfolio management tool that may support management of multi-projects can be appreciated (Szalay et al., 2017). Major motivation of this study has been development of a project portfolio management tool for construction companies. The study was held under TUBITAK 1001 Project with Grant No 213M493 with the title of “Development of an IT-based tool for portfolio assessment and management for construction companies”. This chapter presents the introductory information on the context of the study undertaken in terms of “motivation”, “aim and objectives”, “scope”, and “methodology”. The last section represents organization of the thesis.

1.1. Motivation for Research

Construction companies are carrying out temporary one-off undertakings (entitled as “projects”) and the success of a company is believed to be dependent on the success of its projects as in other project-based industries. Main focus in analysis and decision-making (bidding, risk assessment, etc.) has been the “projects” within traditional management routines of the construction companies. However, it is evident that construction companies need to focus on success at the organizational level by considering the company strategies and providing a holistic management on their projects for the sake of the permanent organization rather than only success of temporary projects. As a natural consequence of the recent developments and increasing competition in the industry, projects in the construction sector are becoming gradually complex than before, and construction companies generally have to carry out multiple projects simultaneously. This situation has led an increase in the burden of project management of construction companies and the traditional project management methods in use are also becoming inadequate since they are responsive for decision-making at the “project level”. The selection of projects according to only their expected returns in the pre-bidding phase and not taking into account other factors such as strategic objectives, external factors, capabilities, etc., may lead to ignorance of projects that would be appropriate for the company's mission and provide long-term value for the company (Masoumi and Touran, 2016). Additionally, projects are generally executed simultaneously, and there may exist dependencies between these projects due to shared resources, similar technical requirements, physical locations, contractual agreements and similar external environment. Therefore, evaluation and decision-making considering all the projects at hand is required since they have interactions among each other. At this point, project portfolio management consideration, which focuses on managing projects with a holistic perspective, could be a solution for the sector. With this management approach, instead of making decisions based only on project-based targets, companies aim at achieving company strategic objectives and efficient use of company resources by evaluating and undertaking projects of the company as a whole. Decisions made at the single “project level” may bring problems at the “portfolio level” (Martinsuo et al., 2014), therefore “portfolio level” analysis and decision-making are required for the selection and effective management of the right projects for the organizations (Baptestone and Rabechini, 2018; Meifort, 2016). Portfolio management provides; making more successful choices by eliminating the projects through the strategy filter, making decisions regarding company strategies and using existing resources more efficiently (Canbaz and Marle, 2016). Keeping past, current and potential projects in a portfolio; reflects the strategy pursued, as well as offers the opportunity to develop a portfolio in the direction of new strategies. While the project management objectives are constrained with the duration of a project, a portfolio of all projects will provide opportunity for the company to have a lifetime of long-term strategic development (Project Management Institute, 2013). Thus, projects need to be evaluated within a “portfolio” perspective and managed at the “portfolio level” as it has been widely discussed in the literature (Collyer and Warren, 2009; Elonen and Artto, 2003; Rungi, 2010a).

“Portfolio management” has first emerged in the finance industry, where allowing diversity in selection of the investments could result with more valuable investment combinations at the identified risk level. Hence, financial portfolio management depends on the idea that rather than examining investments one by one, they should be evaluated as a whole within a portfolio. Adoption of this idea through project-based industries has recently took place with further considerations regarding projects. The “project portfolio management” consideration has firstly emerged in management of information technology projects. Additional focus on other project-based measures such as employee safety, customer satisfaction, business partnerships, and company capacity is required for successful evaluation of project portfolios specifically pursuant to characteristics of project-based industries (Sun et al., 2010). The term “portfolio” to be used in these industries simply refers to collection of single projects that are consuming the same resources and executed under management of an organization (Kock et al., 2016). Thus, project portfolio management should be related with identification of shared demand between the projects and allocation of the available resources considering the projects at hand and situation/capability of the organization (Project Management Institute, 2013). Project Management Institute (2008a) defines project portfolio management as, “the centralized management of one or more portfolios, which includes identifying, prioritizing, authorizing, managing, and controlling projects, programs, and other related work to achieve specific strategic business objectives”. Therefore, major aim of portfolio management is to maximize contribution of each project in the portfolio to the organizational success. Project portfolio management mainly consists of; measures undertaken to ensure that the resources available are allocated in a balanced way in line with the priorities of the projects by making choices according to the determined strategy. At this point, portfolio management differs from single project management by targeting primarily investment in the right projects, rather than managing projects correctly (Project Management Institute, 2013). Project portfolio management provides a bridge between the intended strategy and projects, enabling projects to be selected and managed in accordance with the established strategies (Clegg et al., 2018). Through performance measurement, priorities of projects can be changed, projects can be stopped and new strategies can be developed. Thus, the portfolio can be eliminated from the projects that do not serve for strategic purposes and the maximum portfolio value and portfolio balance can be established (Kendall and Rollins, 2003). Thus, portfolio management is simply the contemporaneous management of projects that depict the investment strategy of an organization (Kock et al., 2016), it mainly creates and maintains the link between formulation and implementation of the organizational strategy (Clegg et al., 2018; Kopmann et al., 2017; Meifort, 2016).

A portfolio management process basically involves the sub-processes of identifying, categorizing, evaluating, selecting and prioritizing projects in line with strategic objectives. In addition to these processes, ensuring portfolio balance, ensuring interdisciplinary communication and distributing authorities, measuring portfolio performance and reflecting the strategies to the portfolio constitute the main considerations of portfolio management (Project Management Institute, 2013). Special attention may be required on strategic matters such as successful strategic alignment, adaptability to internal and external changes, and execution of projects with high value/benefit. Additionally, operational requirements should also be of concern such as, ensuring project visibility, transparency in portfolio decision-making, and predictability of project performance (Patanakul, 2015). It is a complicated process since it requires dealing with various parameters, which need to be taken into account in analysis, such as strategic objectives, financial returns, project performance, demand conditions, resources, capabilities, risks and other similar parameters (Levine, 2005; Martinsuo et al., 2014). Therefore, tools and techniques are required to go through these comprehensive evaluation and management processes of portfolios. The need for development of methods and tools to support portfolio management is widely emphasized in the literature (Babayev, 2017; Cooper et al., 2001; Levine, 2005; Masoumi and Touran, 2016). In summary, portfolio management requires extensive investigation and complete control of the contribution of the projects that can be undertaken, the state of the existing resources, the company's objectives and the external factors on the projects. Therefore, with adoption of portfolio management principles and successful execution of portfolios, decision-making about project investments may become coordinated, risk and resources may get balanced and the value of the project portfolio may be maximized (Kopmann et al., 2017). A management understanding that will be implemented in this way can provide an opportunity for the companies to achieve sustainable success and competitive advantage in project-based industries (Blismas et al., 2004; Wu et al., 2013; Kock et al., 2016; Meifort, 2016; Padovani and Carvalho, 2016). Studies held in portfolio management area are generally focused in investment, technology management, innovation and research and development projects; however, construction industry related studies have been very limited in portfolio management literature (Vergara and Boyer, 1977; Kangari and Boyer, 1981; Han et al., 2004).

Although the construction sector, where strategic execution of multi-projects is considerably needed, is one of the potential industries for portfolio adoption, there have not been enough work held in this respect. Despite the fact that the project portfolio management understanding is appreciated with the potential benefits to the construction sector, studies focusing on this issue have been very limited (Abbasianjahromi and Rajaie, 2012). There has been no practical solution to support the companies for managing their portfolios. This situation shows that, the current routine is not capable to meet the requirements of large multi-project portfolios of construction clients. The work done by the Construction Industry Institute (CII) (2015) highlighted the need for a comprehensive and objective method for project selection. In addition to companies' resources and budget constraints, a method should be developed to ensure that portfolio projects are selected according to company objectives, while taking into account global risks (Masoumi and Touran, 2016). As long as the multi-partied, variable and complicated nature of construction projects is taken into consideration; the importance of such study would be appreciated. Rather than adoption of single-project management techniques for management of portfolios, techniques tailored to portfolio management are required. Success with traditional methods is limited, so adoption of portfolio management procedures in construction industry is essential and there is a need for an effective solution that would also address the current issues in portfolio management literature (Blismas et al., 2004). Therefore, this study aims to present an attempt for construction industry by development of a portfolio management tool for construction companies.

Various methods and tools have been developed to serve for different purposes and support the different phases of the project portfolio management process in several industries. Investigation of provided attempts considering tools on project portfolio management shows that, dealing with project dependencies has been an issue in portfolio management. In most of the studies, project dependencies are not completely handled, namely some of the studies are evaluating the dependencies in a subjective way and the others are already neglecting them (Killen and Kjaer, 2012; Neumeier et al., 2018; Rungi and Hilmola, 2011). Since portfolio management is focusing on achievement of success in multi-projects, relationships/dependencies between the projects should be at most importance (Bathallath et al., 2019). Therefore, portfolio success is considerably dependent on identification of dependencies between projects and generation of strategies accordingly (Elonen and Artto, 2003). Sound evaluation of project dependencies and consideration of them in portfolio management process is required for achievement of a successful portfolio management (Verma and Sinha, 2002; Rungi, 2010b; Bathallath et al., 2016). Rungi (2010a) underlined the importance of evaluation of dependencies between projects to achieve portfolio success and investigated the knowledge on dependency evaluation between company professionals. The results show that the professionals are aware of the importance of dependencies between projects; however, they are not capable of their evaluation due to lack of user-friendly evaluation techniques. Considering this situation, studies on more efficient, practical and user-friendly evaluation methods for dependencies are highly appreciated in portfolio management (Rungi and Hilmola, 2011).

Importance of evaluation of dependencies between projects has been considerably mentioned in the literature; however, there has not been a comprehensive study held that is focused on evaluation of dependencies (Bathallath et al., 2019; Neumeier et al., 2018; Rungi and Hilmola, 2011). The available studies generally consist of subjective evaluations as self-reporting methods, optimization methods, and visual representation based methods (Rungi, 2010a). Between these methods, visualization of dependencies has been accepted as the most efficient method for the evaluation; and this situation has leaded studies that are more focused on visual representations. Although these visualization methods have been accepted to be contributing to more realistic evaluation of portfolios, they still have some limitations. The dependencies of projects are generally shown through 2x2 matrix representations; however, these representations are not capable of depicting multi-level dependencies between projects. They are capable of pairwise dependency analysis between projects and not capable of representing accumulated effects between projects. For example, in case of a dependency of project A to B, and Project B to C, this method is not able to evaluate the effect of Project A to C (Killen and Kjaer, 2012). Accordingly, problems in dependency evaluation between projects is a drawback of available portfolio analysis methods (Elonen and Artto, 2003). Therefore, methods that will be capable of quantification of dependencies between projects of portfolios and inclusion of these in decision support systems are crucial (Aritua et al., 2009).

Killen and Kjaer (2012) proposed that use of Visual Project Mapping (VPM) can provide the evaluation of multi-level dependencies between projects. VPM enables the visualization by “network maps” through “nodes” as projects and “arrows” between them as relations. These network maps generally have the ability to record and analyze the relations, and to represent the relations graphically. This advantage of network maps can provide more realistic evaluation of relations when it is compared to existing matrix representations (Hanneman and Riddle, 2005). Network maps constitute the basis of many decision support systems; however, their use in portfolio management focused studies have not been held yet. Killen and Kjaer (2012) provided initials of this kind of study and presented a network map that shows the dependencies between projects. First, they identified the dependencies between projects and provided that in case of presence of a project success that is dependent on other projects, it can be stated that there exists a relationship between these projects (Killen and Kjaer, 2012). Therefore, projects may share many resources and may have common objectives to be accomplished. There can be a “resource”, “outcome”, “market/benefit”, “financial”, or “learning” dependency between projects (Verma and Sinha, 2002). They categorized these dependencies as “less important”, “important” and “critical” on the importance basis. Additionally, they define dependency types as “outcome”, “learning”, “resource” and “other” dependencies. Accordingly, they constructed a representational network map for a set of projects and validated the capability of their use in dependency management between projects by company professionals. Since the study was focused on visualization of dependencies, the dependencies were subjectively quantified in the provided example and future work was underlined to be possible improvements in the provided network map. This study constitutes the most manageable approach as a successful origin for handling dependencies in portfolio management.

As a summary, need of a portfolio management tool in construction industry has been identified and this granted research project aims generation of a tool as a response to this need and current issues identified in portfolio management. Specifically, handling of project dependencies is one of the major drivers of project portfolio management success; however, current efforts have been criticized for being incapable of assessment of multi-dependencies. Consequently, generation of a decision support tool that will be capable of mathematical assessment and visual depiction of dependencies between projects is aimed in this study. Within this context, development of a conceptual model in which relations between construction projects can be determined, a measurement method that can calculate relationships, and a tool that can make use of them in risk management, resource sharing and corporate learning is aimed. An intelligent tool is planned to be designed that would be able to calculate dependencies between projects numerically, to define dependencies visually, and to guide the user in portfolio management and selection. In the light of the above literature information; the primary goal of the study; is to develop a tool that will enable large-scale construction companies, especially those operating in international market, to manage project portfolios in the best possible way. The tool will provide visualization of the project portfolio and it will be an intelligent tool that can offer guidance in management of the risks considering the dependencies between the projects, resource sharing and inter-project learning opportunities. For this purpose, a conceptual model and measurement method will be developed to deal with the dependencies in portfolio management, and a tool will be designed to visualize the portfolio and support management decisions. In brief, the tool will be "visual" to depict the portfolios and dependencies between projects, will be "dynamic" since it will be adaptable to changing external circumstances (updating) and will be "intelligent" as it will be capable of generating and suggesting strategies (using knowledge) for management of construction portfolios.

1.2. Research Aim and Objectives

In the light of the presented research background, this 2.5 year granted research project hypothesized that generation of a portfolio management tool could respond to the current need of construction companies for effective management of contemporaneous projects that will also serve for strategic management of the companies. Therefore, “research aim and objectives” can be listed as follows within the context of identified “research problem”.

Research Problem: traditional project management in construction industry is weak in handling projects managed simultaneously due to lack of reliable/appropriate portfolio assessment/management framework in construction engineering context.

Research Aim: is to develop portfolio management tool for construction organizations that would be designed to be specific to need and practical, and to evaluate the applicability of portfolio management principles in construction organizations. More specifically the aim is development of the tool with the help of input from construction professionals by drawing the main support from a large global engineering and construction company as a “focus group” for identification of problems and possible solutions through in depth investigation and supporting the overall process by maintaining contributions of various professionals to ensure a wider perspective on the study. Since there have been no effective solution for portfolio management application in the industry or no prior research existed on designing such portfolio management tool for construction organizations, the research aim is also serving for the class of field problems as “portfolio management for construction organizations”, which may generate a benchmark study for the further studies to be held on the issue.

Research Objectives: that are serving for the stated aim can be listed as;

1. **Exploratory aim:** to investigate and identify the current problems and the need for portfolio management applications in the construction organizations: identification of problems that require change as problems either anticipated by researchers (literature survey) or perceived in practice (surveys with company professionals)
2. **Constructive aim:** to generate a process model and a solution as a tool for portfolio management utilization in construction organizations: the tool can support portfolio management for the construction companies working internationally and it will provide visualization of the portfolio with the relations between projects; accordingly, sub-objectives of the tool generation objective can be stated as:
   i. to develop a conceptual model that will enable identification of dependencies between projects and management of portfolios by taking these dependencies into consideration
   ii. to establish the method of measurement (measurement model) that will provide quantification of dependencies, and
   iii. to generate an intelligent tool that will measure the dependencies between projects, visualize the dependencies in different categories, and direct the user as a decision support tool for risk, resource and learning management at the portfolio level according to the obtained dependencies.
3. **Empirical aim:** to test feasibility of the generated solution by usability testing and actual implementation in a construction organization (case study)

1.3. Research Scope

Within the context of the research project, a tool has been generated (COPPMAN - COnstruction Project Portfolio MANagement) that would meet the requirements of construction companies in management of their portfolios. The study is based on identification of the requirements through literature survey and studies held with company professionals from leading Turkish construction companies. The tool is designed to be utilizable for all types of construction projects and has adjustable options to be adapted according to company specific requirements and preferences. It will accepted to be serving for the purpose as long as it integrates a valid process model and usable tool architecture in addition to its successful utilization on real project portfolios. The tool is believed to help professionals of medium to large-scaled construction companies, especially those undertaking projects in the international market, since they would be the ones establishing portfolios.

The research project also paved the way for another research study, which has been undertaken contemporaneously, as a separate design for one of the functions embedded in COPPMAN. The "Corporate Memory" function, which is focusing on the management of "lessons learned" in a construction company, has been generated as another tool (LinCTool - Learning in Construction Tool) with its potential value in utilization by construction companies regardless of establishment of portfolios. The details of this study is beyond the scope of the current study, but the study (Eken, 2017) will be referred with minor details as long as it is required within the full extent of the overall study.

1.4. Research Methodology

The main motivation of this research study has been development of a practical portfolio management tool for construction companies to meet their current need for transforming their project focused management perspectives to portfolio focused initiatives. Since the study is based on an observed problem and aims generation of a product that would be beneficial for construction company professionals, early integration of the company professionals to the development process can result in more successful end-product. Therefore, research methodology followed in this study constitutes joint effort of researchers and construction company professionals. The study has proceeded in three stages where developments have been either obtained with this joint effort or achieved by the research team and evaluated by the company professionals. The "focus group" has made significant contribution and in depth analysis starting with the early stages of the study and followed the improvement of the study in each main stage. The employed methodology is structured around three main research task groups as:

1. Needs Analysis,
2. Development of the Process Model, and
3. Development of the Tool.

The point of departure of this research study has been investigation of the literature first on "portfolio management" for establishing the fundamental issues and then "project portfolio management tools" for identifying the main requirements of a tool architecture. The obtained information has been supported with evaluation of the portfolio management initiative of a global construction company through surveys on the initial requirements. The "Needs Analysis" has been carried out in the light of the following research questions:

- What are the essentials of portfolio management, what the literature says?
- What are the main properties of portfolio management tools?
- How the construction company adopts portfolio management, what are its deficiencies?
- How should be the process model of portfolio management for construction companies?
- What should be the properties of the tool?

Following identification of the requirements through the "Needs Analysis", "Process Model" has been generated at the end of an iterative process where further literature study, brainstorming, and surveys among construction company professionals have been held. The questionnaire conducted on identification on some functional requirements has provided contribution of a broad range of professionals. The model has been substantially constructed following illustration of the process through a numerical example (paper prototype). Based on this initial model, the “modules” and “requirement specification” of the tool have been identified and these have been validated through surveys with the company professionals from the selected construction company as a focus group study. The alpha version (first release) of the tool has been coded by a professional software company at the end of an iterative process of “Tool Development” where the versions of the tool have been verified by the research team through black-box testing methods and charrette test with the numerical example. The final details of the process model have been reformed with the capabilities integrated by implementation of the model in the machine environment. The opportunity opened up by the software company has finalized some of the details in question. The process model and the tool have been restructured through the study on its face validation by an expert panel consisting of two academicians and two company professionals. The panel has been made to include both academicians and practitioners (out of the research study) to establish the link between the overall study as a joint effort of researchers and practitioners. Therefore, there has been an opportunity for objective evaluation of the methodology of the study together with the usefulness of the tool. The tool has been improved according to the feedback obtained in this study. Pilot testing has been made with different company professionals as the trial of the studies its actual utilization before release of its beta version. This study has provided an overall evaluation of the tool as well as opportunity for testing of the surveys that would be held in usability testing and actual implementation. The study has provided evaluation of the initial test results and resulted in small improvements in the tool. As the final attempts for its evaluation, first the tool has been tested for its usability in a lab environment with selected participants as its potential users to obtain data on its performance by using a special technology which would not be possible to obtain otherwise. At the end of usability testing, there has been no requirement for an update due to successful results obtained. Therefore, the updated alpha version is accepted to be the beta version of the tool and as a final validation, the tool has been utilized in the selected construction company by construction professionals (focus group) with a real case of portfolio. The evaluation studies demonstrate that the tool has been generated following a sound needs analysis and model development processes, and it has been validated by its users for its potential benefits. The capabilities integrated with the help of technology and full realization of the tool has led to further considerations for its improvement together with direct utilization in the company through a real portfolio. A final update of the tool has been performed following the actual implementation in the company and its verification has been made by the research team. As it is presented in the methodology, the tool has been generated and tested with involvement of company professionals in different stages. The initial evaluations of the tool indicate the first signals of its potential success; however, actual benefits can only be observed with its adoption and utilization by construction companies.

1.5. Organization of the Thesis

Further details of the introduced research study are provided under forthcoming chapters of the thesis. Within this context, “Chapter 2” presents the literature survey held for the needs analysis. “Chapter 3” explains the details of the methodology undertaken. “Chapter 4” reveals the stages of tool development process starting with the requirements identified in the needs analysis and extending to release of the updated alpha version. “Chapter 5” presents the tool, COPPMAN, in its latest version for usability testing. “Chapter 6” depicts the findings of the usability testing process. “Chapter 7” presents the details of implementation process within the construction company and the update required. Finally, “Chapter 8” concludes the study with presentation of outcomes of the study and possible future work.

CHAPTER 2

RESEARCH BACKGROUND

This chapter expands the introduced gap in the literature for reinforcing the aim of the study. It presents the fundamentals with portfolio management and its solutions as the foundations of the study while highlighting the issue of dependency assessment in portfolio management as the initial requirement to respond. Following that, the chapter focuses on the relevant research in the construction industry for reinforcing the need and shaping the potential areas of progress as well.

2.1. What is Portfolio Management?

This section starts with introduction of the fundamentals of “portfolio theory” in the financial field and its transition to “project portfolios”. The concept of portfolio is provided in detail starting with its “definition” and with the basics of its “management”. The difference of “portfolio management” from “project management” is explained to convey its meaning and extent clearly. Basic “processes of portfolio management” are presented to provide the breakdown of its typical implementation. The link between “portfolio management” and the “strategic planning” is underlined in the following section since strategy constitutes one of the drivers of portfolio management. Additionally, “goals of project portfolio management” is presented. The section is finalized with the information focused on outcomes of portfolio management in terms of "successful project portfolio management" and "benefits of project portfolio management".

2.1.1. Fundamentals of Portfolio Theory

Around 1950's Harry Markowitz achieves a revolution in financial investing with the theory known as "modern portfolio theory". Markowitz points out that, greater return at lower risk can be obtained by evaluating the risk of the portfolio as a whole rather than investigating their individual potential ("Lee Merkhofer Consulting I", n.d.). Sun et al. (2010) explain the theory in a simpler form with the recall of the idiom "*don't put all your eggs in one basket*" and draws the attention on "diversification" in investment that can mitigate the risks considerably. When it comes to what lies behind this theory, the "portfolio efficient frontier" discovered by Markowitz should be mentioned. Markowitz defines the portfolio risk as the standard deviation of the current returns. Therefore, when the selection is made through the assets that are not perfectly positively correlated, risk of the portfolio can be lowered while maintaining or increasing the expected return. Accordingly, minimum risk for a given level of return, or maximum return for a stated level of risk constitute "the portfolio efficient frontier" as in the following figure (Figure 2.1). This figure provides "annual return" against "annual risk" and depicts efficient portfolios through the limit as the frontier (blue line) where combinations above the frontier are not possible, whereas the combinations below the frontier are not efficient due to higher risk and lower return (Markowitz, 1952; "Portfolio Optimizer Pro", n.d.).

Selection through the efficient portfolios depends according to the investor's risk tolerance. Accordingly, Markowitz enables investors to select their investment with a better strategy by focusing on the greatest possible value while taking into account the risk. The same reasoning also applies while selecting projects for an organization. Goal of project-based organization is also selecting the risk-adjusted greatest possible value. However, project selection is not limited with risk and return evaluations as in financial portfolio theory; more complex strategies are required during project portfolio selection process ("Lee Merkhofer Consulting I", n.d.).

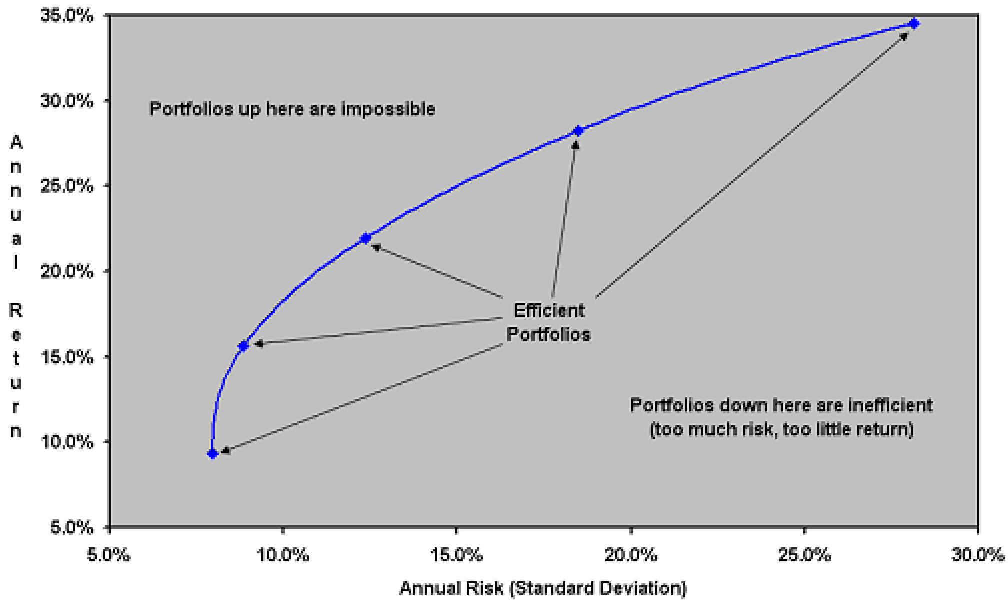


Figure 2.1: Portfolio Efficient Frontier ("Portfolio Optimizer Pro", n.d.)

2.1.2. From Financial Theory to Project Portfolios

Firstly, F.W. McFarlan adapts portfolio approach to projects through risky Information Technology (IT) projects in 1981 (McFarlan, 1981; Sun et al., 2010; Shiwang et al., 2009; ter Mors et al., 2010). The first studies on Project Portfolio Management (PPM) available in the literature are generally focused on project selection. Afterwards, studies focused on prioritization of product selection and multiple project management issues are presented (Miguel, 2006). What differs with project portfolio when it is compared to financial portfolio is there are more expectations from a project rather than the financial savings. The improved cash flows in forms of cost savings or increased revenues are also expected from projects, but there may be other benefits of projects that cannot be expressed financially. A project portfolio may be worthy to undertake with its benefits of improvements in worker safety, customer service, relationships with business partners, organizational capability and such. Therefore, project portfolios differ from financial portfolios with their complex evaluation criteria (Bucher and Min, 2017). Another difference may be the uncertainty related to the returns of projects. Past data on financial investments give some valuable information on the expectations for the value returned from these investments. However, no such data is available to predict the uncertainties with the project investments. Accordingly, difficulties in evaluation of the project value and prediction of the uncertainty constitute the main differences and the difficulty with application of portfolio theory to project investments ("Lee Merkhofer Consulting I", n.d.).

2.1.3. Definition of Portfolio and Portfolio Management

In Merriam Webster dictionary online portfolio is basically defined as "*a set of drawings, paintings, or photographs that are presented together in a folder*". The definition is restructured from the financial point of view as "*the investments that are owned by a person or organization*" ("Merriam-Webster Online", n.d.). When it is considered from the project management perspective, Project Management Institute (PMI) (2013) introduces the concept as "*a component collection of programs, projects, or operations managed as a group to achieve strategic objectives*". A portfolio can be made up of components as projects, programs, sub-portfolios and operations that are either related with each other or independent as in the following figure (Figure 2.2). "Programs" represent group of projects that serve for the same benefits. They are basically sets of projects that are either related by a relationship, or aiming the same goal, or using the same resources. Management of projects under programs brings benefits that would not be possible if they were to be managed individually. Another component of a portfolio may be "operations" that imply the day-to-day organizational activities like production, manufacturing, finance, marketing, legal, information services, human resources, administrative services, and such. These components are quantifiable and so they can be measured, ranked, and prioritized in the process (Project Management Institute, 2013; Schwalbe, 2006).

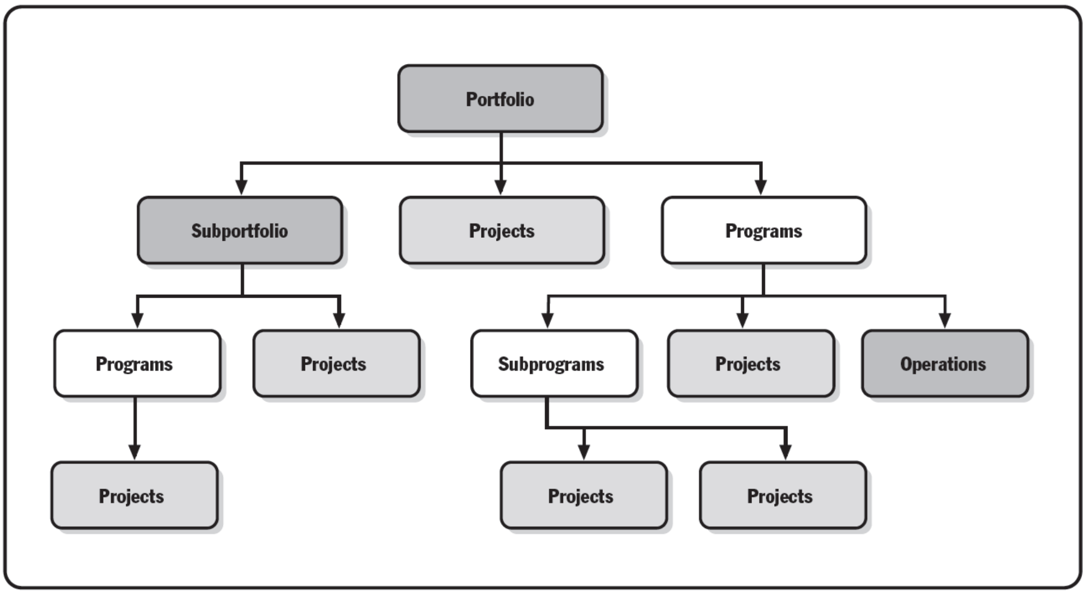


Figure 2.2: Portfolios, Programs, and Projects (Project Management Institute, 2013)

Issues and changes arise during any management process that cause the managers to make a decision at some point. The facts available are investigated in detail and evaluated according to experience of managers and the decision is made accordingly. At this point, Project Portfolio Management enables decisions to be made with strategic thinking in terms of what the organizations want to be and what they should be doing to reach there. Thus, PPM leads management process to be structured according to strategic objectives (Pennypacker and Retna, 2009). Portfolios are made up of any past, present and future components that make them long-term focused rather than their short-term ingredients as projects that are continuously circulating in the portfolio. Any component is identified, evaluated, selected, and authorized according to the objectives. This is how portfolios serve for the strategic thinking. Therefore, at any time, the portfolio presents the intent, direction and progress of an organization through the components in the portfolio. Portfolio management identifies the interrelationship between these components and prioritizes them according to their value and share in meeting the organizational objectives (Project Management Institute, 2013).

Project Management Institute (2008b) defines Project Portfolio Management as,

> "*The centralized management of one or more portfolios, which includes identifying, prioritizing, authorizing, managing, and controlling projects, programs, and other related work to achieve specific strategic business objectives*".

The shared demand between the projects and programs are identified and the available resources are allocated in the light of these components at hand and organizational capability. Thus, the components are selected and structured according to the mission, vision, and values of the organization and are managed in an optimum way. Since portfolio management depicts the current status on how the organization is acting, it also serves valuable information to support or change the strategic objectives and investment decisions of the organization. Therefore, portfolio management not only leads the organization to be strategically aligned, but also enables the organization to restructure its strategy (Project Management Institute, 2013).

Portfolio management can be summarized as follows. It is mainly about (Cooper et al., 1999);

- **Making Strategic Choices:** which markets, products, and technologies our business will invest in,
- **Project Selection:** on which new product or development projects to be chosen from the many opportunities faced,
- **Resource Allocation:** how the scarce engineering, R&D, and marketing resources will be spent,
- **Balance:** having the right balance between numbers of projects to be done and the resources and capabilities available.

To be adequately managed, all components of a portfolio should have common features. The components of a portfolio should (Project Management Institute, 2013);

- "*be representative of investments made or planned by the organization;*
- *be aligned with the organization's goals and objectives;*
- *typically have some common features that permit the organization to group them for effective management;*
- *have the ability to be quantifiable and, therefore, can be measured, ranked, and prioritized; and*
- *share and compete for organizational resources*."

2.1.4. Project and Program Management vs. Portfolio Management

"Project Management" includes and deals with any participant that contributes to project success. Meeting stakeholders' needs and expectations requires integration of different knowledge areas (e.g., scope, time, cost, quality management, etc.) with the tools and techniques available that all together lead to project success. However, successful projects do not always bring enterprise success directly. If the projects do not suit with the strategy of the enterprise, they may not add value even if they are successfully completed. Therefore, consideration of projects under a portfolio concept can actually lead the intended enterprise success. Management of projects as a "portfolio" carries the success from "project level" to the "enterprise level". Thus, successful projects may lead successful enterprises as long as they are managed as a part of portfolios as it is depicted in the following figure (Figure 2.3) (Schwalbe, 2006).

"Project portfolio management" can assist meeting strategic goals and so achieving success at the enterprise level. Use of programs as a group of projects is mainly the concept of managing related projects that serve for the same benefits in a coordinated way rather than managing them individually (Project Management Institute, 2008b and 2013). For example, for a contractor, managing single-family houses, apartment buildings and office buildings together in terms of coordination in staffing, purchasing and such may be stated as a "program" that brings further benefits. Whereas, PPM is rather managing whole "projects and programs" of an enterprise as a "portfolio". In this context, portfolio managers are required to investigate each project from the strategic objectives perspective and to analyze their individual effects to the overall enterprise success. Therefore, PPM focuses on long-term strategic goals, whereas project and program management consider short-term tactical goals. The difference can be further stated through the following matters (Schwalbe, 2006);

- Project and Program Management addresses;
  - *Are we carrying out projects well?*
  - *Are projects on time and budget?*
  - *Do project stakeholders know what they should be doing?*
- Project Portfolio Management addresses;
  - *Are we working on the right projects?*
  - *Are we investing in the right areas?*
  - *Do we have the right resources to be competitive?*

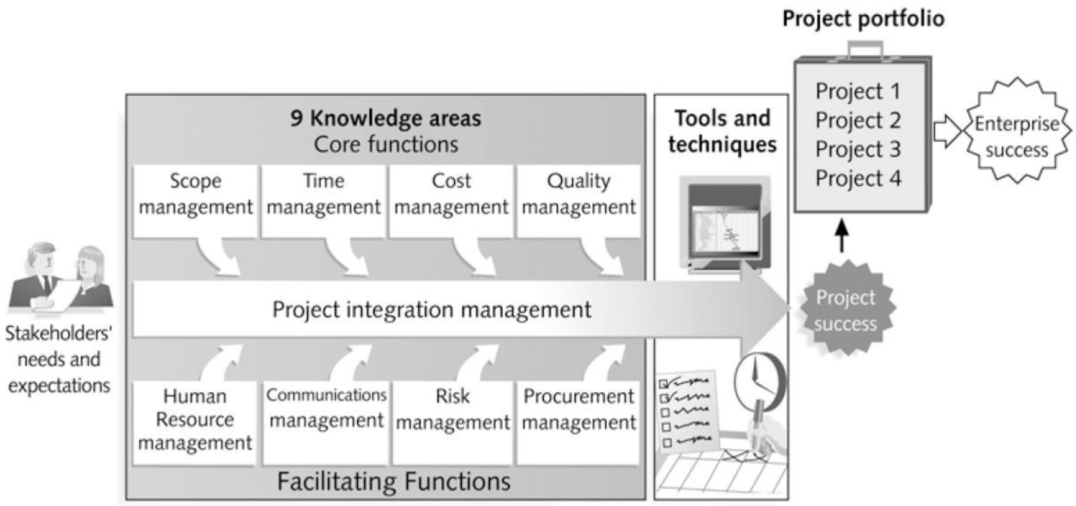


Figure 2.3: Project Management Framework (Schwalbe, 2006)

To sum up, “project management” aims achieving success within the context of a specific project scope and requirements, whereas “program management” indicates management of different projects together that serve for the same benefit. Program management provides possibility of optimization or integration in cost, schedule or effort and with its optimization potentiality it is more akin to portfolio management. Program management brings benefits that would not be possible if the projects in the program were managed individually. “Portfolio management” carries program management one-step forward and it sets the aim on enterprise/organizational success by selecting and prioritizing projects and programs, and aligning resources through organizational capability and strategic objectives. Project, program and portfolio management are all utilized together to sustain “Organizational Project Management (OPM)” that establishes the systematic achievement of success (Project Management Institute, 2013). In light of the strategic goals, a portfolio manager can increase, decrease, discontinue or change specific types of projects in a portfolio to obtain the best portfolio of projects in line with the intended enterprise success (Schwalbe, 2006). The organization should have the correct project mix that will balance the needs of the market with the need of the internal capability of the organization to supply the market. Therefore, the organizations should keep their portfolios balanced between the supply-side and the market-side (Kendall and Rollins, 2003).

2.1.5. Processes of Portfolio Management

The standard provided by Project Management Institute (PMI) divides the portfolio management process into five main processes as follows (Project Management Institute, 2013);

- **Portfolio Strategic Management:** includes developing strategic plan, making selection according to the strategy stated, and updating the strategic plan in response to the performance,

- **Portfolio Governance Management:** focuses on the implementation of portfolio management and includes developing the management plan, defining-optimizing-authorizing the portfolio, and providing portfolio oversight,
- **Portfolio Communication Management:** developing the portfolio communication management plan and managing portfolio information,
- **Portfolio Performance Management:** includes managing the balance between supply and demand and managing the portfolio value through measuring, capturing, validating and reporting the portfolio value, and
- **Portfolio Risk Management:** developing portfolio risk management plan and managing portfolio risks through identifying, analyzing, developing responses to, and monitoring and controlling the risks.

Each process has its own inputs, tools and techniques to be used and the outputs to be obtained specific to the process. Between all these processes, "Governance Management" has an importance in PPM implementation since it is required for organization of the overall operation. Main steps of the governance management can lay the foundations of portfolio management implementation and they can be listed as (Project Management Institute, 2008b):

1. **Identify Components:** creating a list of all qualified components,
2. **Categorize Components:** organizing the components into sets of some criteria that will ease the components to be evaluated, selected, prioritized, and balanced,
3. **Evaluate Components:** gathering all the information for reviewing the components,
4. **Select Components:** creating a subset of components for further evaluation,
5. **Prioritize Components:** ranking the components by the established criteria for balancing,
6. **Balance Portfolio:** creating the component mix that has the maximum potential to support the strategy,

7. **Communicate Portfolio Adjustment:** providing clear understanding of portfolio and its potential between all participants,
8. **Authorize Components:** allocating resources to execute the portfolio,
9. **Review and Report Portfolio Performance:** tracking the progress of the portfolio against preset performance measures, and
10. **Monitor Business Strategy Changes:** enabling responsive portfolio to the strategic changes.

2.1.6. Portfolio Management and Strategic Management

Portfolio management assists organizations in critical decision-making processes and helps to realize strategic goals, so it is an important part of strategic planning of an organization (Baptestone and Rabechini, 2018). Working towards the strategic goals together with portfolio management enables balanced use of resources with maximum value and pursuant to the intended strategy as it is depicted in Figure 2.4 (Project Management Institute, 2013).

Figure 2.4: The Organizational Context of Portfolio Management (Project Management Institute, 2013)

Portfolio acts as a link between strategic concepts and portfolio components as programs, projects, and operations. Portfolios include any past, present, and future short-term projects and programs, and keep them alive in the long-term portfolio. Thus, portfolio leads projects to be handled in a long-term focus and enables strategic thinking in this way. Portfolio management not only leads the projects to serve for the strategic objectives, but also assists restructuring of the strategic objectives through the feedback obtained by monitoring of the portfolio performance. By this way, greater business value can be obtained through optimization of objectives, dependencies, costs, timelines, benefits, resources, and risks based on expected performance. Portfolio is expected to serve for the strategic planning through the following key areas (Project Management Institute, 2013);

- **Maintaining portfolio alignment:** every portfolio component should be serving for at least one strategic objective,
- **Allocating financial, human, and material or equipment resources:** resources should be allocated according to prioritization of the components,
- **Measuring portfolio component performance:** the contribution of the component to the achievement of strategic objectives should be measured to be able to take corrective actions, and
- **Managing risks:** each component should be analyzed for their risks that may affect the achievement of strategic goals.

By continuously handling the processes of strategic alignment, optimization, impact analyses, and developing organizational enablers, organizations can provide effective investment management and business value realization (Project Management Institute, 2013). Therefore, the strategic alignment of portfolio plays a crucial role in the portfolio management. The traditional “Go/No-Go” decisions of single projects based on their profitability does not respond to the current requirements of organizations. The complex strategies of the organizations should be stated clearly and the set of projects should be evaluated under this strategy rather than evaluation of single projects as it is depicted in the following figure (Figure 2.5). Only the holistic effect of the projects can best respond to the organizational strategy defined that searches for many criteria in addition to the criterion of profitability of projects.

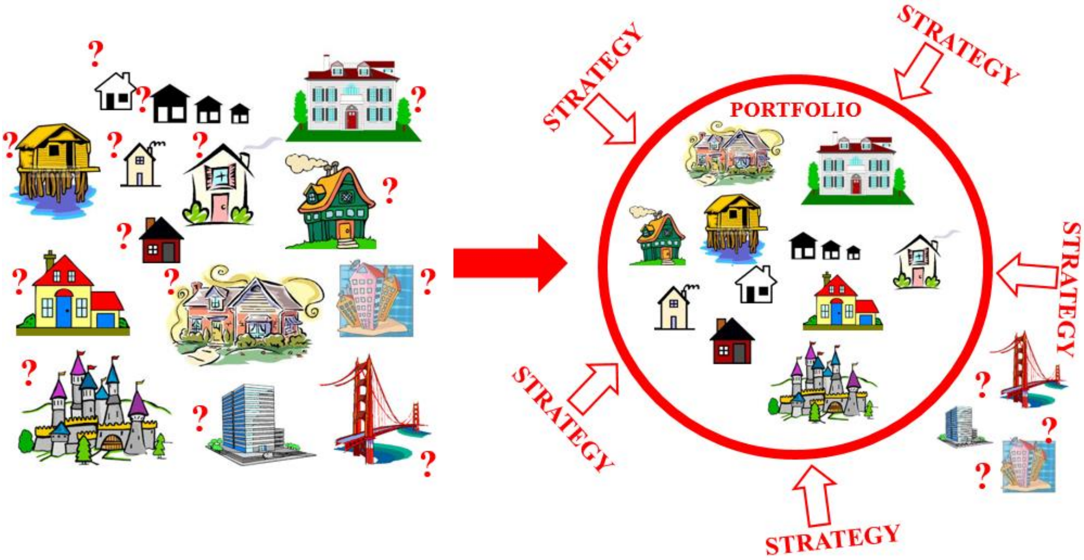


Figure 2.5: Evaluation of Portfolio of Projects with the Strategy Defined

2.1.7. Goals of Portfolio Management

Goals of portfolio management can be stated at the outer set as selection of the right components, keeping them strategically aligned and checking the performance of the portfolio. According to Cooper and Edgett (2001) goals of the portfolio can be stated as;

- Maximizing the “value” of the portfolio,
- Seeking “balance” in the portfolio,
- Aligning the portfolio “strategically”, and
- Picking the “right” number of projects.

Kendall and Rollins (2003) also mention similar goals but they add performance checking process. They state the goals as;

- Choosing the right project mix,

- Linking the executive team's strategies to current and planned projects,
- Managing the project portfolio correctly, and
- Measuring to tangibly improve project performance relative to the executives' strategic goals.

Similarly, Lerch and Spieth (2013) state the main goals according to the results of their questionnaire survey as;

- Strategic alignment of projects,
- Balance,
- Resource fit, and
- Value maximization.

Other goals stated in the study are; financial growth, efficiency, and transparency.

According to these goals stated, Kendall and Rollins (2003) define that the main focus of an organization should be its project investments, resources, assets and most importantly its strategic objectives. When the requirement of periodic performance and strategy measurements is thought, the main focus should also be;

- Possible changes in relative priorities of projects,
- Addition of new projects,
- Stoppage or cancellation of active projects,
- Decisions to be taken to effect the specific project plans or investments, and
- Adaption of new strategies.

2.1.8. Successful Project Portfolio Management

A sound PPM process includes informed managers, involved participants, good facilitation, and appropriate processes, systems, and tools. Therefore, PPM mainly requires a change in the culture of the business. To lead a successful PPM, it is suggested to be able to answer the following questions, which are depicted in Figure 2.6 (Pennypacker and Retna, 2009).

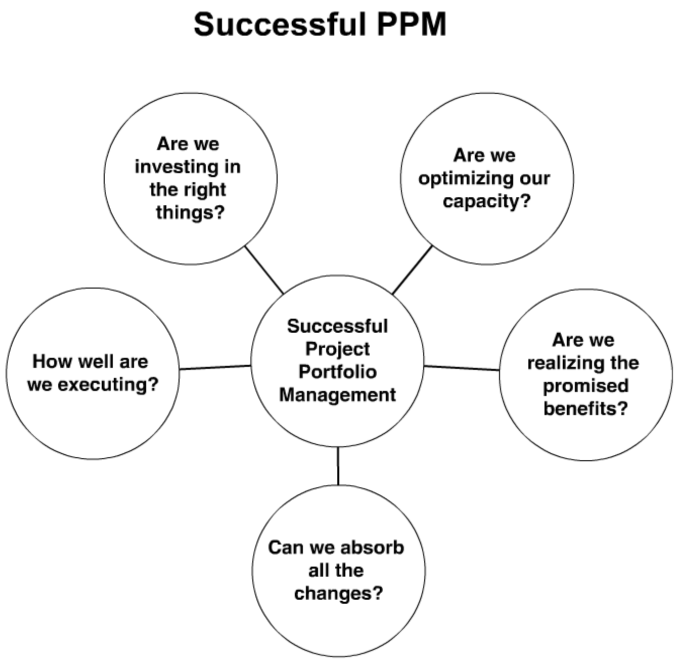


Figure 2.6: Five Key Questions that Successful PPM Addresses (Pennypacker and Retna, 2009)

The critical success factors for project portfolio management are identified as follows (Pennypacker and Retna, 2009):

- **Are we investing in the right things?** All the inputs of a project can be equalized to some value of money, even the time spent. Therefore, the projects should be evaluated as investments. The main point of the organizations should be the balance between the limited money spent on different kinds of projects in the light of strategy. Besides evaluation of new projects in this context, the performance of the active projects should also be checked against their benefits. The capital allocated to the projects that do not bring the expected benefits should be transferred to more beneficial projects. Additionally, since the whole business process is dynamic, the PPM process should also be dynamic to meet the requirements of dynamic organizational strategy.

- **Are we optimizing our capacity?** Another focus should be aiming the use of the resources in the most efficient way. The organization should be getting the maximum value from the resources being used up. Therefore, the balance should be established between the supply side and the demand side. The resources, which can be grouped as skills, technology environment, and facilities, should be optimized to establish the balance between the needs and the capabilities available.
- **How well are we executing?** Since business is a completely dynamic process, PPM process should also be dynamic. The expected results should always be checked against the realized results. Accordingly, the corrective actions should be taken in case of a mismatch with the intended strategy. The portfolio should be responsive for the changes in business strategies.
- **Can we absorb all the changes?** Not every new idea can be suitable for the current organizational capabilities. Therefore, the changes should be done in a way that the organization is at its best to apply them. Besides the suitability of new alternatives to the organization itself, its timing should also be questioned. A sound change analysis should be made also to search what or who would be impacted by the changes.
- **Are we realizing the promised benefits?** The benefits of each project should be identified and their realization should be checked. To be able to realize benefits, sound management processes are required. Accordingly, the related staff should be trained to exploit the capabilities, and business processes and the resources need to be re-evaluated.

In their study, de Reyck et al. (2005), investigate the PPM adoption level of the IT companies and identify the following “key elements” to measure the adoption level of portfolio management in the company, which may also serve for structuring a competent portfolio management system:

- **Centralized view of the project portfolio:** establishing a centralized view of all projects,

- **Financial analysis:** enabling a financial analysis of the projects,
- **Risk analysis:** enabling risk analysis of the projects,
- **Interdependencies:** investigating interdependencies between the family of projects,
- **Constraints at portfolio level:** investigating the constraints on the resources that are shared between the projects,
- **Overall portfolio analysis:** managing diversification, risk-reward analysis and financial analysis of the portfolio,
- **Categorization, selection, accountability and governance:** enabling of prioritization, strategic alignment, project selection processes and ensuring accountability and governance,
- **Optimization:** tracking the benefits and the performance and the reporting process,
- **Specialized software:** using standardized processes and software tools.

The identified elements may also constitute the key elements required for a successful PPM application, since they together constitute a considerable extent of its application.

2.1.9. Benefits of Project Portfolio Management

There are not many studies on realized benefits of PPM but there is considerable claim on its expected benefits. Datz (2003) mentions the main benefits that organizations should expect from adopting PPM approaches as;

- maximizing value investments while minimizing the risk,
- improving communication and alignment,
- encouraging business leaders to think as “team” not “me” and to take responsibility for projects,
- allowing planners to schedule resources more efficiently, and

- reducing the number of redundant projects and making it easier to kill projects.

In addition to these benefits, Turbit (2005) also mentions expected benefits of portfolio management as follows. With portfolio management;

- portfolios can be constantly reviewed and altered if necessary to produce the highest returns based on changing situations,
- management team see the projects as groups of activities contributing to an initiative so they are not a series of unrelated work, and
- dependencies are easier to identify.

According to Kendall and Rollins (2003) lack of PPM processes and tools may lead some management problems as there may be;

- too many active projects,
- projects that do not add value,
- projects not linked to strategic goals, and
- an unbalanced portfolio where misaligned or low priority components consuming critical resources (Project Management Institute, 2008b).

Although there are various theoretical studies on benefits of the Portfolio Management, this issue has not been generally investigated in detail through real case studies. There are many studies that investigate effect of a factor on PPM success but there is not considerable research on effects of PPM on company success. For example; Martinsuo and Lehtonen (2007) investigate role of single-project management in achieving portfolio management efficiency, Meskendahl (2010) researches the influence of business strategy on project portfolio management, Jonas (2010) studies how management involvement impacts project portfolio management performance, Voss (2012) investigates impact of customer integration on project portfolio management and its success, Teller and Kock (2013) study how portfolio risk management influences project portfolio success, and

Beringer et al. (2013) investigate behavior of internal stakeholders in project portfolio management and its impact on success.

Patanakul (2011) states that the effectiveness of portfolio management concept is not clearly defined and there is very limited research on effectiveness of PPM. Lerch and Spieth (2013) also state the scarcity of research on effect of PPM on firm's performance. The information on benefits research is limited with researches made through surveys among company professionals. Accordingly, the benefits of portfolio management are presented with the research studies available on the issue. Following the research studies, company examples that report some quantifiable benefits are also presented in the following sections.

2.1.9.1. Findings of Previous Studies on Benefits of PPM

In this section, two research studies that investigate effects of PPM performance on the organizational success in IT projects and innovation projects are presented below respectively.

2.1.9.1.1. Study on IT Projects

De Reyck et al. (2005), investigate the impact of portfolio management on IT projects. They identify the gap in the literature as the lack of research on the evaluation of whether the PPM adds value or not. Therefore, objective of the study is identified as investigation of the relation between use of PPM processes and improvements in the performance of the projects and portfolios, and so the organizational impact. Accordingly, firstly they determine the adoption level of the PPM processes in the companies and then investigate the value created with management of projects as portfolio. The hypotheses of the study are stated as follows;

- **Hypothesis 1:** adoption level of PPM processes and techniques varies across organizations, therefore classification of organizations is required according to their level of adoption.
- **Hypothesis 2:** higher adoption levels of PPM methods and techniques result in increased value gained from information technology projects, therefore value gained through PPM should be investigated among the categorized companies.

34 companies that are mainly from United Kingdom are surveyed within this context. The companies are mainly from IT sector, and the rest ranges between Business Operations (15%), General Management (15%), Strategy (12%), and Finance (3%). The PPM adoption level of the companies are investigated through their adoption level of the key elements of the PPM process. The rating data of the respondents are analyzed through statistical methodology (SPSS, k-means cluster analysis with Ward's method) and the companies are ranked as "Stage I", "Stage II", and "Stage III" in accordance with the increasing level of adoption. The adoption level is scored through a scale from "1: don't have any or don't plan to have" to "5: always use" and the organization impact level is scored with "-1: significant negative impact", "0: no impact", "+1: significant positive impact". The positive (correlation) relationship between adoption level and organizational impact is obtained as a result of the analysis. Additionally, the problems encountered in the companies are scored through the professionals as "0: do not have problems" and "1: have problems to a great extent". A negative (correlation) relationship between adoption level and problems encountered is obtained at the end of analysis. De Reyck et al. (2005) also share the project issues in case of lack of PPM and the challenges in the organizations that may be encountered during PPM implementation. The results also reveal the decreasing effect of issues and challenges with the increasing level of adoption.

According to the results obtained, the study is concluded with proposal of implementation plan that is again phased according to the stages of the companies. Very fundamental advices are given to the "Phase I" companies, since basics with the implementation are lacking in the companies, whereas advices in detail are given to the “Phase III” companies, since they have already adopted the process but may be lacking some details. The complete implementation plan is proposed as follows;

- Stage I: Portfolio Inventory
  - Centralized project administration.
  - Risk evaluation procedures.
  - Explicit incorporation of resource constraints.
  - Increasing business leaders’ accountability for project results.
- Stage II: Portfolio Administration
  - Project categorization.
  - Evaluation of customer impact of the project portfolio results.
- Stage III: Portfolio Optimization
  - A project portfolio committee.
  - Assessment of the financial worth of the portfolio.
  - Management of project interdependencies.
  - Tracking project benefits.

2.1.9.1.2. Study on Innovation Projects

A similar research study by Lerch and Spieth (2013) is presented and benefits of PPM is investigated through different aspects. The study includes a cause and effect study and depicts effect of “Usage of Innovation PPM (IPPM) methods”, “IPPM design” and “Project characteristics” on “IPPM Performance” and “Management Perception and Satisfaction”. Effect of “Management Perception and Satisfaction” is also investigated against “IPPM Performance”. Finally, the effect of “IPPM Performance” is investigated against “Firm Performance” and “Project Performance”.

Within the context of the study, 29 interviews are held through 12 internationally acting companies in Germany. The propositions obtained through the study are as follows;

- **Effect on IPPM Performance:** A high degree of management satisfaction and perception, a strong usage of team decision-making, a high degree of explicitness and formality, and higher information availability leads to high “IPPM Performance” measures. A strong focus on strategy-oriented criteria for evaluating projects combined with a strong focus on financial criteria for prioritizing projects results in a high “IPPM Performance”. Additionally, there is an inverted u-shape relationship between the review frequency of the innovation project portfolio and “IPPM Performance”. Finally, resource and benefit interactions negatively impact “IPPM Performance”.
- **Effect on Management Perception and Satisfaction:** A strong usage of team decision-making, the more frequent review of an innovation portfolio, and the more transparency in IPPM process lead to higher “Management Perception and Satisfaction”. A strong focus on strategy-oriented criteria for evaluating projects combined with a strong focus on financial criteria for prioritizing projects also results in a higher degree of “Management Perception and Satisfaction”. Finally, information availability is positively correlated to “Management Perception and Satisfaction”.
- “IPPM Performance” correlates positively with Innovation “Project Success”.
- “IPPM Performance” correlates positively to “Company Performance”.

Therefore, the study positively relates the “IPPM Performance” with “Project Success” and “Company Performance”. Most of the respondents (55%) rate the importance of “IPPM Performance” for the company’s overall performance as “very high” (the maximum). Respondents also state that they use either qualitative or quantitative evaluation techniques to measure the company’s performance like measure of competitive position as qualitative, and financial ratios as quantitative measures.

2.1.9.2. Quantifiable Examples on Benefits

There is very limited study on the benefits of PPM implementation as Patanakul (2011) states. De Reyck et al. (2005) mention a company example presented in the United States General Accounting Office (GAO) report (GAO, 1994). The report presents a company that adopts portfolio investment techniques to manage its IT projects after encountering disappointing results. They realize that they were previously spending too much on old systems and projects. The company sets an evaluation criteria for benefits, costs, and risks of the projects and obtains their best mix of the projects. By this way, they observe better balance between maintenance expenditures and the strategic investment projects. In three years time, the company reports 14-fold increase in the return on investment from IT projects.

Ter Mors et al. (2010) also share the America Online, Inc. (AOL) example where they decide to implement PPM after realizing that their project-based management processes were informal to support growth. As a result of this, they adopt PPM principles to make sure themselves that the selected projects are suitable to meet their strategic and business objectives. They mainly aim selecting right mix of projects, balancing the projects and maximizing the value. At the end, AOL obtain 40% reduction in their project man-hours and also realize improvements in the portfolio ROI.

2.2. IT Solutions for Portfolio Management

As a result of the development in computer and software-based tools, there have been variety in visualization capability of the solutions together with the improvement in information gathering and display options (Dansereau and Simpson, 2009). Decision support systems can be improved by provision of visual tools with flexible cognitive systems (Tergan and Keller, 2005). Performance of the tools used for decision-making in project management can be increased with visuals methods supported with various algorithms (Rivera and Duran, 2004). However, it is emphasized in the literature that there is a need of progress in supporting project portfolio management processes with computer-aided systems since there has been no enough improvement in the area (Marcus and Coleman, 2007).

The existing tools and methods developed for portfolio management have been produced for different purposes. Cooper et al. (2001) group the tools used in portfolio management into three categories as “mathematical programming tools”, “classical portfolio tools”, and “mapping tools”. “Mathematical programming tools” are the ones that are using mathematical models to optimize resources, “classical portfolio tools” are the tools used for scoring and classification processes, and “mapping tools” include the tools that can graphically represent the balance of portfolios. Oh et al. (2012) underline that there are more than one hundred methods for project portfolio management, which can be categorized according to the adopted approach into three main groups as the tools structured with “prioritization approach”, “mathematical optimization approach”, and “strategic management approach”. The methods following “prioritization approach” mainly handles the prioritization of the returns of the projects as a result of a comparative financial analysis such as “scoring method”, “analytical hierarchy process”, “net present value method”, etc. Although this method is appreciated to be the most widely used method, it is insufficient to sustain the portfolio balance since it is solely based on financial evaluation. The “mathematical optimization approach” refers to the methods in which various functions are optimized by a limiting criterion such as “resource”, “project logic and dynamics”, “technology” and “project related strategies”. These methods are theoretically successful; however, the reliability of the results cannot always be provided due to differences in circumstances. Finally, methods undertaking “strategic management approach” provide establishment of a balanced portfolio as a complementary approach to the prioritization approach through “bubble charts”, “portfolio maps”, etc.

Therefore, wide variety of methods can be used according to the purpose and approach undertaken for generation of a solution for portfolio analysis. The following sections handle the fundamentals of these solutions as “techniques and analyses”, and further present the “software and other solutions” where following section handles the “studies provided in the literature” as examples of utilization of these techniques.

2.2.1. Techniques and Analyses

This section presents the techniques and analyses, which may be used in structuring a portfolio management solution, as an overview and specifically with respect to PPM processes.

There are various techniques and analyses advised in the PMI Standard, which can be used in the various steps of the processes of portfolio management. The techniques and analyses are listed as follows (Project Management Institute, 2013):

- Strategic Alignment Analysis
- Prioritization Analysis
- Capability and Capacity Analysis (human, financial, asset)
- Interdependency Analysis
- Weighted Ranking and Scoring Techniques
- Quantitative and Qualitative Analysis
  - Scenario Analysis
  - Probability Analysis
  - SWOT Analysis
  - Market/Competitor Analysis
  - Business Value Analysis
- Graphical Analytical Methods
- Value Scoring and Measurement Analysis
  - Scoring Models
  - Cost-Benefit Analysis
  - Comparative Advantage Analysis
  - Progress Measurement Techniques

    - Value Measurement Techniques
    - Portfolio Efficient Frontier
- Benefits Realization Analysis
    - Results Chain
    - Outcome Probability Analysis of the Portfolio

Cooper et al. (1999) also group the available portfolio methods provided in the literature as follows;

- **Financial Models and Financial Indices:** evaluating projects/portfolios according to their "NPVs", "IRRs" and "Payback Periods" and such,
- **Probabilistic Financial Models:** like "Monte Carlo Simulation" ("Crystal Ball", "At Risk"), "Decision Tree", etc.,
- **Options Pricing Theory:** treating each stage of the product as a new option,
- **Strategic Approaches:** approaches based on strategic analysis like creating "Strategic Buckets" through categorization of projects according to their types, markets, products, etc.,
- **Scoring Models and Checklists:** prioritizing projects according to their scores assigned for each evaluation criterion,
- **Analytical Hierarchy Approaches:** decision tools that enable paired comparison of projects, for example "Expert Choice",
- **Behavioral Approaches:** tools to bring the managers to a consensus in decision, such as "Delphi" and "Q-Sort",
- **Mapping Approaches or Bubble Diagrams:** "Boston Consulting Group Portfolio Model" (i.e., stars, cash cows, dogs, wildcats) and "GE/McKinsey Model" that is plotting resources across business units constitute the basics of these models and nowadays various parameters are plotted against each other in "Bubble Diagram" format.

Although there are many tools presented in literature, there is very scarce study on use of these methods and their contribution to the PPM process (Cooper et al., 1999). One of the objectives of PPM is “maximizing value” so the methods like “NPV”, “Expected Commercial Value”, and “Scoring Techniques” search for the value of the portfolio. When “balancing the portfolio” is considered, “Bubble Diagrams” and “Pie Charts” can be used to depict the situation and to help to discuss on the situation. For “keeping the portfolio strategically aligned” top-down approaches like “Strategic Bucket” and “Roadmap” and bottom-up approaches with the aim of making sound decisions at the project level and obtaining the sound portfolio accordingly can be used. Finally for “picking the right number of projects”, “Resource Capacity Analysis” should be made and the available resources should be shared according to the prioritization result of the projects (Cooper and Edgett, 2001; ter Mors et al., 2010). Zheng (2009) groups portfolio management techniques together with their intended use as in the following table (Table 2.1).

Table 2.1: Portfolio Management Techniques Grouped under Tasks (adapted from Zheng, 2009)

Methods/Tools	Tasks	Examples
Mathematical models and financial models	Project selection, performance tracking, portfolio evaluation	NPV, IRR, ROI
Rating and scoring models	Portfolio balancing, strategic planning, project prioritization, project categorization	McFarlan (1981)’s portfolio approach, Murphy’s decision model (Kesner, 2004), Balanced Scorecard (Kaplan and Norton, 1996)
One dimension diagram	Descriptive statistics, quick report, big picture view	Dashboard, Gantt chart
Two-dimensional (2D) mapping	Project prioritization, portfolio balancing, portfolio composition, strategy planning	Matrix/quadrant/bubble diagram, pivot table
Cluster map	Project prioritization, portfolio balancing, portfolio composition, strategy planning	Self-Organizing Map
Profile chart	Project profile report, project comparison	Radar/star/spider diagram

In an alternative grouping of the tools in the most cited studies in PPM literature, de Carvalho et al. (2013) identify the studies based on the used methods, which are dominating all time periods, as the ones using (in descending order):

- financial methods (present value, option pricing theory, etc.),
- mathematical programming (optimization tools with constraints such as integer programming, linear and nonlinear programming, etc.), and
- statistical models (Monte Carlo Simulation, Bayesian Network, etc.)

De Carvalho et al. (2013) extend the list for the other studies as follows as further usage in time series as:

- Initial attempts: the basic tools (scoring models, checklists, etc.), bubble diagrams and decision trees.
- Recent attempts cover concepts of fuzzy logic, Analytical Hierarchy Process (AHP), Data Envelopment Analysis (DEA), or mix of these two techniques (AHP and DEA) with fuzzy approach.

Considering process centered techniques, “Strategic Alignment Analysis”, “Portfolio Roadmap”, “Multi-Criteria Scoring Model”, “Graphical Analytical Methods (Portfolio Balancing via Bubble Diagram)”, “Scoring Component Performance” and “Portfolio Efficient Frontier” are some of the most widely used techniques that support specific steps of PPM such as “strategic alignment”, “prioritization”, “balancing”, and “performance checking”. The details with the stated techniques and analyses are provided in the following sections.

2.2.1.1.1. Strategic Alignment Analysis

“Strategic Alignment Analysis” is a graphical representation that basically focuses on the fit of portfolio alignment to the strategy intended. As it can be seen in the following figure (Figure 2.7), it is a graph for depiction of the projects to be handled to reach the specific vision. The possible projects are located with their differences in time and business area information to ease visualization and focusing. The “As-

Is" notion located in the left bottom corner represents "today" and implies the company's current position with current projects. The circular intervals figure out the time intervals that will be required to reach a specific vision, which is also located in the right upper corner as "To-Be Vision". With the help of this figure, different projects, sub-portfolios or operations can be depicted together with the information of their timing and business areas. By this way, projects that will lead the company to the vision set are presented in the phases together with contemporaneous projects as an integrated view of the overall strategy.

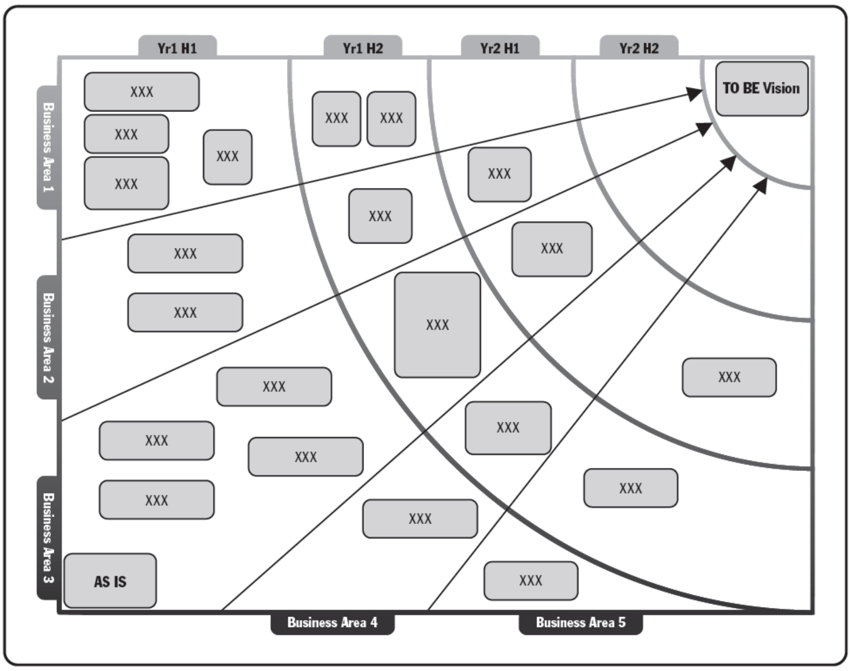


Figure 2.7: Integrated View of Overall Portfolio Strategy (Project Management Institute, 2013)

2.2.1.1.2. Portfolio Roadmap

"Portfolio Roadmap" is another basic tool used in portfolio management. Basically, it is a "Gantt Chart" with the projects, programs and operations as activities presented with their detailed time information of start and finish dates of each. An updated version of the roadmap can be obtained with depiction of the completed projects in a shaded region as it is shown in the following figure (Figure 2.8).

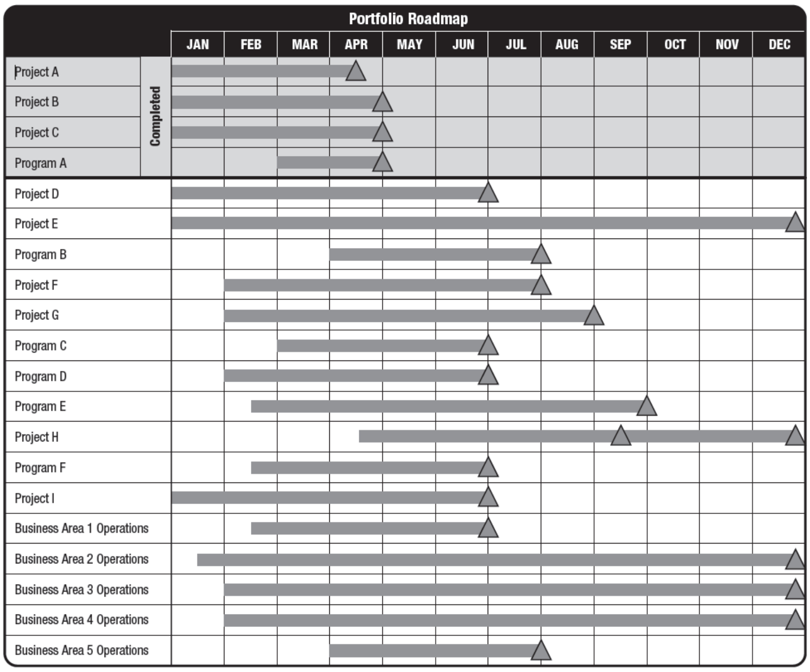


Figure 2.8: Portfolio Roadmap (Project Management Institute, 2013)

2.2.1.1.3. Multi-Criteria Scoring Model

"Scoring Models" constitute the heart of project ranking and prioritization processes in portfolio management. As it can be seen in Figure 2.9, different indicators as "X" and "Y" in the example can be listed in terms of their evaluation criteria. The weight for each criterion is assigned according to the nature of the portfolio and the evaluation requirements. Once the scores for each of the criterion are determined according to the given evaluation chart, a "total score" for the project and normalized scores for each indicator of the project can be obtained. Through scoring techniques, each component gets a score according to same evaluation process and the components in the portfolio are ranked accordingly. The criteria to be used in the “Scoring Model” can be exemplified as (Cooper and Edgett, 2001);

- Strategic Alignment
- Product/Competitive Advantage
- Market Attractiveness
- Synergies (Leverages the core competencies)
- Technical Feasibility
- Risk vs. Return

SCORING MODEL

		Evaluation					
List of Criteria	Weight	Low	Medium	High	Score	Total	
Criteria 1	20%	0	5	10	10	2	Indicator “Y”
Criteria 2	20%	0	5	10	10	2	
Criteria 3	10%	0	5	10	5	0.5	
Criteria 4	15%	0	5	10	10	1.5	
Criteria 5	5%	0	5	10	5	0.25	
Criteria 6	5%	0	5	10	0	0	
Criteria 7	5%	0	5	10	10	0.5	Indicator “X”
Criteria 8	5%	0	5	10	5	0.25	
Criteria 9	10%	0	5	10	0	0	
Criteria 10	5%	0	5	10	5	0.25	
TOTAL WEIGHT = 100%				TOTAL SCORE		7.25	
				Indicator “Y” (0 to 1)		0.83	
				Indicator “X” (0 to 1)		0.4	

Figure 2.9: Multi-Criteria Scoring Model (Project Management Institute, 2013)

2.2.1.1.4. Graphical Analytical Methods: Portfolio Balancing via Bubble Diagram

“Bubble Diagram” as exemplified in Figure 2.10 is one of the most used techniques in portfolio balancing process. This diagram locates a project as a “bubble” at the intersection point of two criteria, which can be criteria “X” and “Y” of the previous scoring chart (Figure 2.9), and also depicts another criterion or value through the “sizes of the bubbles”. “Colors of the bubbles” also have the capability of indicating any other criterion. For the case depicted, sizes of the bubbles may indicate the NPVs of the projects, whereas the colors of them may differentiate the types of the projects. Therefore, clear depiction of projects together with considerable different criteria helps to depict the options in hand and consider the comparative values of the projects. By this way, "Bubble Diagrams" help to decide on a more balanced portfolio through realization of the options.

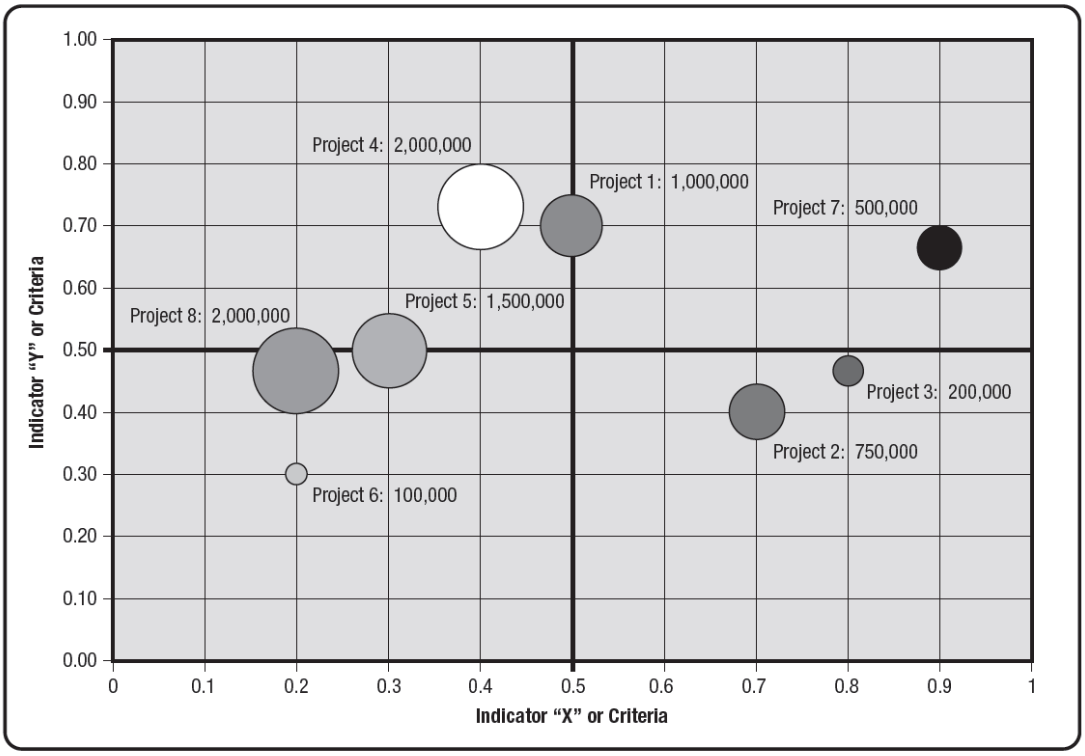


Figure 2.10: Portfolio Balancing Using Indicators or Criteria (Project Management Institute, 2013)

2.2.1.1.5. Scoring Component Performance

The following figure (Figure 2.11) is an example for performance checking process of a portfolio. In this figure, the targeted criteria scores for a specific project are shown through the solid lines drawn on the figure, whereas the actual performance of the related criteria are indicated through the dashed lines. This figure shows the performance of the project, namely actual scores for the criteria and so their contribution to the aimed strategy. It may be required in the regular performance checking processes of a portfolio to analyze the current status, and to be able to take required actions to keep the portfolio responsive to the strategy or its changes.

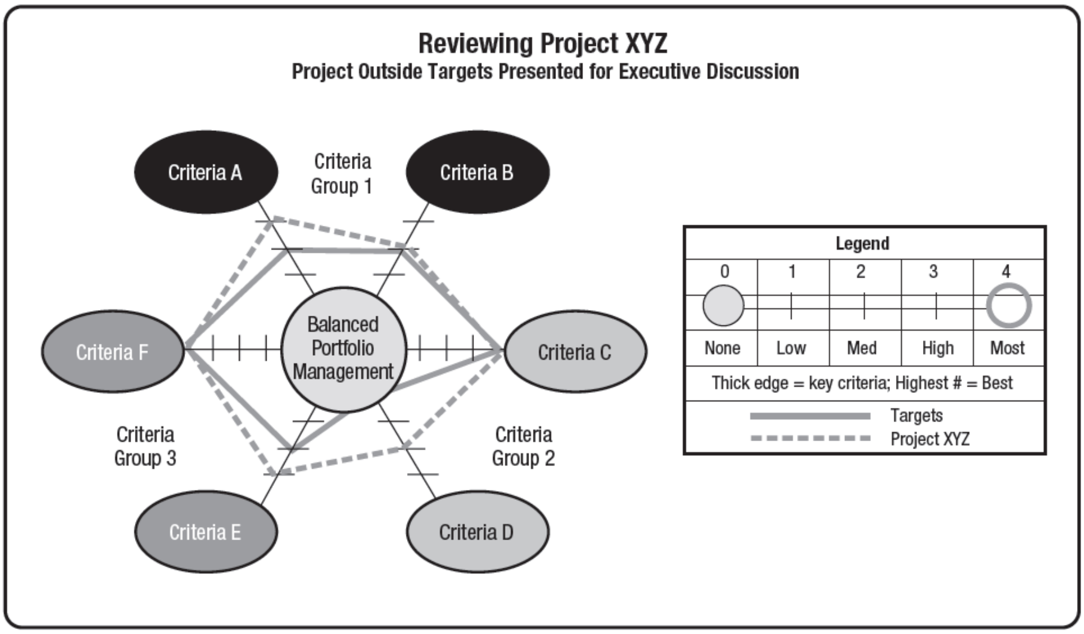


Figure 2.11: Scoring Component Performance (Project Management Institute, 2013)

2.2.1.1.6. Portfolio Efficient Frontier

The "Portfolio Efficient Frontier" constitutes the initials of "Financial Portfolio Theory" by Harry Markowitz as it is mentioned previously at the beginning of this chapter. Its use in PPM is also applicable since today's projects are not much different from financial investments with their budgets of million dollars (Gruia, 2005). All possible combinations of a portfolio, where the "frontier" represents the most efficient portfolio combinations either in the form of "value-maximized" or "cost-minimized" portfolios are considered. The combinations above the frontier are "not possible", whereas the ones below the frontier are "not efficient".

Accordingly, through this analysis, it is possible to obtain a portfolio that best responds to the need.

Organizations make their decisions on either making value or cost savings. As a result of this, making decisions through "NPV Analysis" may not be sufficient for today's portfolios. Therefore, importance of portfolio optimization can be realized. "*Efficient Frontier*" is a scientific method for the optimization process. With the advent of use of "*Efficient Frontier*" in PPM, the organizations are able to search for the best possibilities with the given budget and organizational capabilities. They can also identify whether they are getting the maximum value from their portfolios or not. If the selected portfolio is in the inefficient portion of the "*Efficient Frontier*", then it means the organization is getting less value from or paying more for its selection of projects. The "*Efficient Frontier*" can be obtained by presenting cumulative values of ranked projects versus available budgets in a graph. Thus, as it is moved from left to right on the graph, the cost increases together with the value. Accordingly, another decision is required that how much the organization is ready to pay for the intended value (Gruia, 2005). Another care should be taken for inefficient portfolios; since the value can be maximized for the same cost, or cost can be minimized for the same level of value.

The real efficient frontier should not be depiction of cumulative values of ranked projects. The exact one should include all the possible portfolios through an optimization process under constraints. The previous can be deemed as a ranking curve and can be valuable only if the projects in the portfolio are independent from each other ("Lee Merkhofer Consulting II", n.d.). If there exist "N" potential projects in a portfolio, then there would be "2^N" combinations of the portfolio. Therefore, through use of computers with any optimization engine, it would be possible to obtain all the portfolio combinations and the efficient frontier.

To conclude on efficient frontier, it is a powerful technique for obtaining an optimized portfolio for an intended value or budget.

2.2.2. Portfolio Management Software

There are many tools presented under concepts of project prioritization, capital efficiency, enterprise project management, portfolio analysis, multi-project management, asset management, resource allocation, and such. They all have properties of creating, managing, and viewing data from a database of proposed, planned, and on-going projects. They mainly differ in capabilities for prioritizing projects, optimizing the project portfolio, planning projects and managing the execution of approved projects, managing the supply and demand for project resources ("Lee Merkhofer Consulting I", n.d.). Between all of the tools available, the two of them need to be mentioned in detail since they are provided by the major planning software packages as Primavera and Microsoft Office.

2.2.2.1. Primavera P6 Enterprise Project Portfolio Management

Primavera P6 Enterprise Project Portfolio Management (EPPM) Program has user-friendly interface with its calendar view and excel based import export functions. With P6 EPPM real time view of the project performance can be achieved through options provided for effectively analyzing, recording and communicating the project details. Key indicators related to the project that need to be checked can be identified within the program. Through use of "*What if Scenario Modeling*", portfolio can remain aligned with the strategic objectives. "*Capacity Analysis*", *"Tabular Scorecards", and "Resource Optimization"* help to maintain the right balance of the projects in a portfolio. Prioritization and optimization of the projects can also be managed through the program and the selection of right strategic mix can be achieved. Project performance can be monitored and visualized against the initial plan. The software offers that, by using P6 EPPM an organization can improve collaboration, respond quickly to the unexpected events, create value and achieve competitive advantage ("Oracle", n.d.; "P6 EPPM Video", n.d.). The screenshot of the Bubble Diagram used in portfolio balancing process in P6 EPPM is available in the following figure as an example from the program interface (Figure 2.12).

Figure 2.12: Bubble Diagram Example from Primavera P6 EPPM

2.2.2.2. Microsoft Project Online: Project Portfolio Management

Microsoft Project Online offers cloud based solutions and Project Portfolio Management is among the solutions offered. All large, small or just started projects in a portfolio can be handled through this application. It enables working on projects together as a team, fostering visibility and insight over everything, and aligning vision and effort. All the related work within the portfolio becomes visible within a single view and this makes smart decisions possible. Projects can be prioritized based on their strategic alignment, assignment of resources can be done easily, and also team can access to the project information from anywhere with any device. Accordingly, flexible reports can be obtained and updated easily within the application. Therefore, the organization can achieve its intended business through prioritizing, collaborating and managing the projects within the portfolio ("Project

Online Video”, n.d.). User-friendly interface increases the participation of different users and the flexible PPM platform enables quick innovation (“Project Server 2013”, n.d.). The appearance of the interface is provided in the following figure (Figure 2.13).

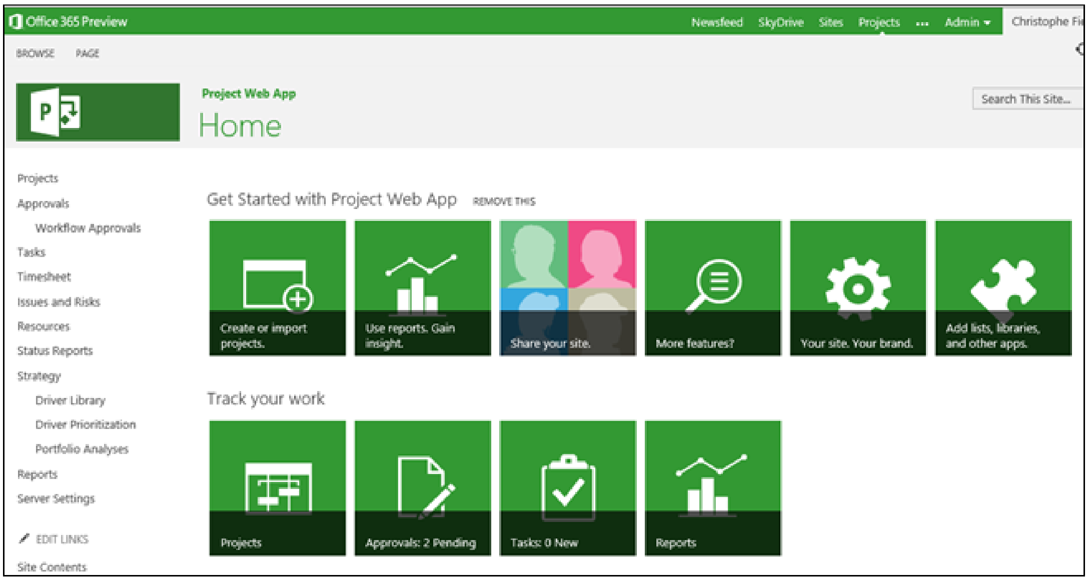


Figure 2.13: Microsoft Office Project Server Interface

2.2.2.3. Other Solutions

In addition to well known portfolio management software there have been generation of PPM tools generated with different purposes and capabilities responding to need in different industries. The complete list of the identified tools within the context of the study are presented in the table below together with producer information (Table 2.2).

Table 2.2: Investigated Portfolio Management Tools

Generator	Tool	Generator	Tool	Generator	Tool
1000Minds	1000Minds	Expert Choice®	Comparion™ Suite	PowerPlan	PowerPlant
3P Works	Portfolio Intelligence	Extensis	Portfolio Server	PowerSteering	Enterprise
4c Systems	4c Portfolio Manager	Fujitsu	sDIS+	PPMRoadmap	PPM Roadmap
AceProject	AceProject	Genius Inside	PPM	Project Insight	Project Insight
Achievo	Achievo 1.4.5	GenSight	Gensight® PPM	Project InVision	InVision 8

Table 2.2: Investigated Portfolio Management Tools (continued)

Generator	Tool	Generator	Tool	Generator	Tool
Algorithmics	Algo Risk	Glomark-Governan	GeniusCompare/Optimizer™	Project Portfolio Office	Project Portfolio Office
Antura	Antura Projects	Guidon	GuidonVue	Project.net	Project.net
Artemis	Artemis 7	HP Software	PPM Center	ProjectObjects	ProjectFolio
Asta	Teamplan	Hydra	Hydra PPM	Projectplace	Projectplace
Atlantic Global	PPM	IBM	Rational Focal Point	ProModel	Portfolio Simulator
AtTask	@Task	i-lign	i-lign	ProSymmetry	Tempus Decisionware™
Augeo Software	Augeo5™ PPM	InfoHarvest	Criterium DecisionPlus®	Psoda Limited	Psoda
Automation Centre	Project Tracker	Innotas	PPM Solution	PwC	PPO
Barometrix	Precision IQ™	Inventx®	SP2M™	QuickArrow	PSA Solution
Bestoutcome	PM3	iPlanWare	TeamWorks	SAP®	Port. & Proj. Management
Bicore	FlightMap	KeyedInSolutions	KeyedInProjects	Saviom Software	Saviom Project Management
BMC Software	IT Service Management	Logical Decisions®	LDP Portfolio	Sciforma	Sciforma 4
Borland	Tempo™	Lumina	Analytica	Semanticspace	PPM Studio
BOT International	Processes on Demand PMO Architecture	MaestroTec	Maestro-PPM	Sentient	PPM
CA	Clarity™	Make It Rational	Make It Rational	Serena	Mariner PPM
Cambridge Systematics	Prioritas™	Meridian Systems	Proliance	SigmaFlow®	Lean Six Sigma
Canea	Canea Framework	Metier	PPM Central	Skire	Unifier™
Cardinis	Cardinis Suite	Microsoft	EPM	Smart Org	Portfolio Navigator™
Catalyze	Equity3	Mindmap	MindManager	SOA Software	Eclipse PPM
Clarizen	Clarizen	One2Team	One2Team	Softexpert	PPM Suite
Cogentus	Promax	OneDesk	OneDesk PPM	Solution Q	Eclipse
Compuware	Changepoint	Onepoint Software	Project Enterprise	Sopheon	Accolade™
CopperLeaf	ESP	OpenAir	Enterprise	Stand by Soft	RationalPlan Multi Project
CorasWorks	PPM Version 1.3	Oracle	Crystal Ball®	Standpipe Studios, L.L.C.	Vertabase Pro
Cranes Software	InventX™ ePM	Oracle E-Business	E-Business Suite PPM	SumOpti	SumOpti
Daptiv	Daptiv PPM	Oracle Fusion	Fusion PPM	Syncopation Software	DPL Portfolio
Davies Consulting	AIS™	Oracle JD Edwards	EnterpriseOne	TeamDynamix	TDPortfolio Planning
Decision Lens	Decision Lens	Oracle PeopleSoft	PeopleSoft PPM	Tenrox	PPM
Dekker	PMIS™	Oracle Primavera	Primavera Enterprise PPM	Transparent Choice	TransparentChoice
Deltek	Deltek Enterprise	Palantir	PalantirPLAN	UMS Group	POP©
Digite	Swift PPM	Palisade	Decision Tools Suite	UMT	Project Essentials
D-Sight	D-Sight	Planisware	Planisware 5	Unanet	Project Portfolio
Eclipse	Eclipse PPM	PlanningForce	Portfolio Planner	Unit 4	Agresso Business World
EcoSys	EPC PPM	PlanView	Enterprise™	Vanguard Software	Business Analytics Suite™

Table 2.2: Investigated Portfolio Management Tools (continued)

Generator	Tool	Generator	Tool	Generator	Tool
Enrich	R&D Portfolio Management	Portfolio Decisions	Customized software	VCSonline	VPMi
EPM Live	PortfolioEngine	Portfolio Decisionware	PDWare™	XenLogic	TOBi
Exepron®	Multi-Project Portfolio	Post Vision Technology	PPO™		

2.3. Portfolio Management Tools Depicted in Literature

Tools available in project portfolio management literature vary according to their main purpose/function. Most of the tools are serving for a specific phase of the overall portfolio management process and not practical enough to be easily operational in project-based organizations for adoption of portfolio management principles. The available tools can be grouped under following items according to their purposes:

- **Project/Portfolio Selection:** tools with various specific considerations such as;
  - optimization by taking into account measurement and balancing strategic factors (Daniels and Noordhuis, 2003),
  - using financial models, bubble-chart diagrams and strategic approach for portfolio selection (Vacek, 2008)
  - knowledge management by similarity analysis and analysis of dependencies (LearnIT) (Rahmouni et al., 2010)
  - investment decision-making by taking into account risk and the effect of the interdependence of projects (Belaid, 2011),
  - parameterized optimization by considering risk, dependency, impact of delay and some other factors (Li et al., 2012)
  - selection by implementing a grasp-based heuristic algorithm (Mira et al., 2012)

    - considering the major uncertainties in the cost elements by using a combination of real option theory and mean-variance portfolio optimization (Jain et al., 2013)
    - evaluation by integrating the use of technology roadmap (Güemes-Castorena and Uscanga-Castillo, 2014)
    - net present value based selection based on roadmaps derived from different scenarios (V3PM: Value Based Process Project Portfolio Management) (Lehnert et al., 2016)
    - incorporating a general multi-objective model and using a metaheuristic algorithm as a search engine for portfolio selection with further consideration of scheduling (PPST: Project Portfolio Selection Tool) (Gómez et al., 2017)
    - using a robust optimization algorithm considering complexities and uncertainty to make selection by maximizing real options value of the portfolio (Montajabiha et al., 2017)
    - value-based analysis of most profitable alternative (REDIS: Renovation Decision Support) (Gade et al., 2018)

- **Portfolio Planning/Screening/Balancing:** tools that are capable of;
    - making comparison of alternative delivery scenarios to formulate and align with strategy for capital projects and services (CHOICES) (Miller and Evje, 1999)
    - deadline planning of company portfolio based on estimation by probability model (PROJMAN) (Fewster and Mendes, 2003)
    - analyzing information with respect to portfolio mix and resource allocation to assess the company's existing portfolio and identify potential areas of improvement (Dooley et al., 2005)
    - portfolio risk analysis as a reference to bid/no-bid decision-making and portfolio balancing (Caron et al., 2007)

- knowledge-based and ontology-driven tool for investigation of similar projects in the portfolio with the aim of resource optimization (PROPOST: Project Portfolio Support Tool) (Newton and Girardi, 2007)
- simplifying and rationalizing the project evaluation and prioritization process through Analytical Hierarchy Process (AHP) methodology and considering both the financial and non-financial performance measures via the Triple Bottom Line (TBL) (Turan et al., 2008)
- providing interactive production process planning subject to multi-project environment constraints by knowledge-based constraint programming model (DST4P3: Decision Support Tool for Project Portfolio Prototyping) (Bocewicz and Banaszak, 2009)
- web-based enhanced information management and data fusion to support analysis and decision-making in critical situations by creating, modifying, and managing geospatial portfolios (GeoPAD) (Mitten and Parsons, 2011)
- web-based risk diagnosing for systematic risk management (Spotrisk) (Pereira et al., 2013)
- scheduling with imprecision in activity duration and cost (Relich and Jakábová, 2013)
- practically assisting resource allocation in a new product development portfolio (Ferrarese and de Carvalho, 2014)
- portfolio level risk management through contingency estimation by considering both neural network modelling of systemic risks and expected value analysis of project-specific risks (van Niekerk and Bekker, 2014)
- resource allocation at project and portfolio levels for portfolio planning and also for performance reporting and monitoring (EV-Gantt: Earned Value Gantt Chart) (Ong et al., 2016)

- **Portfolio Control and Monitoring:** tools for;

- monitoring strategic performance of portfolios through monitoring matrix by considering strategic interdependencies of projects (Sanchez and Robert, 2010)
- measuring, analyzing, and benchmarking the performance of software project portfolios considering size, cost, duration, and number of defects to foster innovation in company's software delivery capability (EBSPM: Evidence-Based Software Portfolio Management) (Huijgens, 2016)

2.4. Dependency Assessment in Portfolio Management

Among the provided solutions based on stated methods, it can be seen that dependency assessment in portfolio management is a considerable issue to be addressed, who needs further investigation in this study. According to nature of the industry and projects, there can be many kinds of interdependencies to deal with in many industries such as "country dependency", "company dependency", "people dependency", "task dependency", "objective dependency", "alliance dependency", "project dependency", etc. (Rungi, 2010a). According to "coordination theory", any process consists of main three elements as "resources", "activities" and "dependencies" (Lillieskold, 2003). Therefore, when the projects are considered as processes, "dependencies" should also be a major consideration as well as the "resources" and "activities". However, dependency assessment constitutes the major drawback of the most of the studies existing in the portfolio management literature (Neumeier et al., 2018). Projects naturally have dependencies due to sharing of limited resources, similar technical requirements, constraints for duration, relationships due to same physical location, relationships due to contract conditions, vulnerabilities due to similar external environment. Therefore, evaluation of the dependencies between the projects and development of the strategies accordingly have crucial importance in the success of project portfolio management (Elonen and Artto, 2003). Dependencies between the projects must be clearly identified and included in the evaluation process in order to improve portfolio performance (Verma and Sinha, 2002). When the success of a project depends on other project or projects, it can be considered that there exists a dependency between these projects (Killen and Kjaer, 2012). There may be various types of dependencies between the projects due to share of common matters between the projects. For example, there may be "resource dependency" between the projects where limited resources are used jointly in the projects or resource can be a constraint to starting/ending of another project. There may be "market/benefit dependency" when there exists any complementary or competitive effects of projects to each other. Additionally, there may be "outcome dependency" when there is a technical requirement or return/outcome expected from one project is to be used in the other. Moreover, there may be "learning dependency" when knowledge accumulated in one project is to be used in another project. There may be "financial dependency" where financial relationships exist between the projects (Verma and Sinha, 2002). Rungi (2010a) focuses on "resource", "technological" and "market-related" dependencies in portfolio management. Another categorization can be provided where a "flow dependency" refers to a situation in which an activity is an output of another activity, a "sharing dependency" where a number of activities use the same resource, a "fit dependency" if there are coherent outputs of different activities (Lillieskold, 2003). Rungi (2010a) states that determination of the dependencies provides more effective project selection in portfolio management and helps to increase the portfolio success. Rungi (2010a) also reports that although companies are generally aware of the existence of inter-project dependencies, they do not consider them in their evaluations due to their belief about difficulty in analysis and effort required for evaluation of dependencies. In line with this, Rungi and Hilmola (2011) suggest that the handling of dependencies can be made more attractive by developing existing methods and making analyzes more effective by generating practical and easy solutions. Zimmermann et al. (2012) point out that portfolio risk would be different from the risks of individual projects in the portfolio when portfolios are analyzed by considering inter-project dependencies.

Despite the frequent emphasis in the literature on the importance of the dependencies among the projects in portfolio management, there have been no comprehensive studies focusing on handling dependencies (Rungi and Hilmola, 2011). The methods that deal with the existence of dependencies between projects consist of methods such as each of which has its own advantages and disadvantages (Rungi, 2010a):

- informal methods based on subjective evaluations of people (such as “sacred cow” and “gut feeling”),
- optimization methods (where an objective function with constraints, including interdependencies is optimized through different methods such as, integer programming, goal programming, fuzzy programming, stochastic programming, and dynamic programming), and
- methods providing visualization of dependencies (through methods such as design structure matrix, intra-dependency index, nested options model, program-level network, and roadmapping).

Since visual methods are appreciated to be more useful for handling the dependencies, use of visual methods is mostly preferred in the literature. These methods are based on enabling managers to examine effects of a project in the portfolio on other projects and so making them to conduct a more successful portfolio analysis (Shenhar et al., 2001). Demonstrations of the dependencies between projects in the tools developed for portfolio management are generally achieved by 2x2 matrix representations with the aim of structuring a visual mean for communication and learning and so supporting decision-making (Killen and Kjaer, 2012). It is known that these notations strengthen the process of evaluation and sharing of knowledge by supporting the decision-making process in many studies (Bresciani and Eppler, 2010). However, it can be seen that existing tools and techniques are inadequate to handle multi-level dependencies between the projects in portfolio studies (Killen and Kjaer, 2012). A study shows that it is not appropriate to use matrix-based approaches in portfolio studies of complex and inter-related research and development projects (Laslo, 2010). Relationship matrices show the analysis of bidirectional relationships for each project pair in the portfolio using a 2-dimensional “grid”. These matrices are limited with pair-wise analysis of relationships, so they cannot depict multi-level dependencies and cannot consider the accumulated effects of the dependencies. For example, in a portfolio where “Project A” is dependent to “Project B”, and “Project B” is dependent to “Project C”; the impact of “Project A” on “Project C” is not examined with the current methods (Killen and Kjaer, 2012). They are also insufficient to define different types of dependencies (e.g., resource, financial, output, etc.) in similar projects and similar types of relationships between different projects. Many models are based on the principle that the person in the position of decision-making defines the relation between the projects qualitatively. Therefore, the inability to examine the relationships is becoming one of the weak points of project portfolio management (Elonen and Artto, 2003). Campbell et al. (2003) present that “portfolio analysis without considering dependencies” is stated as one of the main reasons for unsuccessful portfolios in the survey studies. Therefore, methods that will be capable of quantification of dependencies between projects and providing decision support considering these dependencies will be a differentiating factor for the tools to be developed for portfolio management (Aritua et al., 2009).

Regarding the issue of handling the project dependencies, Killen and Kjaer (2012) propose that use of “network maps” can help to understand the accumulated and multi-level project dependencies between the projects. Network maps are designed with tools that can save, analyze, and graphically display dependencies in general. These maps also allow modeling of existing networks to evaluate the current situation or to make changes more clearly and easily reflected. This advantage of network maps provides a clearer and more realistic representation than the verbal explanation or matrix representation (Hanneman and Riddle, 2005). Although network maps are used in many decision support systems, it appears that they have not been incorporated sufficiently in project portfolio management yet. In this respect, Killen and Kjaer (2012) develop a technique that has the potential to create project network maps and show relationships within the portfolio. This technique, which is called as “Visual Project Mapping (VPM)”, represents each project as a “node” within the network and shows the dependencies between them as “arrows”. In addition to this notation, Killen and Kjaer (2012) suggest easing the process by classifying project dependencies according to their “importance” and “dependency type”. They provide a preliminary study and represent dependencies of a portfolios through network map. They categorize the dependencies as “less important”, “important” and “critical” considering their importance, and as “product/return”, “learning”, “resource” and “other” according to their relation types. They construct a “network map” as an exemplification to visually represent project dependencies and validate their method considering its adoption by construction company professionals in dependency assessment in portfolio management. Thus, network maps provide an innovative way of handling dependencies in portfolio management; however, current efforts are still lacking measurement of dependencies and visualization capability of the network maps should be fostered to ease identification of dependencies.

2.5. Portfolio Management in Construction Industry

This section presents the overview of portfolio management initiatives in the construction management literature and summarizes the studies available in the literature for underlining the importance of generation of a tool as aimed in this study.

2.5.1. Overview

Transition from financial asset selection within an optimal portfolio to selection of right projects for the portfolios has begun with initial considerations as selection of projects simply by the factors of risk and return as in modern portfolio theory. Improvements in PPM evolved to a more comprehensive considerations based on a larger set of factors such as continuous risk management, controlling, and reporting in management of project portfolios (Kaiser et al., 2015). Therefore, initiatives in construction project portfolio management also bear the same effect in the evolution of the efforts in the area as financial considerations to gradual improvement in consideration of resources, time constraints, strategic concerns, etc. However, industry is still lacking a complete solution for implementation of PPM principles and the placed effort is very poor (Abbasianjahromi and Rajaie, 2012). Most of the studies underline the requirement of effective mechanisms to adapt portfolio management initiatives rather than holding on project centered management traditions to foster benefits (Blismas et al., 2004; Kock et al., 2016; Kozlov and Shnyrenkov, 2017; Masoumi and Touran, 2016; Meifort, 2016; Wu et al., 2013). A research held by Construction Industry Institute (CII) (CII, 2015) revealed that lack of systematic approach for project portfolio formation was emphasized as the main obstacle in successful portfolio management, while underlining the primary need as a comprehensive and objective method for project selection (Masoumi and Touran, 2016). Project/portfolio selection is challenging due to variety of tangible and intangible strategic goals, conflicting constraints, lots of alternative initiatives to be pursued, and issues like uniqueness of project conditions, complexity and dynamism of projects, dependencies among tasks/assets/projects, risky nature of projects/industry, resource constraints, etc. (Abbasianjahromi et al., 2016; Abbasianjahromi and Rajaie, 2012; Blismas et al., 2004; Chitchian and Bekkering, 2007; Siew, 2016; Shafahi and Haghani, 2018). Therefore, successful mechanisms are needed for supporting the overall process for construction professionals to meet the company level objectives rather than simply focusing on project objectives.

2.5.2. Previous Studies in Literature

There is very limited research held on use of portfolio theory in construction industry. The first use of portfolio theory in construction projects is provided by Vergara (1977). In his study, Vergara first investigates projects individually. After evaluation of the existing portfolio of the organization, the selection of appropriate projects according to the expected characteristics of the portfolio is made. Handa and Georgiades (1980) propose a method to measure value of construction projects in uncertain environments and utilize this method in selection of construction portfolios. As initial considerations of portfolio theory Gareis (1981) utilizes portfolio theory in verification of investment decision in a construction company. Kangari and Boyer (1981) propose a project selection model based on portfolio theory to handle risk of projects in project selection process. They structure their model on standard deviation and expected NPVs of the projects. However, in their study Kangari and Rigss (1988) state the problems with application of this model due to difficulties in calculation of covariance for projects. Veshosky (1994) mentions the importance of strategic management and portfolio approach in Architecture, Engineering and Construction (AEC) firms while improving their position or entering in new markets (Abbasianjahromi and Rajaie, 2012). Miller and Evje (1999), integrate portfolio approach to capital procurement and generate a tool (CHOICES) that is capable of making comparison of alternative delivery scenarios to formulate and align with the strategy. Tong et al. (2001) recommends use of a model based on generic algorithm optimization in the building and construction portfolio management to forecast long-term asset management strategies and enable minimization in total maintenance and replacement costs by smoothing fluctuations of expenditure and resource requirements. In their study, Han et al. (2004) study on evaluation of risk of international projects both individually and at the corporate level by their financial portfolio risk management process based on multi-criteria decision-making method. In another study, Blismas et al. (2004) construct a typology that enable depiction of features of a client's construction portfolios. The study provides identification of program composition of a portfolio, and draws attention of management team to the highlighted features of the program of the portfolio. Therefore, the study enables establishment of optimization within the portfolio. Hauc et al. (2010), present a model for optimal project portfolio for the construction of railway infrastructure including project identification and prioritization considering financial assets and deadlines. Sun et al. (2010) present a method based on vague sets and enable project selection according to the enterprise strategy. They use the following selection criteria for construction projects;

- nature of the construction organization (investor),

- financial index (profit margin),
- complexity of the construction technique,
- amount of investment,
- number of the similar projects,
- limitation of material and equipment resource, and
- synergy of the projects in construction.

Touran (2010) constructs a mathematical model that enables investigation of impact of a cost overrun risk in single project's budget to the portfolio budget. Liu and Wang (2011) generate an optimization model for project selection and scheduling problems with time-dependent resource constraints for determining an optimal portfolio with the specified resource constraints. Wibowo and Kochendoerfer (2011) present a methodology with chance-constrained goal-programming framework for selecting infrastructure projects for a portfolio of guaranteed projects that brings maximum welfare gain, maximum total net change in financial net present value with the lowest fiscal risk for a given budget constraint. Ye and Mao (2011) investigate the effect of project portfolio management on cost control of communication construction projects. Abbasianjahromi and Rajaie (2012) present a new framework that provides optimized project selection based on the endurable risk level of a company with regard to the existing portfolio by applying fuzzy multi-criteria decision-making approaches. Wu et al. (2013) mention the pre-portfolio decisions of new energy construction projects in China through methods and models for major aspects of portfolio management. Guo and Yu (2013) underline the necessity of project portfolio implementation in the Chinese construction industry and mention that it is applicable and should be adopted in the construction industry. Van Niekerk and Bekker (2014) develop a tool for contingency estimation for large portfolios by considering both neural network modelling of systemic risks and expected value analysis of project-specific risks to decrease subjectivity in the estimation, which is required for portfolio level risk management. Qi et al. (2014) investigate the effect of Project Management Office (PMO) on project portfolios by structural equation modeling and find a strong positive relationship with respect to its effect on program and single project management. Kaiser et al. (2015) introduce “structural alignment” by strategy implementation as a new perspective in successful PPM based on case studies in German construction industry. Dobrovolskienė and Tamošiūnienė (2016) mention consideration of sustainability criteria as well as return and risk of projects in portfolio management to include the effect on environment and society and present a sustainability measurement index in this respect. Masoumi and Touran (2016), propose a framework for selection of most valuable projects for organizational goals. Siew (2016) focuses on sustainability in PPM and presents a method for integration of sustainability at two stages as “screening” and “optimal portfolio selection” where outputs as means and variances of sustainability measurements obtained in the “screening” stage is used to establish portfolio efficient frontier for the “optimal portfolio selection” stage. Ezeldin and Ali (2017) develop a computational model analyze and optimize the cash flow requirements for large engineering portfolios for contractor’s case. Farshchian et al. (2017) use agent-based simulation model for simulating budget allocation and its effects on the progress of projects in an owner’s portfolio of construction projects. Kozlov and Shnyrenkov (2017) generate a process model for portfolio management system for investment projects. Gade et al. (2018) propose a tool named as “REDIS” (Renovation Decision Support) for value-based analysis of most profitable alternative to renovate within portfolio of buildings. Hurtado et al. (2018) present a model with the aim of measuring construction portfolio performance and assessing portfolio management maturity in a further study. Namazian and Yakhchali (2018), generate a project portfolio risk assessment model based on the Bayesian network approach where the probabilities and expected values of schedule delays and cost overruns in construction projects are evaluated with respect to different risk levels of the project portfolio. In the light of the presented studies, available research clusters around either project selection processes or portfolio analysis through some generated methods. Some of the studies mention importance of portfolio management in construction industry and the others handles different stages of portfolio management through a core focus on issues. It is evident that, multi-project resource allocation, cash flow, and finance-based scheduling of projects in a portfolio share a considerable part in the available literature (Farshchian et al., 2017). Current studies focus on the processes of “project selection” and “financial risk management” and there have been no complete/integrated solutions reported in the literature yet that consider “balanced resource usage” and “institutional learning”.

2.6. Gap in Literature

The deficiency in the construction management literature regarding portfolio management solutions for construction company professionals constitutes the major motivation of this study. Construction industry is lacking a comprehensive framework that would enable adoption of project portfolio management initiatives by construction companies. Professionals need tools that may ease the complicated processes of portfolio management where they are responsible with handling/executing multiple projects contemporaneously. This multi-project environment brings extra considerations as evaluating the effects of projects to each other, namely their dependencies. However, portfolio management literature is very limited responding to this issue. Improvements obtained with visualization of dependencies have some potential; however, current efforts are still limited with subjective evaluations of dependencies. Therefore, a comprehensive portfolio management tool for construction companies, which can calculate and visually depict the dependencies between projects, is identified as the current gap in the literature.

2.7. Potential Areas of Progress / What the Research Claims?

This research aims generation a response to the current gap with joint effort of academicians and company professionals. It aims identification of the need first, which may add to current body knowledge and further foster the studies focusing on portfolio management in the industry. Development of a process model as the main structure of the tool design that would be responsive for the current need constitutes the second objective of the study. The study aims generation of a measurement model for dependencies and integration of the model to the tool for automatic quantification and visual representation. Generation of the tool also fosters the expected benefits of the model through help of technology and provides realization of whether the current approach is successful or not. The provided framework has also value since it provides an exemplification of the overall process and may be adopted to other project-based industries. Integration of technology also brings benefits as "intelligence" which further increases capability of the decision-making tool and also "dynamism" which is highly needed in portfolio management due to its potentiality in strategic management of companies as well. Overall testing that will be provided throughout the study would be another contribution as gradual evaluation of the progress and its outcomes.

2.8. Concluding Remarks

This chapter reinforces the raised problem and identifies the gap in literature. The chapter mainly investigates the available literature for generating a method as a remedy to this problem and reveals the need of generation of a novel approach in order to achieve the intended outcome. The presented piece of literature on portfolio management solutions, dependency assessment issue in portfolio management and current work in the industry as portfolio management initiatives is the point of departure of this study as forming a sound basis for needs analysis and development of the process model and the tool. The next chapter handles the methodology undertaken to pursue the study and its expected outputs in the light of the presented literature.

CHAPTER 3

METHODOLOGY

Methodology followed in this study is mainly based on identification of the requirements and development of the model and the tool with the support of its possible users. Considering this major attitude, the study has proceeded in three main stages as the needs analysis, development of the process model and generation of the tool where construction company professionals provided comments on development and evaluation of each stage. Three professionals from a leading Turkish construction company participated in the research as a focus group. They shared their expectations in the needs analysis, provided comments on the process model, its modules and the requirement specification, and as a final step, they participated also in the validation studies of the tool where they utilized the tool with an actual portfolio of projects. Active participation of the same professionals from the company has established a continuity in the progress of the study. On-site monitoring of the problem and development of the study would bring successful results for generation of an ideal solution; however, this may lead further problems with existence, generality and quantification of the solution (Fischer, 2006). To overcome the major drawback of this study as ending up with a tool that may be company or project type specific, firstly the point of departure has been literature for adaptation of existing methods or identification of requirements for generation of a novel approach. Study was based on an extensive literature study and initial requirements of the tool was identified. Following that, the focus group made evaluations on initial requirements and the requirements were reinforced with their contribution as investigation of the need in their company. A novel approach was developed as a result of further literature study held for functional requirements of the tool and a process model was generated in the light of the requirements. Additionally, a questionnaire study has been conducted, which was replied by 108 Turkish construction company professionals working in the international market, to support functional requirements of the tool. The generated process model was realized with development of the alpha version of the tool with improvements obtained as a result of finalized requirements with integration of technology. Evaluations for the process model and the alpha version of the tool were made by an expert panel, which has been set up with two academicians and two construction company professionals. This study was concluded with an update in the first release of the tool. The updated alpha version was tested by two other construction company professionals in a pilot testing study for ensuring the tool was ready for further testing for its usability and by real application. Thus, the methodology undertaken offers a considerable level of variety in company professionals participated in the study to prevent development of a company specific tool. As another consideration for dealing with this issue, the tool was structured to be flexible in some of its functions and preferences to support adaptability for different company requirements and it is also able to handle portfolio of all types of projects.

Testing constitutes a vital part in the methodology to provide the generality of the results (Fischer, 2006). Codification of the tool in the light of the problems identified has been in an iterative process of testing provided by the research team and the professionals. Within this process, the problems faced, the current design and the design principles were continually evaluated and the necessary considerations were taken for their improvement (Figure 3.1). Evaluation through iterations for the alpha version generally becomes "formative", especially contributing to the refinement of the tool and revealing anticipated as well as unanticipated consequences. These add more to the design and functions of the tool. Whereas, evaluation of the beta version becomes "summative", namely it is assessing mainly the product through its value and utility outcomes (Sein et al., 2011). Since this study aims generation of a practical tool with its expected benefits in portfolio management, the tool has been validated with usability testing and its actual implementation by the focus group to examine its capability and possible benefits. These studies also ended up with successful results, so these constitute the final studies held within the methodology. The following sections handle the details of the methodology undertaken through an overview and further details within the framework of software development.

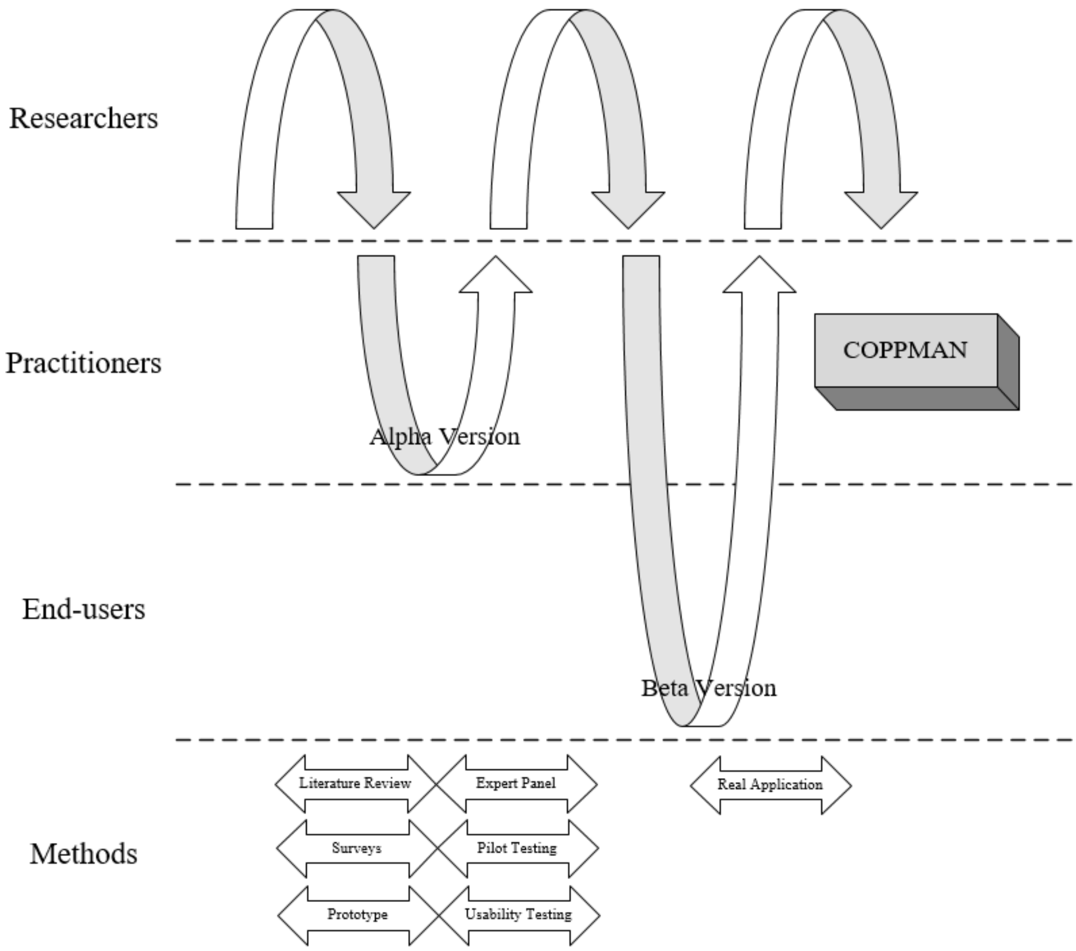


Figure 3.1: Cyclic Development of Tool (adapted from Sein et al., 2011)

3.1. Methodology Overview

Research studies are undertaken either as the effort “in practice” or “in lab”. As long as a design as a response to a problem in practice is in question, exploration of the problem in practice and development of the design accordingly would be a more sound beginning (Fischer, 2006). The methodology undertaken during a design process would be the major contributor to the end-product as the reformer of the design. Identification and categorization of the possible users of the product is important consideration in developing a successful one for its users; however, direct contact between the users and the design team would provide a more effective way of creating a product that fits with the purpose. Adopting an iterative design and testing would foster the benefits of such a design process, and the contact with the users should be maintained throughout the development lifecycle. Late contact with the users in the development cycle may result with minimal changes as only fine-tuning or aesthetic considerations in the design; however, early contact can provide complete analysis and rethinking of the design through iterations. Early testing of conceptual models and the initial design ideas would provide significant improvements. Therefore, for a successful iterative design process the complete cycle of design, test, redesign, and retest activities is required to successfully “shape the product” (Rubin and Chisnell, 2008). In the light of the provided information, iterative design process was adopted in generation of the tool and a “focus group” as three professionals from a leading Turkish construction company was assigned to supervise the overall study. Focus group is an ideal solution to obtain evaluation from representative users even in the very early stages of a design project as evaluation of the preliminary concepts through paper-and-pencil drawings, storyboards, and/or more elaborate screen-based prototypes, plastic models, etc. It provides in depth investigation of the users’ judgements and feelings on “how acceptable the concepts are, in what ways they are unacceptable or unsatisfactory, and how they might be made more acceptable and useful” (Rubin and Chisnell, 2008). Thus, evaluation of the focus group was obtained in three main stages of the methodology to enable early and continuous feedback on the development of the study. “Survey” namely “questionnaire” was undertaken to obtain input from a broader range of construction professionals to achieve some level of generality in the preferences used in some of the identified functions of the tool. Details of the functions were determined through the “paper prototyping” of the overall process through a numerical example. This method allows quick and inexpensive evaluation with the intended level of detail where the aspects of the product are shown through drafts on a paper (Rubin and Chisnell, 2008). Report of the tool functions depicted numerically through an excel sheet was used for realization of the overall process both by the research team and the practitioners. This example was further used for verification of the tool functions in the alpha version. Alpha version of the tool and the process model generated were evaluated by an “expert panel” which has been established by two academicians and two company professionals with no previous involvement in the study. Expert evaluation provides an external review considering the target user of the product and would be effective if the expert has knowledge in both usability heuristics and domain (Rubin and Chisnell, 2008). Therefore, the experts were selected considering their capabilities in both portfolio management and information technologies. “Pilot testing” was conducted with two professionals as the trial of current version of the tool and the surveys that would be held in further testing. Another main consideration has been “usability testing” of the tool, which is deemed to be an important contributor in an iterative design process (Liu and Zhu, 2012). Focus group provides valuable qualitative information; however, do not provide much on analysis of performance of the tool since they are only delivering their expectations. In their study Rubin and Chisnell (2008) underline that “*Although the design team must think about the technology of the product first (can we build what we have in mind?), and then what the features will be (will it do what we want it to do?), they must also think about what the user’s experience will be like when he or she uses the product.*”. Further evaluation of the tool was made with this consideration. Usability testing serves for this purpose and it is the best way for making analysis regarding behaviors and performance issues. It enables collection of data from representative users through using the product by performing realistic tasks (Rubin and Chisnell, 2008).

Therefore, it can be deemed as deeply monitoring the trial of its utilization and collecting data through help of technology in a lab environment, which would not be possible otherwise, even in its actual implementation. As the last step of evaluation, “actual implementation” was made as the actual utilization of the tool by the “focus group” in their company and with their real projects for establishing portfolio. This study constitutes the final evaluation of the tool by its real users with a real case study (beta testing) in the real environment.

In the light of the presented overview, the overall methodology is depicted in its outline in the following figure (Figure 3.2). As it shown in the figure, the research consists of three main stages and their evaluation as needs analysis, development of the process model and the tool. The related methods undertaken in each step is provided in the figure, where testing on alpha version is depicted in “gray”, whereas testing on beta version is in “light orange”.

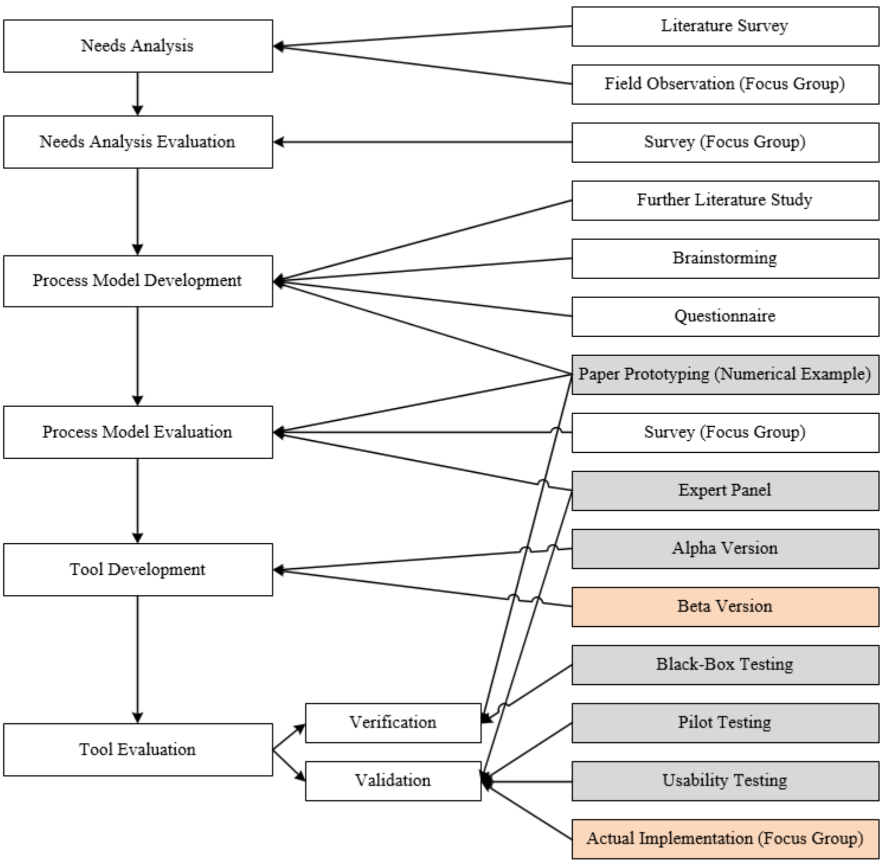


Figure 3.2: Overview of the Methodology

In the light of the provided reasoning and outline of the methodology, further details on application of the methods are presented under main steps as follows. The methods used and the outputs obtained in each step are separately listed under the steps:

- **Needs Analysis:** Within the scope of the study, firstly, a detailed literature survey was carried out and needs analysis was performed. The research started with investigation of “related literature” and “field observation” was made through the survey conducted with the focus group to identify the basic functions of the tool. In this context, firstly the content of the project portfolio management, its importance, the tools developed and used for portfolio management and the conceptual studies made in this area were examined and the fundamentals of the study was established. Then, how to define the relationships between projects in project portfolio management, the classification and visual mapping of such relationships, the analysis methods of these relationships and strategic priorities in project portfolio management were investigated to establish the details of the study. The identified initial requirements were reinforced with the requirements identified through the interviews made with the “focus group” on their current capabilities and assessment of the need for portfolio management adoption within the company. As a result of this investigation, functions suitable for construction industry were identified as making risk and strategic evaluation, development of a knowledge base and knowledge capture system, use of knowledge during analysis, consideration of effect of project dependencies, and decision support system on portfolio analysis and selection.
    - **Literature Review:** on portfolio management and its tools for
        - assessment of requirements of a portfolio management tool
    - **Survey 1 - Needs Analysis:** identification of problems with current practices through “interviews” with the focus group for
        - analysis of current practices or existing technology in the company
        - assessment of requirements for a portfolio management tool

- **Output - Initial Requirements:** as a result of literature review and analysis of the current practices in the organization

- **Needs Analysis Evaluation:** The identified requirements were investigated by the focus group.
  - **Survey 2 - Initial Requirements:** evaluation of initial requirements through "questionnaires" with the focus group for
    - appreciating need of portfolio management
    - appreciating need of a tool
    - assessment of the importance of initial requirements
- **Process Model Development:** Following the needs analysis, "further literature study" was held for more detailed evaluation of the literature in terms of the initial requirements. This secondary review was supported with "brainstorming" meetings arranged within the research team for determining the necessary features and basic functions of the tool with the conceptual model. Initial design was structured through this brainstorming on existing portfolio management systems and procedures and suitability of these systems to construction project portfolios. Following identification of the basics, a "questionnaire" study was conducted where participation of 108 company professionals was achieved, to finalize the initial algorithms and determine the figures/coefficients (such as similarity coefficients, risk factors, default attributes and their weights, etc.) that will be embedded in the tool functions. A "paper prototype" of the model as a numerical example was generated by using the current results of the questionnaire and necessary revisions were made in the model by the research team as a result of complete depiction of the model. It provided an opportunity to test the validity and correctness of the developed method and to make necessary improvements on the model in order to eliminate the deficiencies and mistakes. As a result of this study, the functions of the tool and the modeling details were outlined. The final model mainly integrates dependency analysis and knowledge management to project portfolio management, while providing assessment of risks at the portfolio level and strategic prioritization of the

projects/portfolios. It can calculate and visually define the dependencies between projects and take these into consideration while guiding management of the portfolio and making project/portfolio selection. The revised prototype was further used in studies of evaluation by focus group, verification of the alpha version, depiction of the model and the tool to the expert panel, and generation of task scenarios in usability testing.

  - **Output - Initial Model:** by further literature study and brainstorming
  - **Survey 3 - Functional Requirements:** identification of requirements of basic components
    - identification of attributes
    - identification of weights
  - **Paper Prototyping:** numerical example as paper prototype, initial evaluation by the research team
  - **Output - Final Model / Updated Paper Prototype:** updates in the numerical example as simplification of the lessons learned structures, predictions, etc.
  - **Output - Modules:** identification of the modules based on the final version of the process model
  - **Output - Requirement Specification:** identification of the requirement specification as translation of principles to features based on the final version of the process model and the modules of the tool

- **Process Model Evaluation:** The generated process model was first presented to the focus group for evaluation and they replied a survey on modules and requirement specification based on the current model. A latter evaluation of the model was made by the expert panel within the context of evaluation of the alpha version of the tool and the methodology undertaken.
  - **Survey 4 - Model Details:** investigation of the numerical example, and evaluations by the focus group through “interviews” and “questionnaires” for
    - validation of the established model and modeling assumptions
    - assessment of the modules

        - assessment of the requirement specification
    - **Expert Panel / Survey 5 - Expert Evaluation:** a retrospective evaluation on the model was made by expert panel, where the numerical example was provided in the tool (alpha version) as a base model to "mirror the mental image" of the model
        - validation of the research methodology
        - validation of the model
- **Tool Development:** The model was actually realized and finalized by generation of the tool, where service procurement was provided for its codification in main two versions as "alpha version" representing the "feature functionality" and "beta version" as the version representing the "complete product functionality" (Goldberg and Wichansky, 2003). In accordance with the determined features of the tool, negotiations with the software firms were made and the development process was started. The tool was generated in an iterative model where verification of the completed parts of the tool and discussions for their improvement were continued throughout the development process. It was developed within a spiral model, which allows generation in sprints where each sprint follows evaluation and acceptance of the previous one, by joint contribution of the research team and the developer company through evaluation of the current possibilities. Therefore, early evaluations of the tool was made within its development process by the research team as verification of the tool to ensure that it is working as expected. The final properties were decided within the iterative stages of its development and the final design was completed as a result of this process. For verification of the tool, "black-box testing" methods were followed in addition to comparison with the "paper prototype" (numerical example) as a simulated data case study. During development process, several initial algorithms were generated for operation of the tool and these were finalized with the capabilities provided. Within this context, calculation methods were provided for assessments of similarities and dependencies between projects, learning potential of a project, predictions for a project based on past project

information, risk and strategic fit of a project/portfolio, project/portfolio and dependency map properties, and necessity and presentation of a warning. Since tool development and evaluation processes were held together, evaluation methods and the development outputs are distributed under these two steps as follows. "Verification methods" are presented under "development" since they mainly serve for development of the "alpha version", whereas "validation methods" are presented under "evaluation" since they serve more improvements made for the "beta version".

  - **Black-Box Testing:** verification of the tool by various black-box testing methods
    - verification of the tool generated in cycles
  - **Paper Prototyping:** verification of the tool by the numerical example
    - verification of the tool generated in cycles and the alpha version
  - **Output - Alpha Version:** generation of the first release

- **Tool Evaluation:** The first investigation of the "alpha version" of the tool representing the example of paper prototype was made by the "expert panel" in terms of evaluation of the process model, the methodology followed and the first release. Initial update for the alpha version was received following this evaluation. Therefore, "pilot testing" of the "updated alpha version" was done to validate the current version and the initial survey results through utilization by two company professionals. This evaluation resulted in an update as minor changes in the tool. "Usability testing" and "real application" by the "focus group" were undertaken as the studies investigating the performance and expected benefits of the tool within the context of validation studies for the tool. The usability of the tool was investigated through direct utilization by its possible users, with the metrics such as the ease of use of the tool interface, the ability to perform the functions of the tool at a specified speed and without error, and the ability to meet the needs of the tool user. Since the version used in "usability testing" did not receive any update, this final version was accepted to be the "beta version" of the tool. As a result of the actual implementation with a real case of portfolio, the “focus group” provided further improvement for the accepted version of the tool as the initial reformation in the light of its current capabilities.

- **Expert Panel / Survey 5 - Expert Evaluation:** the numerical example was provided in the tool (alpha version) as a base model to enable the experts to “manipulate within the tool”
  - validation of the tool
- **Output - Updated Alpha Version:** updates as improvements in functionality
- **Pilot Testing / Survey 6 - Pilot Testing:** use of the tool by two different company professionals and conducting “questionnaires” and “interviews” for
  - validation of the initial test results
  - checking construct validity of the tool
- **Output - Re-Updated Alpha Version (latter Beta Version):** updates in some buttons, tables, etc.
- **Usability Testing / Survey 7 - Usability Testing:** performance evaluation of the tool by its possible users through 14 task scenarios and surveys on the tasks as “questionnaires” and “interviews” for overall evaluation
  - validation of the usability of the tool
- **Output - No Further Update / Beta Version:** alpha version of the tool becomes beta version
- **Real Application / Survey 8 - Real Application:** surveys on the overall evaluation and expected benefits of the tool, real application by focus group as the end users and evaluation through “interviews” and “questionnaires”
  - validation of usefulness of the tool
  - validation of the tool in terms of expected benefits
- **Output - Final Update:** update in the final version based on improvements in the current functionality of the tool

3.2. Software Development Phase

For development of the tool, the following software development procedure was followed for the overall process, which supported structuring the methodology of the study as well (Desikan and Ramesh, 2007). Therefore, the methodology is presented in this section in a more technically oriented presentation.

3.2.1. Requirements Gathering and Analysis

As a result of requirements gathering through literature survey and observation of the problem in the construction company, analysis through meetings within the research team were organized in order for shaping the project portfolio management principles to enable their application by construction companies. Further studies on evaluation of the needs analysis, the conducted questionnaire survey, paper prototype, process model development and evaluation of the model, modules and the requirement specification mainly serve for this step. At the end of this process, details were formalized in the System Requirements Specification (SRS) document and this document was shared with ten software companies for their investigation. Meetings with each company were held as one on one interviews. At the end of the evaluation process, one of the companies was selected due their quick feedback and the references provided. The additional determined details were delivered and further meetings were held with the selected developer company, and the contract was signed for the service procurement.

3.2.2. Planning

The scope of the service included development of the tool, its visual front face design, its testing and release. Development of the first version of the tool was planned to be completed within 55 working-days and within five sprints to be issued. Outputs to be delivered with the completion of development process were:

- System (source codes),
- Database schemas belonging to the system,
- Setup instruction documents for the system, and
- Use instruction documents for the system.

3.2.3. Design

Details of the tool were laid out according to the main structure provided with the SRS document, and some further details of the tool were identified during development process according to the options provided by the company within the capability of current development. The company began design on the basis of basic requirements and further details by the research team were provided once the delivered functions of the tool were approved. As a result of these processes, deficiencies in the design of the submitted parts were identified by either the developer company or the research team through the verification studies and they were corrected as soon as they are detected. Other details were decided as a result of mutual negotiations between the software company and the research team, and the design process was proceeded with these cycles. The final version of the tool was obtained and the verification work of the tool was made simultaneously by both controls of the research team and the software company. Following further evaluations of the tool versions by practitioners as validation studies, changes in the design of the tool were made in accordance with the delivered comments.

3.2.4. Development/Coding

Software development life cycle models can be listed as (Desikan and Ramesh, 2007):

- Waterfall Model
- Prototyping and Rapid Application Development Models
- Spiral or Iterative Model
- The V Model
- Modified V Model

For development of the tool, "Spiral/Iterative Model" was adopted (Figure 3.3). Within this model, requirements gathering, design, coding and testing are done within an iterative process. Development of the tool proceeds incrementally as long as the success of the requirements are ensured. Therefore, with adoption of this development model functionality of the tool can also be tested during its development process.

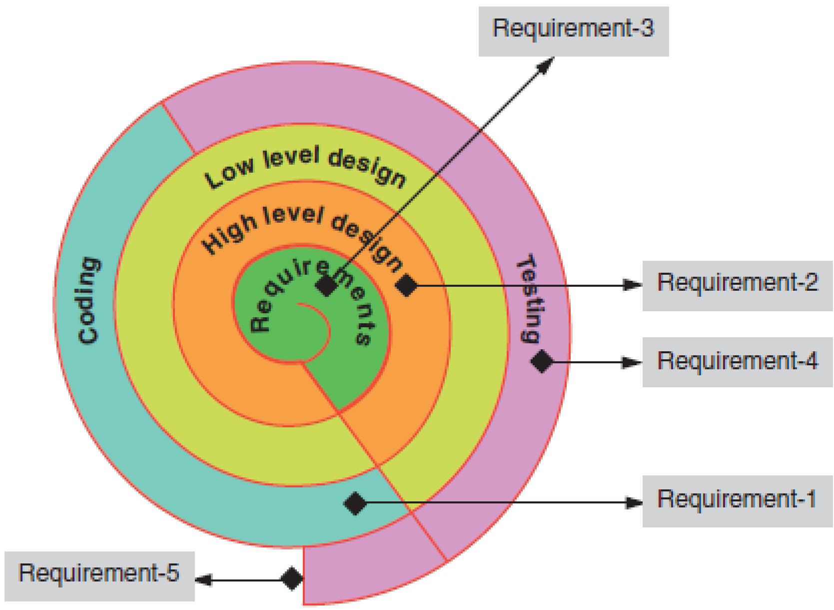


Figure 3.3: Spiral Model (Desikan and Ramesh, 2007)

In the light of the selected iterative development process, the completed functions of the tool were provided by the company for investigation through the sprints. Following the feedback process, coding was continued based on the verified functions of the tool.

3.2.5. Testing

Due to the lack of a standardized method for the development of software products, it is necessary to check for the quality of the end-product. Therefore, “product controls” are needed rather than “process controls” to ensure the quality of a software product, and this makes software testing a main concern in software development (Mili and Tchier, 2015). Testing can be defined as planning preparing, executing and analyzing the difference between the actual status and the required status of the tool. It is verifying and validating a software program to ensure that it meets business and technical requirements that makes the program to work as expected (Mustafa and Khan, 2007). In essence, the testing process consists of evaluating the difference between the expected situation and the actual situation. This evaluation can be done with two different major aims of (Mustafa and Khan, 2007):

- **Verification:** Testing the tool in terms of its level of meeting the “technical requirements”. The test methods available under this heading are divided into white-box and black-box test methods. Software code is directly examined in the white-box test methods while verifying the tool, whereas the codes are not examined in the black-box methods and the verification of the tool is done through behavioral examination through the results that should be obtained in terms of certain data (Desikan and Ramesh, 2007).
- **Validation:** Testing the tool in terms of its level of meeting the “functional requirements” of the tool. For example, testing in a simulated use environment (alpha testing) or testing in user site (beta testing) are examples of validation

tests. Testing the tool with a real application is one the leading testing methods for validation studies (Mustafa and Khan, 2007).

There are various methods of testing according to different evaluation perspectives that can be undertaken in various steps of software development (Desikan and Ramesh, 2007):

- **White Box Testing:** tests the programs by having an internal knowledge of program code,
- **Black Box Testing:** tests the product behavior by only knowing the external behavior as dictated by the requirements specifications,
- **Integration Test:** tests applied when software gets developed in a modular fashion and the modules have to be integrated together,
- **Functional Testing:** is a black-box testing for functional requirements of the application (Mustafa and Khan, 2007),
- **System and Acceptance Testing:** tests a product completely from a user's perspective in environments similar to customer deployments,
- **Performance Testing:** tests the ability of the system to withstand typical and excessive work loads,
- **Regression Testing:** is required, since software is always characterized by change, regression testing provides that changes do not break what is working already,
- **Internationalization Testing:** are the tests applied when software has to be deployed in multiple languages across the world,
- **Adhoc Testing:** addresses the methods of testing a product in typical unpredictable ways that end users may subject the product to,
- **Alpha Testing:** is testing by actual use of the application by a customer within the development organization (Mustafa and Khan, 2007), and
- **Beta Testing:** it is the "live operational test" of the software out from the environment of the development organization, it is conducted at one or more customer sites by end users (Mustafa and Khan, 2007).

Between all of the stated test methods, two main types covers the others as "white box testing" and "black box testing" that are generally used for "verification" and "validation" studies respectively. In its simplest form, "white box testing" is the investigation of the written code directly, whereas "black box testing" is the evaluation of the behavior of the software in terms of the specifications provided without investigation of the code. As a more detailed explanation can be provided as follows (Desikan and Ramesh, 2007);

- **White Box Testing:** "*Every software product is realized by means of a program code. White box testing is a way of testing the external functionality of the code by examining and testing the program code that realizes the external functionality. This is also known as clear box, or glass box or open box testing.*"
- **Black Box Testing:** "*Black box testing involves looking at the specifications and does not require examining the code of a program. Black box testing is done from the customer's viewpoint. The test engineer engaged in black box testing only knows the set of inputs and expected outputs and is unaware of how those inputs are transformed into outputs by the software.*"

Within this context, the following figure can be presented for the depiction of the summary on test method selection (Figure 3.4). When there is knowledge of codes, one can proceed with "white box testing", otherwise with knowledge of the specifications "black box testing" can be performed. In case of there is no specifications available, operations of the software can be tested by pure "domain knowledge" that would be provided by the "experts" in the area.

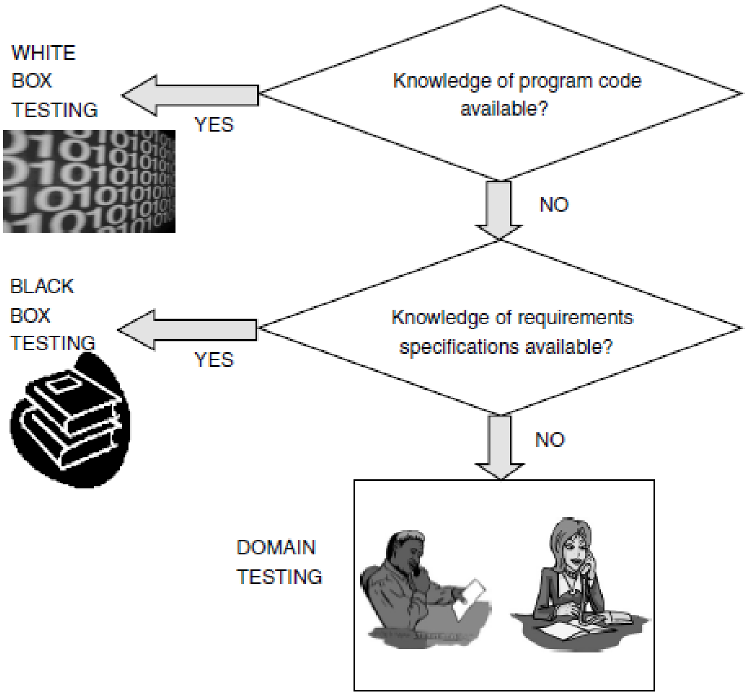


Figure 3.4: Context of White Box, Black Box or Domain Testing (Desikan and Ramesh, 2007)

Therefore, each testing serves for a different purpose, so there should be the aim set and the metrics that the tool is being tested against should be identified for structuring of the testing process. In a broader view, the "quality attributes" that can be used in any software testing process can be summarized as follows (Mili and Tchier, 2015):

- **Functional Attributes:** characterize input/output behavior of the software product
  - **Boolean Nature Attributes**
    - **Correctness:** software product behaves according to the specification within the domain
    - **Robustness:** software product behaves according to the specification within the domain and behaves reasonably outside the domain
  - **Statistical Nature Attributes**

- **Dependability:** the system behaves according to its specification for a period of time
  - **Reliability:** probability that the software product operates for a given amount of time without violating specification
  - **Safety:** probability that the software product operates for a given amount of time without catastrophic failure
- **Security**
  - **Confidentiality:** system's ability to prevent unauthorized access to confidential data
  - **Integrity:** system's ability to prevent loss or damage to critical data
  - **Authentication:** system's ability to properly identify each user that gains access to its resources and to grant users access privileges according to their rightful status
  - **Availability:** system's ability to continue delivering service to its user community under attack

- **Operational Attributes:** characterize the operational conditions of the software product
  - **Latency:** response time that elapses between the submission of a query to the system and the response to the query
  - **Throughput:** is the volume of processing that the system can deliver per unit of operation time, relevant to batch systems
  - **Efficiency:** ability to deliver its functions and services with minimal computing resources
  - **Capacity:** capacity of a system is the number of simultaneous users that a system can sustain while reserving a degree of quality of service (in terms of response time, timeliness, precision, size of data, etc.)
  - **Scalability:** system's ability to continue delivering adequate service when its workload exceeds the original capacity
- **Usability Attributes:** characterize the extent to which the software product can be used and adapted to user needs

- **Ease of Use:** includes simplicity of system interactions, uniformity of interaction patterns, availability of help menus, use of simple vocabulary, tolerance to misuse, etc.
- **Ease of Learning:** includes intuitiveness of system interactions, consistency of interaction protocols, uniformity of system outputs, etc.
- **Customizability:** system's ability to be tuned to specific functional requirements of the end user, user's control on the functionality
- **Calibrability:** ability to be tuned to specific operational requirements of the end user, user's control on the operational attributes
- **Interoperability:** ability to work in conjunction with other applications, for example breadth of file formats it can analyze and process, or by the range of file formats in which it can produce output

- **Business Attributes:** characterize the cost of developing, using, and evolving the software product
  - **Development Cost:** person-month invested in the development of the software product from its requirement analysis to its acceptance testing
  - **Maintainability:** amount of effort invested in the maintenance of the product during its operation phase
  - **Portability:** the average cost of porting the product from one hardware/software platform to another
  - **Reusability:** tool's ability to be reused in design or development of other software products
    - **Usefulness:** is the extent to which the product or component is widely needed in the product's application domain
    - **Usability:** is the ease with which it is possible to adapt the product or components to the requirements of an application within the domain
- **Structural Attributes:** characterize the internal structure of the software product
  - **Design Integrity:** includes simplicity, orthogonality (the quality of a design that results from a set of independent decisions), economy of

concept, cohesiveness of the design rationale, consistency of design rules, adherence to simple design discipline, etc.

- **Modularity:** each component of the system hides a design decision that other components need not know about
  - **Cohesion:** volume of information flow within the component
  - **Coupling:** bandwidth of information interchange that takes place between the components
- **Testability:** the extent to which one can test the system or components
  - **Controllability:** the bandwidth of input values we can submit to the component by controlling system inputs
  - **Observability:** the extent to which we can infer the output produced by the component by observing the system output
- **Adaptability:** the ease with which it can be modified to satisfy changing requirements

Between all these attributes, “functional attributes”, “operational attributes” and “usability attributes” are relevant to “software users”, whereas “business attributes” are for “software operators” and “structural attributes” are for “software engineers” (Mili and Tchier, 2015).

In the light of the provided information, regarding the testing of the tool, “structural testing” was out of scope of this study since it was developed by a professional company. Similarly, the study was supported by a grant and developed within the budget, so business attributes like development costs were already evaluated and provided. With the advantages of the structure of the tool, “maintainability” and “reusability” was to be easily provided, since the entire source codes of the tool were available and maintenance was guaranteed for a one year period by the developer company. There was no extra effort required for “portability” and “reusability” since the tool can be transferred to any other hardware by carriage of the database through copy and paste options following the setup process. Thus, main focus was on “functional”, “operational” and “usability” attributes during testing of the tool.

Within this context, evaluation was structured on two fundamentals as “verification” and “validation”.

Verification of the tool was made at considerable level with the help of the development process undertaken. Following the release of the updated versions of the tool, mainly validation centered evaluation process was aimed. Accordingly, the behavior of the tool was investigated with the intended behavior reflected through the requirements and any defects found in the operation of the tool was corrected before its next release.

3.2.5.1. Verification of the Tool

Verification studies of the tool were carried out and completed with its development in accordance with the followed development method. The tool was delivered at various stages to the research team and tested with various black-box testing methods to ensure that it was working properly. A hypothetical case study (numerical example/paper prototype) was developed through excel and the expected results were compared with the results obtained from the tool. Following detection of the malfunctions in this way, the code was examined by the software company and the problem was solved. Thus, code integrity was provided by the controls made by the software company. These studies continued until the results of the hypothetical case and the results obtained from the alpha version of the tool were the same. This process was a demonstration of that the tool was working as expected. Thus, “functional” testing of the tool was provided.

- **Black-Box Testing:** The tool was developed by a professional software company within a development model where the requirements and their verification was made in an iterative process as it is required in the spiral development model. Through this coding process, accuracy of the code, namely the white box testing process, was in the responsibility of the developer company. Therefore, as long as the problems were met during black box testing, evaluation by the company was made on the code and so the code strength was achieved. The development proceeded with the initial design provided and when the development was achieved in increments, further details were provided. For testing of these increments, a simulated data case study was held and a numerical example solved manually was undertaken as the main reference. Besides checking with this numerical example, some black box testing methods used for random checks in evaluation were as follows:

- Requirements based testing
- Positive and negative testing
- Decision table testing
- Compatibility testing
- Performance testing

Details of the tests will be provided in the following sections (4.3.4.1: Black-Box Testing).

- **Numerical Example/Simulated Data Case Study:** A numerical example that summarizes the whole tool process with 25 hypothetical projects as a simulated data case study was generated. The example was carried out in excel with generation of the required calculations and exemplification of some of the visualization capabilities. Graphs were drawn in excel, whereas the expected dependency maps were drawn with the tool "ORA" provided by CASOS (Computational Analysis of Social and Organizational Systems) center of Carnegie Mellon University. This example was used as a checkpoint to verify the tool functions and matching between the results of the tool and the example was established through an iterative process. Details of the numerical example will be provided in the following sections (4.3.4.2: Charrette Test with Paper Prototype: Numerical Example).

3.2.5.2. Validation of the Tool

In the context of tool validation tests, firstly the suitability of the tool model, whether it is meeting the intended needs or not, reliability and functionality of the tool were investigated through evaluation by expert panel. Following the expert review process, the tool was updated accordingly. In the context of validity tests, the tool was also tested for its construct validity through pilot testing. The tool was directly used by two different company professionals with their own case studies and it was found suitable for further testing as a result of the evaluation made. Following these, validation for usability of the tool in terms of ease of use, speed and aesthetics was made through usability testing. The usability testing of the tool was performed in laboratory setting in the Human-Computer Interaction Research and Application Laboratory of METU. As a final validation, a real case study in a construction company was performed for “beta testing”. The study was carried out in a construction company and a real portfolio of projects was analyzed with direct utilization of the tool. Validation studies were completed at the end of this study with identification of further improvements that may be beneficial.

- **Expert Panel:** An expert meeting consisting of four experts was conducted as the first step of these studies for both “functional” and “operational” testing of the tool including some measures on its “usability” as well. The tool was introduced to the experts before and at the meeting, and access to tool including the numerical example in its database was provided for their investigation and manipulation. As a result, validation for suitability and functionality of the tool was made through this investigation. In line with the comments received from the experts, the tool was updated with the support of the software company. At the end of the process, the visual and searching capabilities of the tool were revised and the library structure was improved. Details of the study will be provided in the following sections (4.3.2: Evaluation of the Alpha Version: Expert Panel).

- **Pilot Testing:** Pilot testing was held for both “operational” and an implicit “usability” testing of the tool as the trial study before usability testing and real application. It serves for construct validity of the tool and the testing materials for the forthcoming testing processes. The tool was directly used by two different company professionals with their own case studies consisting of hypothetical set of real projects under supervision of the research team. They performed portfolio analysis in two steps by eliminating projects after first analysis and establishing second analysis by excluding these projects. They delivered positive comments and this process resulted in minor changes in the tool. This study also proved applicability of the further testing with the tool and the testing material (similar questionnaires were held in further testing). Details of the study will be provided in the following sections (4.3.6: Evaluation of the Updated Alpha Version: Pilot Testing).
- **Usability Testing:** Usability testing at a laboratory setting with eye-tracking abilities develops the potential to analyze the micro-level behaviors of the users that may be indicator of the problems that may not be possibly detected with traditional methods, since these constitute un-reported details with little awareness without support of usability engineering. Thus, these advances provide analysis of details, such as the focus of attention on the interface during a task, distractions of the users during a task, or the visibility of an icon located on the interface, the success of interface by quantifying some measures such as effort undertaken for reading, mental computations, problem solving, thinking about the content, etc. (Goldberg and Wichansky, 2003). By application of usability testing, the ease of use of the tool interface, the ability to perform the functions of the tool at a specified speed and without error, and the ability to respond to the needs of the tool user can be investigated. Validation for usability of the tool can be made in terms of ease of use, speed and aesthetics by usability testing. In this process, participants are asked to complete pre-defined scenarios live with a computer that provides eye tracking and saving of the screen. This analysis provides the heat maps in terms of gaze plots that show whether the participant was looking to the right

points on the screen or not. This reveals the success of the interface design. In addition to that, all of the actions of the participant are recorded by the software in terms of video recordings. This enables the test facilitator to get the success rates of the tasks together with completion times and mouse click counts that also indicate the easiness of the use. Participators can be divided into two sets based on participators getting pre-test training or not. This also provides testing of learnability. Finally, the test facilitator also codes reactions of the participators and carries out post-task and post-test questionnaires to get evaluation by the participators. The factors taken into consideration during usability evaluation process of the tool were, “ease of use”, “effectiveness”, “satisfaction”, “consistency”, “learnability”, “user guidance”, and “error rate” (Yıldız, 2012). Within this context, the users were given “14 scenarios” to be completed and they successfully undertook the tasks with indication of minor problems, which do not add up for a requirement of an update. Details of this section will be provided in the chapter on “Usability Testing” (Chapter 6).

- **Real Application:** Validation with a real case study in a construction company was made in “beta testing” as the final study following the others as “expert panel”, “pilot testing” and “usability testing”. It serves for “operational” testing of the tool for measuring its potential benefits including some further measures on its “usability”. The company professionals created a real set of portfolio and evaluated the tool by analysis of their own case. They appreciated the current benefits of the tool and provided further improvements based on the current capabilities of the tool. Details of this section will be provided in the chapter on “Real Application” (Chapter 7).

3.2.6. Deployment and Maintenance

The maintenance and repair of the tool was in the responsibility of the software company for a one-year period following each updates. Any errors that may be detected during utilization of the tool was guaranteed by the software company for a year. The problems that might be encountered during this process would be corrected by the software company and the tool would be delivered again in its final version.

CHAPTER 4

DEVELOPMENT OF THE TOOL: IDENTIFIED REQUIREMENTS, FEATURES, DEVELOPMENT AND TESTING STEPS

Design process is explained in this chapter starting with the needs analysis and conceptual design, and its gradual evolution to portfolio management tool in accordance with the methodology presented. The chapter mainly reveals the details with each process, where the current output is presented together with the decisions lying behind and improvements obtained as a result of the evaluations made in each step.

4.1. Needs Analysis

In the first stage of the study, it was aimed to determine the functions of the portfolio management tool to be designed by examining and comparing the similar tools to identify the need. Accordingly, a literature search and a market research on the computer aided portfolio management tools currently in use were conducted. Following that, initial decisions on the need were reinforced through the investigation with the “focus group”, which also evaluated the overall decisions. This section mainly handles the details decided based on investigations both in the literature and in the field (i.e., the construction company) together with the identified concepts and background of the required algorithms as the initial considerations on calculation principles.

4.1.1. Decisions based on Literature Review

In the scope of the study, firstly detailed literature survey was done as the first part of the needs analysis. In this context, first the content of the project portfolio management, its importance, the tools developed and used for portfolio management and the conceptual studies made in this area were examined and the background of the study was established. Then the project portfolio management studies that define the dependencies between the projects, classification and visual mapping of the related dependencies, the measurement methods for mathematical calculation of these dependencies and the strategic priorities in project portfolio management were investigated. Based on the investigation, initial decisions were made by the research team through brainstorming meetings. This section presents the details on investigation and the related decisions in the order of provided search on different properties of the intended tool.

4.1.1.1. Portfolio Tools

At the first stage of the study, the current portfolio management tools were examined. Details of the tools were investigated with the main focus on identifying their common properties and differences as referring dependencies between projects. As main common point, “databases” form the basis of all the tools provided in research background (2.2.2. Portfolio Management Software). Databases generally contain information about the projects of the companies including the “completed projects” and “projects still in progress”. These data are further used for evaluation of “new projects”. It can be observed that in all of the tools the main visual consideration is providing “visual depiction” of the projects at both “project” and “portfolio levels”.

When the available tools are examined for their database structures, the following common attributes/features are often recorded as the required data.

- Project Type
- Project Status
- Project Relations
- Prioritization of the Projects

The project status is generally entered as "completed" or "on-going". The inter-project relationships are generally depicted through "Gantt Charts". It is seen that the "priority" of the projects are evaluated by the users where a score for the projects are obtained according to evaluation of some predetermined criteria.

In the portfolio analysis phase, the tools in question are mainly used for;

- Project selection in accordance with the company objectives,
- Risk analysis, and
- Scenario analysis in terms of effect of a project on portfolio considering benefits, time and cost analysis in case of the project is taken or not taken.

Most of the tools are visually supporting portfolio analysis process. "Bubble diagrams", "pie charts", "bar charts" and "dashboards" are identified as the most commonly used display methods (Project Management Institute, 2013).

Following the provided solutions, studies undertaken on tool development in the literature were investigated. These are generally optimization-based studies, studies based on scoring and classification, and studies focusing on visualizing portfolio with the aim of achieving portfolio balance (Cooper et al., 1999; Cooper et al., 2001; Oh et al., 2012). In line with the investigated studies, it is seen that strategic selection is mainly aimed at the optimum portfolio. For this purpose, "strategic prioritization" is made by using optimization methods or various scoring methods where the process is supported with visual expressions.

Regarding "dependencies", initiatives evaluating inter-project relationships in portfolio analysis are rather limited. In the tools focusing on evaluation of dependencies, they are either entered through "Gantt Charts" or they are determined subjectively and displayed in binary matrices. Since these methods are insufficient to handle multiple project relationships, it has been proposed to visualize dependencies via "network maps" (Killen and Kjaer, 2012). Therefore, the primary aim of this study was identified as generating a tool that can draw the "network map" by "defining and measuring the dependencies" according to entered project information, and incorporating the "effects of the dependencies" into the portfolio analysis. By using "scoring techniques" for "risk and strategic fit assessments" in the tool analysis process and "project and portfolio-level visualizations", it will be able to "select the right projects" in line with "value maximization" (or user preferences) and provide "managerial recommendations".

As a result, it was decided that the portfolio management tool to be developed should be designed as a tool that can be used to maximize a certain value ("portfolio value") and allow for "scenario analysis". Therefore, focus of the tool will also be calculation and visualization of the "portfolio value". The three most important items in calculating the portfolio value will be, determination of "dependencies and similarities between projects", "risks" and "compliance with strategic objectives".

Studies that were akin to aim of this study were investigated in more detail. Namely, a few of the identified tools as similar ones were investigated further, tools such as the ones providing sound portfolio visualization or making dependency analysis. Especially, study of Rahmouni et al. (2010) was identified as a benchmark study since it provides portfolio visualization through forced directed algorithm, which also reveals the relationships of the projects, and incorporating similarity analysis for learning from past IT projects and providing improved estimates on cost, time and staffing profiles. The study presents a tool (LearnIT) for supporting portfolio managers in selection of portfolios, with the aim of minimizing the risk and maximizing the chance of success in portfolios. It enables predictive analysis for IT projects by analyzing the similarity between the given project/proposal and set of on-going and completed projects. Then it creates functionality based on experiences in similar projects as predictions for resource, staffing profiles, potential risks and values for projects. LearnIT operates through two main facets providing:

- a “project centric view” through the database of completed or on-going projects, where a project manager can find past projects that are similar conditions to the one at hand and can indicate any likely issues or possible ways that can lead to successful outcomes, and
- a “big picture view” that is depicting all projects through clusters of sets of projects to provide a focus on the related set while indicating the relationships between them.

LearnIT is composed of three main components as:

- **Similarity Calculator Module:** provides computation of the similarity between two IT projects and serves both for the search and the visualization components of the tool, where a sub-module calculates the similarity of the features of the projects and weighted sum of individual/feature specific similarities constitutes the similarity of two projects,
- **Learning Module:** uses feedback from the user to modify and update the weights used in the project similarity module by tuning the weights by using a statistical classifier algorithm or manual setting, and
- **Visualization Module:** depicts the relationships between projects through clusters of projects, which makes common themes visible for the user by using force directed algorithm.

The visualization provided as “big picture view” in the study through use of “force directed algorithm” was evaluated to be not suitable for integrating to construction projects, since it was based on analysis of thousands of projects, which would not be the case with limited number of construction projects in a construction company. However, the main idea lying behind as providing a project centric view and big picture view provided a focus on visualization at both “project level” and the “portfolio level”. This further motivated investigation of portfolio visualization literature through consideration of “clustering with alternative methods” and “visualizations at project level” in portfolio studies (4.1.1.6: Portfolio Visualization). Additionally, the major focus of the study on use of similarity for learning from past projects by categorizing the projects as “proposal”, “on-going” and “completed” was found beneficial. Calculation of similarities by assessing similarities at the features level was also found practical and easily adaptable to construction projects.

Considering the integration of knowledge to project portfolio management, the study by Rosselet et al. (2009) for IT projects was found beneficial. The overall process provided as follows constitutes a successful overall evaluation structure as follows where evaluation of projects are made through “risks and impacts”, “strategic prioritization” is made by evaluation of strategic criteria (by evaluation of their weights) and portfolio balance is obtained through minimization of risks and resources are utilized accordingly (Figure 4.1).

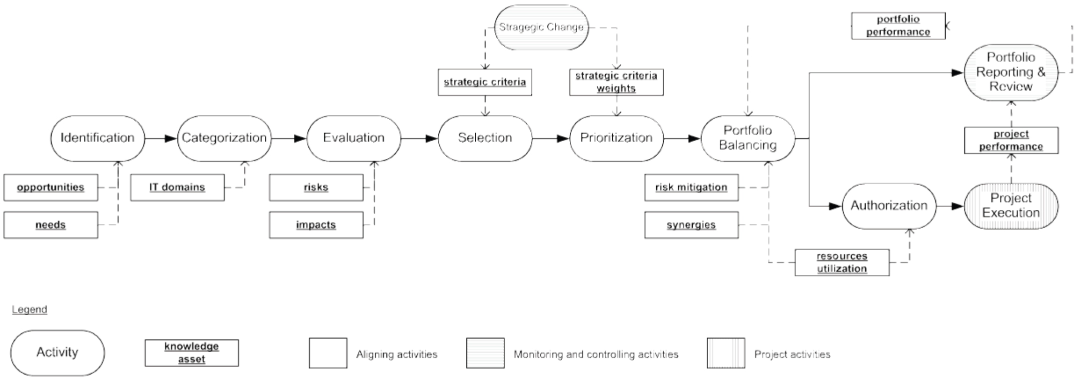


Figure 4.1: IT Project Portfolio Management Process by Rosselet et al. (2009)

In line with the investigation of the studies, initial modules of the tool were decided to be:

- Database Module,
- Similarity Analysis Module,
- Learning Module,
- Predictions Module,
- Dependency Analysis Module,
- Portfolio Analysis Module, and
- Visualization Module.

The identified initial modules, as the basis of possible tool architecture, structured the further investigation of the need as it is presented in the following sections.

4.1.1.2. Project Dependencies and Similarity Analysis

Studies that deal with project interrelationships are more handled in software (Bavota et al., 2013; Prochazka et al., 2012; Fonseca et al., 2006) and research and development (Abbassi et al., 2014; Eilat et al., 2006; Guo et al., 2008; Verma and Sinha, 2002; Stummer and Heidenberger, 2003) industries. When studies focused on the construction sector are examined, it can be seen that the handling of dependencies is limited with consideration at the activities level (Maheswari and Varghese, 2005) and interdisciplinary information sharing level (Froese, 2010; Liao et al., 2013; Pekericli et al., 2003; Srour et al., 2013). Among the studies that can be considered as studying dependencies, Abbasianjahromi and Rajaie (2012) consider projects independently of each other in portfolio selection; however, they use resource constraints in their selections. Li et al. (2011) work on multi-project risk management through providing equations on both "single project risk" and "multiple project risk", which is based on adjustment through aggregation of "single project risks". In most of the academic studies, project dependencies are subjectively identified (Guo et al., 2008). Guo et al. (2008) use 0-1 nonlinear mathematic programming method based for research and development portfolio selection. They identify a function for project portfolio benefit where positive/negative outcomes due to dependencies are included in this equation while their magnitudes are subjectively assessed. Within this context, they consider outcome dependency, resource dependency, technical dependency, and risk dependency. Similarly, Abbassi et al. (2014) use 0-1 nonlinear mathematical programming method for balancing research and development portfolio values and risks while considering interdependencies, types and other constraints with the projects in their mathematical functions. The methods used to handle inter-project relationships can be summarized as (Rungi, 2010a; Killen and Kjaer, 2012):

- subjective evaluation methods (where correlations are directly assigned),
- mathematical models aiming at the optimization of equations defined by relations and constraints (which require considerable amount of numerical input), and
- dependency structure matrices (that provide pair-wise analysis and are incapable of multi-level dependencies),
- visual methods (are more useful but dependencies are generally visualized only through matrices and Gantt Charts).

Therefore, it is accepted to be appropriate to use the technique proposed by Killen and Kjaer (2012) as “Visual Project Mapping”. Unlike this study, development of a measurement model that will be used instead of subjective entry of relationships is aimed in this study. Additionally, visual capability of the proposed map is decided to be improved as it is proposed in the study and already provided in the tool the tool “ORA” provided by CASOS center of Carnegie Mellon University. Different dependencies should be depicted in different colors and magnitudes of the dependencies should be depicted by weights of lines. Additionally the nodes of projects should be designed to show more information. Therefore, the generated method will calculate and visualize project dependencies to support decision-making process through the dependency map, which is proposed not only to identify different dependencies and their effects to the portfolio, but also to take into consideration the combined effect of the dependencies.

Regarding the measurement model, initial consideration was identification of “similarities” between projects as initial indicator of the “dependencies” between projects, which may pave the way for “calculation of dependencies”. “Similarity analysis” was also identified to be used as a means to learning from projects. When the related studies are investigated, it is seen that “similarity analysis” generally depends on the choice of the user and the type of data (Shepperd and Schofield, 1997). It is generally assessed by evaluation of distance between units through various measures as “Euclidean Distance”, “Hamming Distance”, and “Levenshtein Distance” (Rahmouni and Bartolini, 2010). Studies related to the inter-project similarity include “force directed algorithm” (Rahmouni et al., 2010; Rauch et al., 2013) and “self-organizing maps” (Zheng, 2009). However, “self-organizing maps” are based on the existence of a large number of projects, and “force directed algorithm” is primarily visualization-focused. When a limited number of construction projects were considered on a company basis, it was planned to develop a unique method for similarity analysis and to test the developed method with an alternative method (“clustering analysis”). Alternative methods for dealing with similarities for this purpose were identified as;

1. Calculation of similarity, and
2. Similarity by clustering.

Therefore, following testing the results of the alternative methods, the method was decided to be identified as either using the method which would provide better results or keeping both of the methods to make them optional for the user.

Browning (2001) underlines that “*Products, processes, and organizations are each a kind of complex system. The classic approach to increasing understanding about a complex system is to model it, typically by 1) decomposing it into subsystems about which we know relatively more; 2) noting the relationships between (the integration of) the subsystems that give rise to the system’s behavior; 3) noting the external inputs and outputs and their impact on the system.*”. In the light of this, as a response to first alternative as “calculation of similarity”, investigations resulted in decomposition of the projects to “concepts/attributes/features”, which constitute the basis of similarity studies (Rahmouni et al., 2010). Matching of these attributes can be used as it is provided in “overlap similarity measure” presented by Boriah et al. (2008). The process is based on identification of categorical data similarities using project attributes, simply the number of matching attributes between two projects (Boriah et al., 2008). Thus, projects will be more similar to each other as long as they match for the attributes identified. For identification of attributes, it was decided to use “company specific” attributes as well as “project specific” attributes to allow the companies completely define the projects at hand. The identified attributes for calculation of similarity between projects can also be the attributes that will be collected for entry of projects. Therefore, the tool can automatically calculate the similarities through the entered project information. As an initial investigation of the possible attributes for project information the following studies were investigated:

- "Construction Project Definition Rating Index" (CII, n.d.) presented by Construction Industry Institute to measure completeness of scope definition (Cho and Gibson, 2001),
- Domain taxonomy provided by El-Diraby et al. (2005) in terms of entities for "project", "process", "actor", "product", and "resource" for the ontology of construction domain, which also mentions further construction classification standards provided in different countries,
- Project "success criteria" and "selection criteria" provided by Shokri-Ghasabeh et al. (2010) to identify the common overlapping themes for using in the construction company's multi criteria project selection process,
- A set of widely-applicable common views of the project information presented by Froese (2010) with the aim of explicitly defining the interrelationships between the information in the different views of "product", "process", "resource", and "time",
- Design Interface Management System "diMs" proposed by Senthilkumar et al. (2010) where the construction project design is decomposed into entities of "system", "team", "component", "drawing", "sub component", and "design parameter",
- Work breakdown structure presented by Maheswari and Varghese (2005) through identification of lists of input and output parameters for each activity where the overall project is categorized into "disciplines", "components", and "activities",
- A multi-character model of the project definition process identified by Kähkönen (1999) to provide a balanced representation of various characteristics for the project definition process of construction projects through decomposition at the levels of "factors", "subjects", "processes", and "stages",

- Parameter dependency network presented by de la Garza and Alcantara (1997) to identify how one particular design decision affects other decisions, which further affect other decisions for building designers, and
- Project attributes identified by Dias and Ioannou (1996) to test attractiveness of an infrastructure project to be actively promoted by a given company.

As a result of this, initial investigation for both project attributes and the attributes for similarity calculation were made. Initial decision was made as there should be attributes available for "each type of project" and attributes that may be defined by the user according to company priorities, company experience, different phases of the project, special teams used, etc. Project attributes that should also be included were identified as the attributes for resources, risks, learning outcomes, project properties, and suppliers as follows:

- Company Specific Attributes
  - Resources: equipment, labor, material, etc.
  - Experience Area: tunnel, bridge, housing, road, shopping mall, industrial, etc.
  - Personnel: engineering team, design team, field team, management team, etc.
  - Strategy: selection of strategic objectives
- Project Specific Attributes
  - General Information
    - Location: country
    - Type: tunnel, bridge, housing, road, shopping mall, industrial, etc.
    - Status: completed, on-going, to be started
    - Project Delivery System: Design-Bid-Build (Traditional Contract), Design-Build, Construction Manager at Risk, etc.
    - Owner / Financer
    - Contract: Lump-Sum, Unit Price, etc.
    - Schedule / Duration
    - Budget

        - Resource Requirement: Material, Equipment, Labor, Subcontractor, Software
- Process (Engineering / Administrative)
    - Feasibility / Pre-bid
    - Bidding
    - Construction
        - Mobilization
        - Procurement
        - Excavation
        - Rough work
        - Finishing work
        - Demobilization
    - Operation
- Active Teams: engineering team, design team, field team, management team, etc.
- Contribution to Learning: may be identified by "technical topics" provided in the study of El-Diraby et al. (2005) and after topic selection user may define the contribution
- Risk: calculation of averages for the projects through user ratings
    - Country risk level
    - Project risk level
    - External risk level
- Standards used
- Legislation

Similarity Calculation: Similarity calculation was decided to be based on percent matching of the pre-defined project attributes. The weights were determined to be assignable to the attributes to reflect company specific preferences in the calculation, where default weights and additional attributes were decided to be obtained by the questionnaire study. The initial attributes for calculation of similarities between the projects were identified as:

- Country
- Project type
- Client
- Construction technology
- Contract type

Dependency Calculation: For calculation of dependencies as particular similarity of projects rather than overall similarity, project similarities specific for the dependency type was decided to be in the focus. To identify the details, firstly the dependency types were identified, following that attributes required for their measurements were identified according to characteristics of each dependency type.

In this study, it is assumed that there is a dependency between the projects when the "execution" or "success" of a project depends on the other project. Dependencies in literature are mainly identified as "resource", "market", "outcome", "learning", "financial", and "technological" dependencies (Killen and Kjaer, 2012; Rungi, 2010a; Bathallath et al., 2016). Between the stated ones, the following four dependencies were selected to be suitable for construction projects:

- **Financial Dependency:** Dependencies that exist due to dependency on the same financial factors (exchange rate, etc.) (for example, problems with a client in one project may affect the other project with the same client)
- **Resource Dependency:** Dependencies arising from the use of the same resources (manpower, equipment, etc.) (e.g., the problem to be experienced in a critical resource used in a project affects the other project using the same resource, any failure in special equipment used in one project may affect the other project that is using the same equipment)
- **Knowledge/Learning Dependency:** Dependencies in contribution to learning between the projects, which have similar context/content that may improve the knowledge across the projects (problem that affects the knowledge gained during execution of a new process in one project may affect the other project that the same new process is being used)

- **Outcome Dependency:** Any type of dependency that may imply an outcome or success dependency is defined as outcome dependency. If the outcome produced in one project is to be used in the other project, there exists an outcome dependency between the projects. Additionally, any special dependency may be defined with an outcome dependency to provide flexibility to the user (for example, when a special condition is required for wining of a project, namely awarding of a project is dependent on successful completion of a project with the same client).

It was decided that the pre-defined attributes of the projects should be examined in order to automatically distinguish and measure project dependencies. For this purpose, attributes for each type of dependency were identified and matching of these attributes for each project pair was decided to be indicator of the dependency magnitude. For example, percent matching of the "resources" of the projects can constitute the "resource dependency level" of the project pair. However, it may require extra burden to identify overall resources of these projects and expect the tool to extract the dependencies. Then user can eliminate the resources at the beginning and only define the "critical resources" for each project considering the risk with the resource. As another example, percent matching of the contribution to learning of the projects can indicate the learning dependency level of the project pair. If the two projects are using the same new technology together, a knowledge transfer and so knowledge/learning dependency is existing between projects.

Different weights were decided to be assigned for this calculation, and for calculation of overall dependencies as well, which would be obtained through questionnaires between construction professionals as default values. To provide flexibility in options, it was decided that the user would be able change the default importance weights provided in the tool.

Attributes for each dependency have been identified considering the similarities as the causes of the dependencies. In this context, the attributes to be used in the definition and measurement of relationships were set out as follows:

1. Attributes to be used in measuring the financial dependency:
    - Client
    - Currency
2. Attributes to be used in measuring the resource dependency:
    - Qualified personnel (project management)
    - Labor
    - Critical machine-equipment
    - Construction materials
3. Attributes to be used in measuring the learning dependency:
    - Country type
    - Project type
    - Client
    - Construction technology
    - Contract type
    - Project delivery system (turnkey, build-operate-transfer, etc.)
    - Project partner
4. Measurement of outcome dependency:
    - The existence of the outcome dependency between the project pairs will be asked directly to the user.

4.1.1.3. Portfolio Analysis

Project portfolio management mainly consists of making choices in line with the determined strategy and allocating the resources in a balanced way according to the priorities of the projects. Therefore, portfolio management is primarily aimed at investing in the right projects instead of the right management of projects (Project Management Institute, 2013). In summary, portfolio management involves the selection of projects in line with strategic targets and the creation of portfolio balance by distributing the resources in this way (Cooper et al., 1999).

When the construction sector-focused portfolio management studies are examined (Kangari and Boyer, 1981; Veshosky, 1994; Han et al., 2004; Blismas et al., 2004; Sun et al., 2010; Touran, 2010; Ye and Mao, 2011; Abbasianjahromi and Rajaie, 2012; Wu et al., 2013), since most of the work are involved with a specific process of portfolio management, a holistic approach to project selection is appreciated to be important.

In portfolio-based studies, generally "value" and "risk" equations are developed with the major aim of "maximization of the value equation" and "minimization of the risk equation". For optimization of these equations, "0-1 linear/nonlinear mathematical programming" technique is generally used where various constraints and relations are considered within these equations. While the existence of relations is often underestimated, their handling in these equations are generally made through subjective assignments (Abbassi et al., 2014; Abbasianjahromi and Rajaie, 2012; Guo et al., 2008; Li et al., 2011).

"Scenario analysis" is generally adopted in the portfolio analysis and it is aimed to determine the portfolio that should be selected and therefore the project(s) that can be undertaken as the result of comparing the values of the different portfolios that will be formed with the new project alternatives. In this direction, major aim in this study was set to determine the portfolio risk considering the "dependencies" of the projects, and to evaluate the "portfolio value" considering the "portfolio risk" and compliance of the portfolio with the "strategic targets". In the analysis process, it was aimed that the tool should be able to recall the old evaluations and user should be able to change these values in order to meet the changing conditions and to enrich the intended dynamic capability of the tool.

4.1.1.3.1. Portfolio Risk

In most of the portfolio analysis processes, portfolio risk is assessed through assessments made at the "project level" where effects of multi-projects are occasionally considered by subjective evaluation of dependencies to take the analysis one-step further and obtain risk at the “portfolio level”. Further, “risks” are integrated to “portfolio value” to evaluate and compare them through scenario analysis. In its simplest form, each new project to be added to the current portfolio is to effect the “portfolio risk”. Analysis of the risks with the project in two main stages is required as the project’s effect considering its own risk and its effect to the current dependencies of the portfolio. Therefore, it was decided that portfolio risk should be made of two main figures as:

1. Average of the single risks of the projects building up the portfolio, and
2. Risk premium originating from the dependencies of the projects within the portfolio as an addition to the average of the single project risks.

The presence of the dependencies is expected to increase the current portfolio risk, where overall risk may be lowered due to low average of the risks of the projects in the portfolio, although dependencies of the portfolio is increased in case of a highly dependent project is added to the portfolio. The effect of dependency is not to be distinguished by either being “positive” or “negative”, the point is the “uncertainty” existing due to this dependency. In line with this thinking, it was accepted that the “intensity of the dependency network map” obtained as a result of the network analysis can also represent the “intensity of the dependencies”, and therefore can constitute the increase in the portfolio risk. The portfolio risk was decided to be obtained by multiplying the average single project risks by the dependency density.

In this study, first of all risk assessment process should be done for active projects in each portfolio. Standard factors to be used in assessing risk were identified initially as listed follows (“CE703 Lecture Notes”, n.d.):

- Financial Risk
    - Inflation
    - Foreign exchange
    - Cash flow risk
- Political Risk

    - Political will for the project
    - Political interferences in awarding the contract
- Technical/Construction Risk
    - Engineering risk
    - Construction technology risk
    - Availability of resources
- Design Risk
    - Completion of design before construction
    - Complexity of design
    - Competence of designer
- Management Risk
    - Competence of management personnel
    - Organizational complexity
- Contractual Risk
    - Adequacy of documentation
    - Adequacy of definitions/clarity of needs of client
    - Contract/payment mechanism (lump-sum unit price, etc.)
- Requirement Risk
    - Strict quality requirements
    - Strict schedule
    - Strict environmental restrictions
- External Risk
    - Weather conditions
    - Ground conditions
    - Force majeure

The complete list of the factors affecting the project considering the additional factors were decided to be finalized through the questionnaire. Following evaluations on the factors for projects, a risk value/score for each project in the portfolio should be obtained and an average value of the projects should be calculated. After determining the average risk score, the effect of the inter-project relationships on the portfolio risk should be reflected by multiplication with density of dependencies.

In addition to presented portfolio risk assessment process, the tool was decided to provide risk estimation based on past project data as reoccurrence probability of the faced problems previously to ease the evaluation of the current projects.

In line with the provided capabilities the tool can provide warnings based on:

- centrality of the network: the most centralized three projects may constitute the most critical projects that needs special attention,
- density of the network: low density may indicate less centralized network and a safer portfolio when it is compared with a denser one, and
- knowledge database: special advices may be extracted for most critical projects through lessons learned.

4.1.1.3.2. Portfolio Strategic Fit

The importance of strategic goals in portfolio analysis is addressed almost in all of the studies since portfolio management is serving for strategic management as well. Therefore, this study had to address investigation of strategic objectives. In this respect, the following strategic objectives were taken as the basis of strategic analysis. As in the case of risk assessment of projects, a strategic fit assessment process was aimed. Therefore, strategic fit assessment should be performed for the active projects in each portfolio and the average strategic fit score for the portfolio should be obtained by calculating the average. The default objectives to be used in assessing strategic appropriateness of the projects for the company strategies were initially identified as follows;

- Profit maximization
- Gaining reputation
- Learning / Gaining experience

- Reducing risks
- Entering new markets

The complete list of the factors as strategic objectives of a company considering the additional factors were decided to be finalized through the questionnaire. Following evaluations, a strategic fit value/score for each project in the portfolio should be obtained and the average strategic fit score for the portfolio should be calculated by the tool.

4.1.1.3.3. Portfolio Value

When the portfolio value studies are examined, it is seen that the portfolio value is generally expressed through an equation and the portfolio selection is done by optimizing the value of this equation. In this study, the calculation of the portfolio value is adopted instead of the optimization study because the number of possible portfolios in a construction company is not expected to be much enough to be analyzed with optimization. The “portfolio value” is mainly the indicator of the contribution of each project to the portfolio. Therefore, the projects contribution to “strategic objectives” and the effect of the project to the “portfolio risk” is to be evaluated. In this context, it is expected that the portfolio would be more valuable when the portfolio risk is determined to be low, whereas strategic fit is high. Therefore, the equation was determined as multiplication of the inverse of the portfolio risk with the strategic fit of the portfolio. The tool should primarily make a selection based on the portfolio value, but the portfolio value details should also be presented to the user, therefore, it can provide guidance if the user wishes to make a selection based on risk or strategic fit of the portfolios.

4.1.1.4. Tool Database

The database forms the basis of all portfolio management tools. These tools are based on keeping the information of active and completed projects in the database and retrieving information during analysis. For this reason, a database was decided to be designed in this study. It was aimed that this database should also serve for other functions of the tool and that the data to be used in different phases of the tool can be entered at once and to the same database.

It was aimed that the database, which should be designed for the tool should store the related data for,

- calculations of the relationships,
- the potential for learning from the project,
- the data about the project-specific lessons,
- the risks specific to the project,
- the profitability of the project, and
- the managerial warnings to be given.

Considering the lessons learned, initial decision was investigating lessons obtained through the outline provided by Knauseder et al. (2007) as “organizing for learning” as provided experiences and statements, “experimenting” through new materials, working style, technology, and “networking” as sharing experiences between companies through alliancing, etc. The initial attributes that would be helpful in codification of lessons learned were identified as the attributes to keep past project information to provide learning, such as “country”, “client”, “critical material”, “critical equipment”, “critical technology”, “project type”, “project delivery system”, “contract type”, “payment type”, etc., as well as the attributes to keep partnering information such as, “partner company size”, “partner company specialty”, “partnering type”, etc. These attributes were also decided be evaluated through questionnaire to identify their importance in contribution to learning.

4.1.1.5. Tool Functions

Based on the initial investigation, the basic functions of the tool were decided as the ability of "learning from projects" and providing "predictions" based on project data, which can be evaluated through different "data retrieval options", as estimations on "profitability", "risks", and "learning potential". The initial decisions on the functions of the tool are presented as follows.

Learning from Projects: Learning provides development of human resources, information systems and project cultures, by drawing lessons from mistakes made or from good experiences and creating knowledge (He et al., 2013). Integration of knowledge is crucial for improvement of construction organization's capabilities where exploitation of existing knowledge is critical for short-term profits while exploration of new knowledge is essential for long-term profits (Eriksson, 2013). Knowledge accumulation in the construction sector is critical; however, sector-based structure and sector-specific characteristics make knowledge accumulation difficult for construction companies due to fragmented nature, dispersed locations, limited contact among participants, high staff turnover, lack of feedback, etc. (Tan et al., 2010). Knowledge can be mainly differentiated as "explicit" and "tacit". "Explicit knowledge" is the part that is easy to be codified, stored and communicated through sharing by specifications, design documents, physical laws, figures, words, writing, oral transfer, etc. However, "tacit knowledge" implies the experience-based part of knowledge, which is generally "gained by doing" and difficult to share, and strong learning mechanisms and tools are needed for codification possibility of tacit knowledge (Lê and Brønn, 2007; Tan et al., 2010). Therefore, a database that will keep this information is important for preserving the potential of knowledge within the company. In the construction sector, learning mechanisms are defined as learning from business partners, learning from competitors, learning from the communication network, learning from internal research, and learning from individual employees (Kululanga et al., 1999). Considering the learning opportunity from these sources, one of the key features of the portfolio management tool was evaluated to be its ability to learn. In the light of the investigated studies, it was decided to keep the information of the lessons learned in the database in consideration. In line with this, besides the knowledge of construction experience, it was aimed to record information learned from project parties, financial changes, delays, claim processes and dispute cases and to present them to users for future projects. Thus, the general structure of the initial database was considered to be as shown below (Figure 4.2).

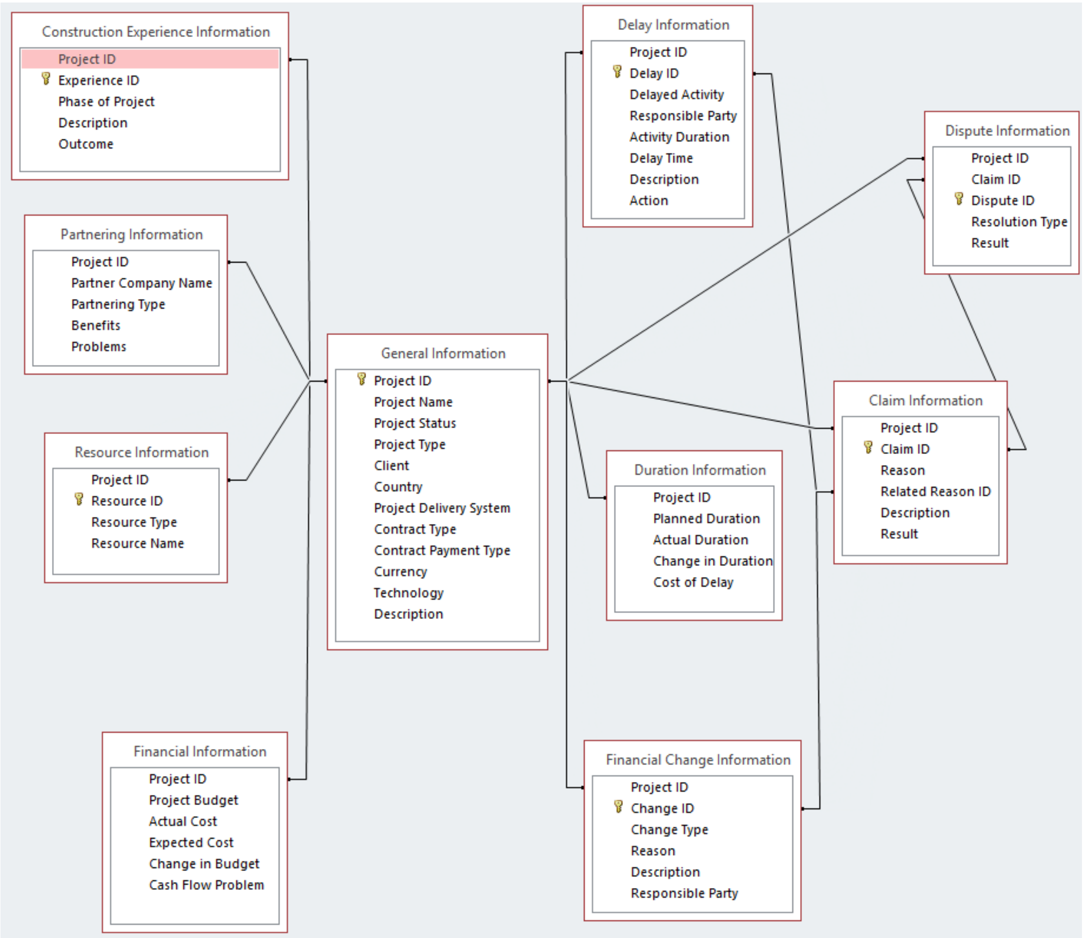


Figure 4.2: Database Schema

“Similarity analysis” was identified as a successful mean also for extraction of the related lessons from the database as direction of the initial focus to the related projects. Additionally, “learning potential” was defined as a measure for differentiating the projects providing learning opportunity, which may also be used in “strategic assessment” of the projects/portfolios. Learning potential of each project was to be decided to calculated automatically by the tool according to available project information. It was appreciated to be helpful in strategic assessment of the projects. Details with “learning potential” are presented under the function of “predictions” of the tool.

Predictions: The tool was also decided to be able to predict the profitability of a new project, its potential problem areas/risks, and its potential for learning.

- **Profitability Estimation:** The “expected profit” and “actual profit” information for each project were decided to be calculated by the tool through the budget and cost information of the existing projects. The ratio between these two values can be defined as “profit risk”. The “average” and “variance” were decided to be calculated for the “actual profits” and “profit risk” values. In addition to this, existence of a “cash flow problem” for each project was decided to be questioned in the project information entry.
- **Potential Problem Area/Risk Estimation:** The percentages of “delay time” and “delay cost” of the current projects were decided to be calculated by the tool together with the presentation of average values. In addition to these two values, “responsibilities” of the current delays and “activities” in which delays occur were appreciated to be notable and planned to be listed to the user. Thus, the user may get informed about total potential risk and risky properties of the new project.
- **Learning Potential Estimation:** It was decided that learning potential of the project would be high as long as it includes processes, which have not been experienced yet. Therefore, to calculate the learning potential, the calculation was decided to be based on investigation of how much the existing project attributes match up to the new project based on the following attributes (as the method also adopted in dependency and similarity calculations):
    - Country

    - Project type
    - Client
    - Construction technology
    - Contract type
    - Business partner

  Matching value obtained through the attributes and the level of learning potential were evaluated to be inversely proportional.

Data Retrieval Options: Data or estimation calculations to be obtained from the database in the tool were decided to be on three alternatives as “search/calculation based on similarity values”, “search/calculation based on filtering”, and “calculation based on pre-selected attributes” to facilitate access of information at the intended level and reliability of the retrieved results.

- **Project Similarity for Search/Predictions:** Similar projects were decided be determined and ranked according to the matching rates of the following attributes. Weights of the qualities to be used in the calculation of similarities were decided to be obtained from the survey results.
    - Country,
    - Project type,
    - Client,
    - Contract type, and
    - Construction technology.

  As a result of the similarity analysis, the projects can be sorted and presented to the user for further analysis. Additionally, predictions can also be presented through use of similar projects only.
- **Project Filtering for Search/Predictions:** Projects were decided to be able to filtered according to the following attributes.
    - Country,
    - Project type,
    - Client,

    - Contract type, and
    - Business partner.

  Thus, the projects can be filtered according to the user's typical selection and the projects obtained can be examined further. Similarly, predictions can be presented based only on the selected attributes.

- **Predictions based on Attributes:** Some of the predictions were decided to be presented in its default based on the following pre-selected attributes and presented to the user as average values regardless of request by the user. This option can provide ready to analyze figures to be presented to the user through the intelligence of the tool. The calculations were planned to be based on the following main attributes:
    - Country,
    - Project type, and
    - Client.

4.1.1.6. Portfolio Visualization

When the studies aimed at visualizing the portfolio are investigated, it is seen that the studies that are visualizing portfolios by clustering the projects according to their attributes is prominent. The clustering oriented studies in portfolio management mainly focus on “force directed algorithm” (Rahmouni et al., 2010; Rauch et al., 2013) and “self-organizing maps” (Zheng, 2009). Zheng (2009) underlines importance of clustering and visual explorations of projects in portfolio management by stating that fitting “high dimensional information” into “low dimensional models” damages the richness of project information. Therefore, assistance in viewing, understanding, and analyzing projects and project portfolios is required through interactive visualization of multiple dimensions of project data to provide a sound decision-making. Zheng (2009) uses Self-Organizing Maps (SOM) for clustering of IT projects to support decision-making. SOM provides clustering to analyze multi-dimensional information of portfolios and also supports with visualization capability.

It is based on the “radar charts” drawn for defined attributes, and the projects are clustered and visualized at three different level views as “cells view”, “clusters view” and “item view”. Investigation of this study reinforced the idea of visualization at different levels; however, the provided approach was not adaptable for the construction projects, when the current similarity calculation option is to be supported with other visualizations at both “project” and “portfolio level” while also visualizing the “dependencies” between projects. Inter-project relationships are of great importance for portfolio management. According to the general characteristics of construction projects, rather than “cluster representation”, it was thought that the representation of dependencies would be more critical. In another clustering oriented study by Rauch et al. (2013) clustering of projects and visualization is provided through “force-directed placement algorithm” (FDP). A “project symbol” is proposed in the study to represent the projects on the maps provided for different visualization levels as “similarity visualization” for overall clustering of the projects as groups of projects sharing particular project properties and “matrix visualization” for 2D matrix visualization through user selected attributes on the axes. The symbol indicates status of the projects through “overall progress”, “risk status”, “project stage”, “progress and size of each work package”, and the “financial, resource and time consumption” at once on the figure. In line with this, it was also planned that the nodes representing the project in the relationship map can be designed to represent several attributes of the project (Rauch et al., 2013). Therefore, it was aimed that the dependency network map should represent not only the relationships, but also the projects. In addition, supportive display options were planned to be provided via “bubble diagrams” and “bar charts” which are often used visualization methods in the portfolio management tools (Project Management Institute, 2013).

4.1.1.7. Overall Summary

Following the research on literature review on portfolio management and the available tools, meetings within the research team were organized and the needs analysis of the tool was evaluated in order to adapt the project portfolio management to the construction projects. As a result of the provided investigations, the following decisions are made regarding the portfolio management tool:

1. One of the most important stages of portfolio management is to identify “dependencies” between projects. Literature survey on the calculation of inter-project relations has shown that subjective methods have been used generally and it has been decided to develop a unique method based on numerical analysis for the evaluation of dependencies.
2. It has been decided that the project database should be designed to ensure that the data to provide learning and forecasting capabilities from the projects are captured in the same database.
3. One of the key stages of portfolio management has been identified as the calculation of “similarities” between projects. Following the literature review on similarity between the projects, it has been understood that a unique method should be developed for construction projects. It has been decided to test the feasibility of alternative methods in similarity analysis (i.e., “cluster analysis”).
4. A criterion called “portfolio value” has been defined to support users at decision-making positions in the selection of new projects. A portfolio value is to be a measure that will be calculated based on the risk of the portfolio and the conformity of the projects to the company's strategic objectives. Alternatives to the method of calculating the portfolio measure have been assessed and decided.
5. A questionnaire study has been aimed in order to be able to decide on the values that are required to use the methods mentioned above and calculate the related criteria.
6. Finally, the conceptual model and basic functions of the tool have been defined as the basis of further structuring of the design. In addition to this, the classical portfolio display options have been examined, but it has been concluded that a new style of mix of the methods or presentation should be

designed for supporting the tool to be developed. Work on the visual characteristics of the tool have been decided to be finalized with the further studies.

Regarding the initial decision in the research aim, the tool to be developed in this study was intended to be mainly an “intelligent” and “dynamic” tool with “visualization ability” where further considerations on its main features were identified as follows:

- **Visual Tool:** In general, strategic decision-making processes require more than one interrelated factors to be evaluated at the same time, under uncertain and dynamic conditions, with the organization having different priorities and contradictory goals. It is necessary to design a visual tool for simple modeling and communication of complex structures. In addition to individual analytical skills, project visualization is also a major challenge in analyzing and evaluating project portfolios in the best possible way (Killen and Kjaer, 2012). Therefore, visualization should be a concern in each step of the analysis as the visualization at both project and portfolio levels.
- **Intelligent Tool:** An intelligent tool is needed to store and transfer experience and information, and to draw lessons from the past projects. With the help of tool, it is thought that past project information can be used for future investments, preventing the repetition of mistakes and contributing to the value increase. Thus, the tool should be able to extract all the information that may be drawn through the entered project information where they are supported with structuring through the help of IT environment.
- **Dynamic Tool:** Construction industry is dynamic due to factors such as variability in project and environment conditions, possibility of change in strengths and weaknesses of the construction companies, instability of the relationships between the project parties and companies, etc. Therefore, it would be more beneficial to create a tool that has the ability to update the data regularly and to create a dynamic project portfolio rather than a tool that treats

the portfolio data statically (Killen and Kjaer, 2012). Project portfolios are not as limited in duration as the projects they contain and represent a wealth of knowledge that will exist throughout the life of the company. Therefore, it is important to regularly review portfolios, keep them up-to-date, and ensure that they serve their strategic goals (Young and Conboy, 2013). Thus, the tool should be flexible in structuring the evaluation metrics and provide mechanisms to keep the evaluations and analysis up-to-date.

In the light of the main features of the tool, the initial considerations on basic features of the tool can be listed as follows:

- **Portfolio Identification/Creation:** The conceptual model that will be created during the first phase of the work will ensure that the information required during the portfolio identification phase can be determined. In this model, the project properties will be entered by the user and the relationship between the portfolio and the project will be identified where the tool automatically provides the portfolio alternatives.
- **Visual Portfolio Map:** Following the creation of the portfolio, the tool algorithm will be able to visually identify the relationships by calculating them. After the dependency types of the projects and the size of these dependencies are determined, the visual map of the project portfolio in question (network map) will be created by the portfolio display function.
- **Decision Support/Warnings:** Through the visualized portfolio map, relationships with critical importance between the projects will be automatically determined by the tool and suggestions on how to manage this specific portfolio will be given. For example; the tool may recommend that users should make the time planning of the projects A, B and C together, benefit from the effective transfer of knowledge/learning between projects D and F, and consider projects E and G together in the risk management plans, after defining the critical relationships.
- **Scenario Analysis:** If a new project is added to the current portfolio, the tool will be used for scenario planning by showing the effect of the new project on

the portfolio and its effect on other projects regarding different types of dependencies.

- **Strategic Guidance/Prioritization:** The tool will identify the strategic objectives of the companies and will show the importance of each project to achieve these goals. This will take into account the priority of each project to reach these targets, while assessing the dependencies and critical relations between the projects. In addition, when a scenario analysis is carried out (e.g., in the case of a new project), it will be determined whether each new project meets the company objectives or not.
- **Dynamic Analysis:** The tool will also be used for dynamic analysis due to the dynamic nature of the construction project portfolios. In this context, the types and sizes of the dependencies between the projects will be revised taking into account the changing project, country, environment and company conditions, and new strategies will be developed according to the latest situation so that portfolio management can reach the targeted success.

Accordingly, the initial flow charts of the tool process were drawn as follows where the tool provides establishment of the database first, and following evaluations portfolio values for the current portfolio and the potential portfolio are obtained to compare the benefit of the potential portfolio through its effect on the portfolio value. The main steps required for the process were identified as follows when there is evaluation of a new project alternative:

- Past and on-going projects, company information are entered, company strategies are selected from the strategies and the portfolio and lessons learned database are established.
- Dependency assessment of on-going projects are made and dependency effect (ΔR) is calculated, risk rating for each project is made and average risk rating of the on-going projects is calculated, final risk level of the initial portfolio is obtained.
- Strategic fit assessment of each on-going project is made and a strategic fit score for the portfolio is obtained.

- Initial portfolio value is calculated.
- Potential project information is entered in the tool.
- Dependency assessment is made including the new project and the new ΔR value is obtained, average risk rating and the profitability potential estimates from the lessons learned database are made.
- According to the estimates and the ΔR value risk level of the current portfolio is calculated (Figure 4.3).
- The strategic fit of the Project is calculated through ranking process of the strategic objectives.
- New portfolio value is obtained (Figure 4.4).
- Final decision is made by comparing the initial portfolio value with the new portfolio value.

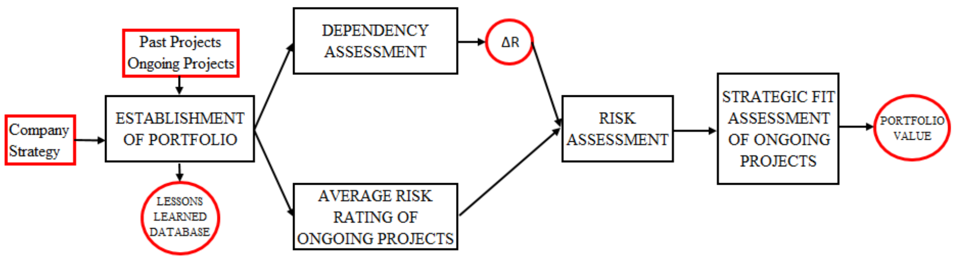


Figure 4.3: Flow Chart for Establishment of the Current Portfolio

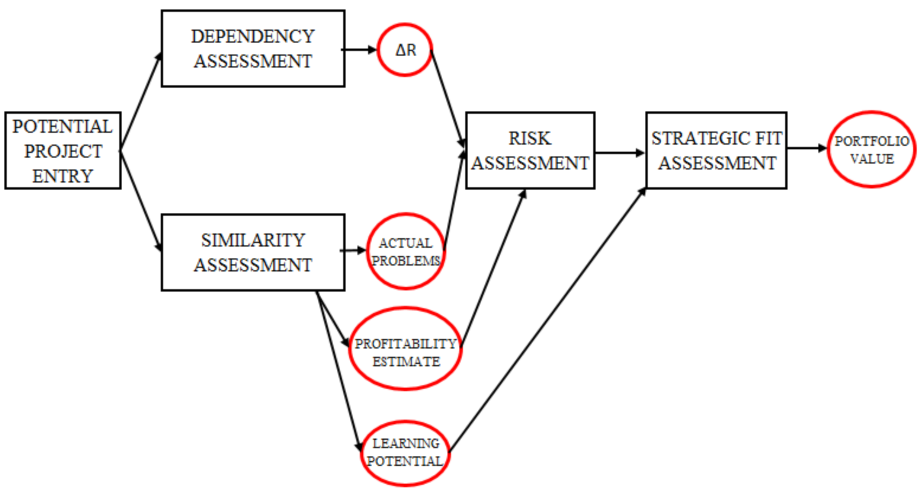


Figure 4.4: Flow Chart for Establishment of the Potential Portfolio

4.1.2. Decisions Made as a Result of Focus Group Findings

Following the initial decisions identified through literature review, the process was reinforced by knowledge elicitation from experts ("focus group") in a construction company. The main consideration with this study was testing the validity of initial decisions made while identifying additional concerns. The aim was to learn the answers of the following queries:

- Is there a need for portfolio management?
- Is there a need for a tool?
- What are the current practices and/or existing methods/tools used in the company?

4.1.2.1. Field Survey: Construction Company (Survey 1)

Field investigation in a construction company was held to support the requirements identified through literature survey. The selected company mainly holds turnkey power generation projects as the Engineering, Procurement and Construction (EPC) contracting arm of a holding, which owns several companies that all serve for construction of power plants, refinery, cement, petro-chemical and gas plants, factories, high-rise buildings, water treatment plants and transmission lines, bridges and other infrastructural constructions including various energy investments. The operations of the power systems company include a combined services of engineering, procurement, construction, commissioning, start-up, warranty and spare parts services for almost all types of power plants. The company is working in diverse locations around the world and aims providing the highest standards in its services through promoting a global mind-set, to achieve understanding in local business environments, language and customs. It mainly aims reinforcing its place among the leading power generation EPC companies in the world through its multicultural management approach.

A survey (Survey 1) was undertaken to identify the "portfolio management principals" of the construction organization between three company professionals ("focus group") whose profile are given below:

- Business Development Director with 23 years working experience, knowledge in information technology and portfolio management is high
- Business Control and Risk Management Director with 21 years working experience, knowledge in information technology and portfolio management is medium
- Enterprise Systems Manager with 11 years working experience, knowledge in information technology and portfolio management is medium

The same company professionals also followed the development process of the tool and participated in further evaluation processes of initial requirements, model features (as model itself, its modules and requirement specification), and actual implementation (Survey 2, 4, and 8) .

The first survey includes five questions regarding their portfolio management perspective, framework requirements of a portfolio management system, current practices in the organization, limitations/rooms for improvement of the current practices, and basic functions/capabilities of a portfolio management tool/decision support system. The survey is provided in Appendix A.

The summary of the initial findings are as follows:

- **Portfolio Management (PM) Perspective:** The main perspective on portfolio management is to manage a group of projects/programs with the aim of providing a systematic and strategic support to all of them. Projects should be managed considering their interrelations and effects so that overall success of portfolio can be ensured and strategic priorities of the company can be met.
- **Required Portfolio Management System/Framework:** First, the needs, expectations and requirements should be determined and an integrated framework should be established accordingly. Cost, time, performance of projects, as well as strategic objectives, resources, capabilities of the company should be considered

within the framework. This integrated framework should be the basis of an integrated process (system) design. A common tool is necessary, to be organized by usage of all relevant parties among different departments. A database is required with all basic and critical detailed information about all the projects/programs within a portfolio. The tool should be able to track the changes and provide comparisons among these. Roles and responsibilities should be defined for each department for evaluation of all criteria about the new project.

- **Current Practices:** The company supports their management process with several tools designed for specific use. They do not prefer to use off-the-shelf big products since they are able to respond to needs up to a limited level. Since construction work proceeds very fast and there exist various projects with various parties and differing expectations, it becomes very difficult to adapt such a solution. Reporting needs to be very fast and every level in the end expects different reporting mechanisms from a tool. Thus, the tool must be highly flexible to be adapted for use in the company. Currently they are developing their tools in terms of small modules by conveying the problems in the process to the IT department. Some adaptable portions of the available solutions are purchased and the additional requirements are developed and integrated to the system to enable a complete solution. They are working on solutions for document control, procurement, go/no-go or bid/no-bid decisions, knowledge management/organizational learning/corporate memory, risk assessment, claim management, etc. More specifically regarding portfolio management, the company uses the central departments specialized in different aspects of a project/program such as budget, schedule, contracts. These departments use the individual tools as specific applications at the project level and use the outputs of the tools to control and report on the status of the portfolio. There is an in house generated tool, which requires providing information to the system by the responsible departments. Different departments provide guidance to the system in terms of previous experiences (lessons learned) and potential hindrances or mitigation recommendations are being provided. Evaluation of new sector, new region, new customer, regulations, codes and standards, administrative issues (permits, etc.), market analysis in terms of material and manpower is required in the process. Risk assessment is being performed for the stated criteria as well as customer's requirements for the specific project under bidding stage. Technical and commercial risk assessment is being carried out before taking the decision of bid/no-bid. Regular reports and high-level meetings take place to evaluate portfolios and to formulate strategies at the portfolio level. Based on the summary report covering evaluations on technical and commercial issues, upper management (company Chief Executive Officer (CEO) and holding CEO) is able to provide final decision on a new project/opportunity.

- **Limitations/Rooms for Improvement:** The major limitation of the existing practice is "lack of integration" of individual tools and "lack of a database" that includes all project data. A system is needed to convert "data" into "knowledge (usable information)". Reporting is mostly done "after the fact". A more real time data monitoring and forecasting is required. Current practice is based on mostly verbal information. Numerical data or result is more important to cover the entire stage, which can visually support the upper management's decision-making and enable time saving. Thus, forecasting and benchmarking are needed at most. Benchmarking is required to reveal history of a similar completed project, which is very difficult to achieve in the current progress of the project. Currently, bidding department is investigating similar projects through filtering with a set of criteria; however, other departments (e.g., execution department) are unaware of this process, this mechanism is not being transferred to other departments. They are also checking past projects on their own through the data available, which is not information. Existing projects are also investigated through meetings and the comparisons are made manually. The tool structured for go/no-go and bid/no-bid decisions is used for monitoring the process; however, its reports are delivered among different groups, and the decisions are undertaken off the tool (manually). Thus, there is a need to unify these processes on one platform. Most of the current processes need improvement in this direction. The right data needs to be captured at the right time; however, in the current practice it is a big problem. An electronic system is required to prevent the file-based or e-mail based (through carbon copying to the recipients) information dissemination process. The risk of conveying the right information to the right people is not undertaken currently, and everybody should eliminate and pull the required information on their own. Portfolio management may respond to all processes by capturing all the project data and comparing them with each other at one platform. The reports of project meetings are conveyed to upper management manually in the current system, thus there is need of a common system where projects would be beheld in total. Portfolio management tool may provide this platform, but current priority in the company is on management of lessons learned. Since the company holds similar and limited number of projects, learning opportunity is much more important in this case. In the corporate memory solution, they have established a rewarding mechanism to promote accumulation of lessons through rewarding with initiatives, i-pads, and holidays. However, this resulted with a huge amount of lessons that are waiting for grouping, which is also very difficult in the current practice. Project manager and control manager together act as a knowledge manager; however, their effort does not meet the requirements to manage all the lessons. Entry of lessons are encouraged with the information of possible users and their effects. At the end, what has been entered is not known. Since there is no evaluation of these lessons, the most important lessons may not be entered and all the existing lessons may be a mess. There is an approval chain of the lessons learned, since there are various processes in one work. The lesson is forwarded to each of the related parties for approval and when there is an ignorant party in the process the lesson gets into loop. Therefore, there is need of a single party/person who unifies all the process and approves the lesson. In utilization all of the solutions, the most important point is capturing the data. The biggest problem lies in management of who enters what and when. For example, there is closing report for projects; however, the project team starts to a new project without completing the report. When there is the profit from the completed project and a new project ahead, the closing report is undervalued.

- **Required Functions/Capabilities of a PM Tool:** The tool should combine "project-level" management functions (such as risk assessment, etc.) and conduct them at the "portfolio-level". Thus, it should include recommendations of relevant departments by providing tasks to each department. It should contain and list all the basic and critical parameters of the projects/programs. Therefore, it should have a detailed database regarding the projects (cost, time, claims, milestones, lessons learned, subcontractors, etc.) and help the company professionals to learn from previous projects. It should be able to compare and report certain parameters. It should have a "forecasting/prediction" capability and should cover the numerical past data/statistical information of the experienced/completed projects such as, major risks encountered, bill of quantity plan vs. actual, legal issues in the project region, material and manpower availability in the region. These data can be compared with company average statistical values in terms of achievement of major milestones achieved during the project lifetime. It should also visualize the data processing across the projects. To achieve this, first there should be a strong data capturing mechanism, and secondly the captured data should be converted into information, more precisely it should be presented in a brief, complete and favorable format. There could be a large variety of ways of reporting data. The essential way of reporting is in displaying the data in a proper and usable format, and so making it a valuable piece of information. The tool should be effortless and require an easy to follow format to be usable for this kind of construction companies that are working on same type of projects. These companies are working with limited number of projects (maximum 6 projects for this company) concurrently. It would be somehow beneficial at the holding level or for other construction companies working with more variety of projects in their portfolios (with 15-20 projects concurrently); however, it should offer minimum effort to be implementable in analyzing portfolios of same type of projects. Otherwise, company would go on manual process rather than taking the burden of coping with the tool. The tool should achieve its aim only, and the further processes should be supported with integration of other tools serving for different purposes. There should be a system that manages who enters what data and who controls the entered data. Reporting may be modified according to requirement of each party; however, the quality of data is at most importance. If there is data, its display can be changed. Finally, change management is very important in construction companies acting in a complicated sector. The major changes should be monitored in portfolio management, thus the tool should provide dynamic analysis.

4.1.2.2. Decisions Given based on Findings

The expected properties of the tool are mainly:

- be construction industry specific, it should respond to needs, expectations and requirements of construction companies.
- provide a common platform to be used by different parties and an integrated framework to enable systematic management of group of projects considering cost, time, performance of projects, changes, strategic objectives, resources, capabilities of the company. Project level functions of different department should be carried at portfolio level. A database is required that would contain and list all the basic and critical parameters of the projects/programs such as; cost, time, claims, milestones, lessons learned, subcontractors, etc. A system is required that would convert this data to valuable information. Roles and responsibility assignment should be provided as a user management system that directs the data entry process and data evaluation for successful utilization of the tool. Evaluation of projects at the same platform by making the whole decision process visible by all departments.
- provide successful reporting of information that would respond to needs of different departments to control and report on the status of the portfolio and enable visualization of data, numerical reporting and more real time data monitoring.
- provide management of group of projects considering the interrelations/dependencies between projects that would affect the overall success of the portfolio.

- provide a comprehensive risk analysis at the portfolio level considering all the factors such as new sector, new region, new customer, etc.
- enable strategic analysis at the portfolio level to meet strategic priorities of the company and formulation of portfolio level strategies.
- support effective evaluation and decision processes for project selection.
- provide strong lesson evaluation, retrieval, and categorization. These are required to manage experiences (lessons learned) that would enable learning from previous projects and be very helpful in the analysis of potential hindrances or mitigation recommendations.
- provide benchmarking and effective similarity assessment for comparing data and provide real time forecasting for reporting statistical information of the experienced/completed projects such as, major risks encountered, bill of quantity plan vs. actual, legal issues in the project region, material and manpower availability in the region in terms of company averages for comparison.
- be effortless and flexible to be used by companies working with same type of projects and limited number of projects.
- be dynamic to respond and track the changes and provide comparisons among these.

4.1.3. Final Decisions about the Features of the Tool

The tool was intended to be developed as a response to the gap in the literature mainly on the portfolio management processes underlined by Cooper et al. (1999) and the requirements identified by research team. As a summary of literature on portfolio management, the following points can be delivered as considerations identified for functions of the tool. It has been mainly appreciated that strategic alignment and balancing in terms of risk positively affect future profits of portfolios (Martinsuo et al., 2014), thus portfolio management functions should address this issue. Additionally, interdependencies between projects are evaluated as main sources of uncertainties for portfolios (Martinsuo et al., 2014), which have generally been underestimated in portfolio management frameworks (Meifort, 2016). Besides, knowledge transfer and learning from/between projects are also appreciated as important considerations for project portfolios (Martinsuo et al., 2014). Some of the provided frameworks for portfolio management also lack industry specific concerns that may effect the success of portfolio management (Meifort, 2016). A solution that unifies all these considerations in the same framework would be valuable as it has been underlined. Therefore, the following properties of the tool have been structured as a response to identified principles with the joint effort of the research team and "focus group" through the investigation in literature and in the construction company. The identified principles are mapped against the properties of the tool in the following table (Table 4.1).

As a result of the needs analysis, main initial requirements for supporting portfolio management initiatives in construction companies have been identified as follows:

- Construction industry specific portfolio management framework,
- Support for establishment/re-engineering of portfolio management processes in construction companies,
- Support for the portfolio management system,
- Development of a portfolio management tool for construction companies,
- Dependencies between projects should be handled,
- Strategic assessment integration should be provided,
- Project selection decisions should be supported,
- Resource allocation decisions should be supported,
- Balance between the projects and resources/capabilities should be established,
- Knowledge management integration should be provided,
- Risk assessment integration should be provided,
- Visualization abilities should be provided,
- A flexible and dynamic tool should be generated, and
- An intelligent tool should be generated.

Table 4.1: Identified Principles and Features of the Tool

Portfolio Management Principles	Related to the Tool
Gap in Portfolio Management Literature:	
- lack of reliable framework for construction projects	The tool should provide portfolio management framework that would act as decision support for all types of construction projects including project selection
- deficiencies in handling project dependencies	The tool should be responsive in measuring and depicting dependencies between projects of portfolios
Processes of Portfolio Management by Cooper et al. (1999):	
- making strategic choices: in which markets, products, and technologies to be invested,	The tool should provide strategic assessment and prioritization of projects and portfolios
- project selection: on which new product or development projects to be chosen,	The tool should provide assistance in decision-making while evaluating different potential projects through scenario analysis
- resource allocation: how the scarce resources to be spent,	The tool should provide warnings as guidance in utilization of resources
- balance: having the right balance between numbers of projects to be done and the resources and capabilities available.	The tool should help keeping the balance between the projects and resources by clearly depicting the current portfolios and the required resources and possible risks
Requirements Identified by Research Team:	
- utilization of past project data into portfolio analysis	The tool should keep past project data together with lessons learned in projects so it would be responsive in management of both tacit and explicit knowledge
- utilization of risk assessment into portfolio analysis	The tool should provide evaluation of project level risks and depicting portfolio level risks by utilizing dependencies of projects
- visualization of portfolios	The tool should provide visualization of both project and portfolio properties in forms of tables, bar and bubble diagrams together with dependency map of projects in a portfolio
- flexibility and dynamism in options	The tool should be designed to be flexible in establishing preferences and updating predefined sets for re-evaluation of outdated data
- intelligence through warnings on portfolio	The tool should provide warnings for guidance in management of portfolios

4.1.4. Evaluation of Initial Requirements (Survey 2)

The “focus group” evaluated the importance of the identified initial requirements that have been decided by combined analysis of literature review and evaluations in the company. The survey (Survey 2) was sent to the professionals by electronic mails. The initial requirements were evaluated on a Seven-Point Likert Scale ranging from "strongly disagree (1)" to "strongly agree (7)" (Appendix B). The result of the evaluation is presented below in terms of average rating for each statement (Table 4.2).

Table 4.2: Evaluation of Initial Requirements

Requirement	Rating
1. There is lack of an appropriate portfolio management framework and tools in construction companies.	6.33
2. Portfolio management process needs to be established/re-engineered.	6.00
3. The established system needs to be IT supported.	7.00
4. Development of a portfolio management tool for construction organizations is required.	6.33
5. Portfolio management tool for construction projects should handle dependencies between projects.	6.67
6. Portfolio management tool for construction projects should support strategic choices.	7.00
7. Portfolio management tool for construction projects should support project selection decisions.	6.67
8. Portfolio management tool for construction projects should support resource allocation decisions.	7.00
9. Portfolio management tool for construction projects should support balancing the projects and resources/capabilities.	7.00
10. Portfolio management tool for construction projects should incorporate past project data into portfolio analysis.	7.00
11. Portfolio management tool for construction projects should incorporate risk assessment into portfolio analysis.	7.00
12. Portfolio management tool for construction projects should enable visualization of portfolios.	6.67
13. Portfolio management tool for construction projects should be flexible and dynamic.	6.67
14. Portfolio management for construction projects should be intelligent and should provide advice/warnings about portfolio decisions.	6.67

All of the identified initial requirements have got average points over "6" which means importance of all requirements have been accepted. In the overall, generation of a tool that would support portfolio management processes for construction companies has been accepted considering the existing company and the companies in general. Most critical requirements are identified as integration of "IT support", "strategic assessment", "resource allocation", "portfolio optimization", "knowledge management", and "risk assessment". Rest of the requirements are identified as equally important and all of them structure the main properties of the tool as "dependency analysis", "project selection", "portfolio visualization", "flexible and dynamic analysis", and "intelligence". Therefore, as a main outcome of the evaluation process, it supports development of the "process model" based on the identified "initial requirements".

4.2. Process Model Development

The process model was generated based on the identified initial requirements and decisions made. Meetings within the research team were continued for constant evaluation of the decisions on the tool. The main model of the tool was created following identification of some details to be used in the model through a questionnaire held between company professionals. The evaluation of the model was carried out with a numerical example and some changes were made. Generation of a numerical example as "paper prototype" substantially contributed to development of the details and evaluation of the model. Within this context, the first numerical example revealed some details with the model and it was updated accordingly. The second numerical example was presented to "focus group" for further evaluation of the process model. Details of process model development are presented in the following sections starting with the "initial decisions and algorithm" and their evolvement to "final model and algorithm" through evaluation by numerical examples.

4.2.1. Initial Definitions and Algorithm (Calculation Decisions)

In the light of the initial investigation and decisions, as the basis of analysis of portfolios some quantifiable data were created to be calculated for comparison of portfolio alternatives. Process regarding quantifiable analysis of the established conceptual framework and the concepts in the process would be as follows. In order to overcome the dependencies issue in portfolio analysis, the proposed tool is intended to be capable of evaluating "dependencies" between construction projects in a portfolio. Within this context, a "dependency network diagram" is created to assist the evaluation of possible change in the "risk" of the portfolio due to the interactions between the projects in the portfolio. Additionally, "strategic fit" of the projects and so the portfolio are evaluated. Accordingly, a "portfolio value" is obtained by taking into consideration the risk and strategic fit of the portfolio. Including this information, difference between current portfolio value and the new portfolio value (including the potential project(s)) is taken as a reference while evaluating the effect of potential project(s). Portfolio value calculation process is summarized as in the following figure (Figure 4.5). In addition to value-based analysis, the tool will also offer options for "selection" based on risk, strategic fit and profitability of the portfolios. During this process, information regarding the completed projects will also be captured in the "database" of the tool and to be used in assistance for the evaluation of potential projects. Additionally, "lessons learned" information will also be captured for all kind of projects and search options will be provided for their retrieval. As a final issue, the tool will also be capable of providing "warnings" specific to the portfolio in hand and on portfolio selection.

Information of the concepts within the process are as follows:

1. **Database:** The project information required for lessons learned information and project dependency assessment is captured in database at two levels for completed and on-going projects.
2. **Predictions:** Prediction results regarding the profitability, risk and learning potential of on-going and new projects are presented to the user from the captured information of the completed projects.
3. **Risk Assessment:** Risk rating assignment of each project is made and an overall risk rating is obtained. Information gathered through prediction process is evaluated by user and taken into consideration in the risk rating process.
4. **Strategic Fit Assessment:** Strategic fit rating assignment of each project is made and an overall strategic fit rating is obtained. Information gathered

through prediction process is evaluated by user and taken into consideration in the strategic fit rating process.

5. **Dependency Assessment:** The interactions between the on-going projects (and the new project) are determined through the project information entered in the database and the dependency values are calculated accordingly.
6. **Portfolio Risk Assessment:** The effect of dependencies on risk value is estimated to be added to the average risk rating of individual projects in the portfolio. This risk premium corresponds to the change in portfolio risk due to dependencies between projects.
7. **Portfolio Value:** The portfolio value is calculated with average risk rating of projects, risk premium due to dependencies and average strategic fit rating of projects.

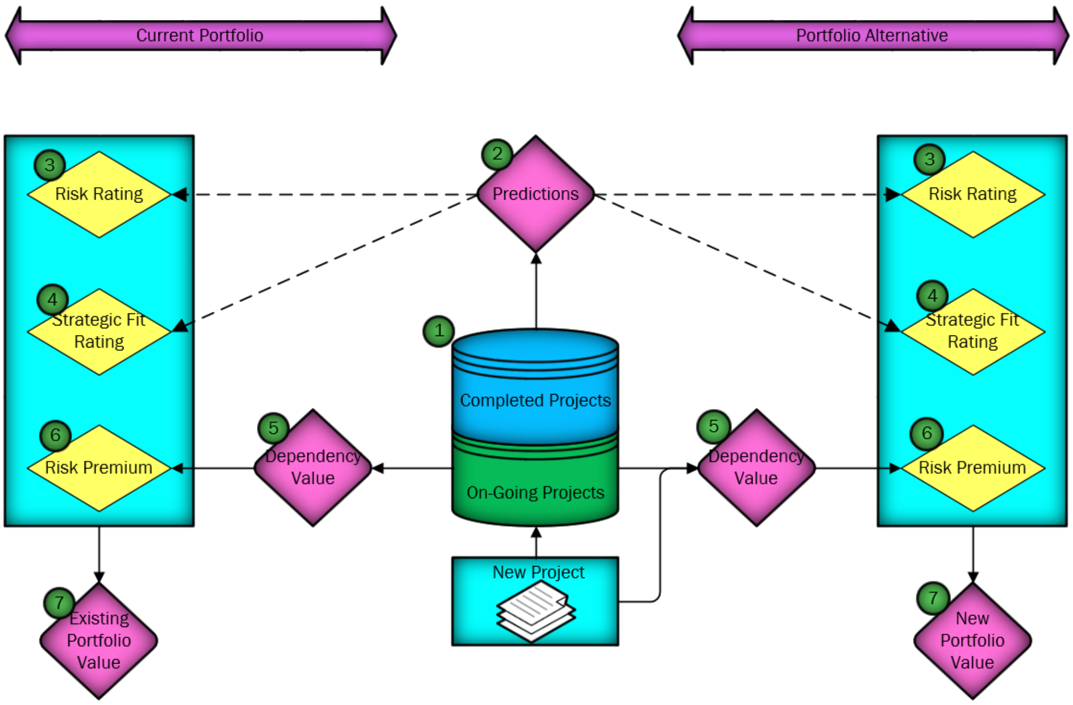


Figure 4.5: Quantifiable Analysis in the Process

In the light of summarized process and concepts, the tool will have following properties:

- Establishment of a Project Information and Lessons Learned Database
  - Extraction of project information through project similarity
  - Extraction of project information on project attribute basis by filtering
  - Extraction of project information through average attribute values as predictions
  - Extraction of valuable comments from lessons learned database
- Evaluation of project dependencies
  - Measurement of dependencies through attribute matching
    - Financial dependency
    - Resource dependency
    - Knowledge dependency
    - Outcome dependency
- Calculation of Portfolio Risk
  - Risk rating process for active projects
  - Calculation of average risk rating for the portfolio
  - Addition of risk premium (ΔR) originating from dependencies of projects in the portfolio, network density is used to multiply the Average Risk
- Calculation of Portfolio Strategic Fit
  - Strategic fit rating process for active projects
  - Calculation of average strategic fit rating for the portfolio
- Calculation of Portfolio Value
- Evaluation of Portfolios
  - Visualization of dependency networks
  - Visualization of bubble diagrams and bar charts of the portfolios
  - Warnings through
    - Information extracted from database as dependencies and predictions
    - Network analysis: density and centrality values.
- Selection of Portfolio

According to the presented information, the identified definitions of concepts and required algorithm for the quantifiable analysis are provided as follows where further changes are indicated in the parentheses provided next to current formulae presented:

Project Similarity Assessment: "Project similarities are used as a retrieval option for focusing on the related projects first by providing retrieval of lessons and predictions based on similar project data only". After the attribute matching between two projects is calculated as a percentage, these values will be multiplied by importance weight of each attribute identified for similarity calculation, which will be obtained through the questionnaire. Thus, the questionnaire should ask the significance of the following conditions in assessment of similarity of a project pair:

- Being in the same/similar country
- Same/similar project type (housing, infrastructure, etc.)
- Having the same/similar client
- Use of the same construction technology
- Having the same contract type

The weighted average of the match percentage will be obtained as similarity.

- Percentage of match (weighted average) (%) = Similarity (%)

Similarity Calculation: Similar projects will be determined and ranked according to the matching rates of the following attributes. While ensuring a direct match of qualifications as "construction technology" and "contract type" (0/1), it is aimed to ask users for the similarity ratios of "country", "project type" and "client" attributes. Thus, it is aimed to evaluate similar aspects in situations where the characteristics of each "country", "project type" and "employer" are not completely different from each other. Therefore, the matching rates of these attributes shall be set to values in the range [0,1] to ensure partial clustering based on these attributes.

- Country (the similarity rate of countries will be asked to the user)
- Project type (the similarity rate of the project types will be asked to the user)

- Client (similarity rate of clients will be asked to the user)
- Production technology (direct matching of the attribute)
- Contract type (direct matching of the attribute)

As a result of the computed similarity values, the projects will be ranked according to their degree of similarity.

Alternative Similarity Assessment by Clustering Analysis: Clustering analysis is defined as placing data with similar characteristics in categories as common groups (Demiralay and Çamurcu, 2005). In this study, it is aimed to group the completed projects using clustering analysis as an alternative to calculating the similarities of the projects. The purpose of the clustering analysis is to maximize similar features of the same group of data, and to have minimum similarities to the data of different groups (Saruman, 2011). There are various types of clustering methods in general, including partitioning methods, hierarchical methods, density based methods, fuzzy clustering methods, artificial neural clustering methods, statistical clustering methods, grid based methods, mixed methods, etc. (Syal and Kumar, 2012). Hierarchical and non-hierarchical methods (partitioning methods) are widely used ones among these methods (Tatlıdil, 2002). Partitioning methods are based on the separation of “n” pieces of data from the “k” pieces of clusters determined before the analysis (Wagstaff et al., 2001). Some commonly used partitioning algorithms are “K-Means”, “K-Medoids” and “Clara-Clarans” algorithms. Hierarchical methods are methods that group objects in a dendrogram (Karabulut et al., 2004). Hierarchical methods are divided into “agglomerative clustering” and “divisive clustering”. In these methods, the number of clusters need not be determined in advance, the number of clusters (k) becomes apparent at the end of the clustering analysis (Everitt et al., 2011). In the light of the presented methods, it is considered to use the methods where the number of clusters are determined as the result of the analysis (hierarchical clustering analysis) and it was decided to make appropriate method selection after using alternative methods (Özyurt, 2018). Possible attributes used in the clustering analysis will be the attributes used in the calculation of similarities in the first place.

- Country

- Project type
- Client
- Contract type
- Production technology

The first method will be compared to the results of this method presented as an alternative and the final decision will be made accordingly.

Predictions: “Predictions constitute the numerical figures calculated or obtained as mode of categorical data, which indicate the possible figures that may be obtained with the current project in question based on the averages of related past project data”. Main predictions that will be presented through the tool are estimations on “profitability”, “risk”, and “learning potential”.

Profitability Estimation: “Probable profitability of the candidate project is estimated from the actual profitabilities of the previous projects”. Additionally, problems with cash flow will be notified for further investigation of the problem.

- Expected Profit = Budget - Expected Cost (updated with calculation of “adapted profit” as long as there exists available data)
- Actual Profit = Budget - Actual Cost (updated with budget change)
- Profit Ratio (%) = Actual Profit / Expected Profit * 100 (updated with budget change)
- Average Profit Deviation (%) = ∑ Profit Ratio / ∑ Number of Projects
- Adapted Profit = Expected Profit * (1+ Average Profit Deviation/100)
- Cash Flow Problem = existence will be asked to the user (integrated in “lessons learned”)

Potential Problem Area / Risk Estimation: “Probable risk of the candidate project is estimated from the actual problems, delays, and disputes encountered in the previous projects”. Namely it is identification of the problem areas and the parties involved (problems may be extended with the ones that do not resulted with delays through codification of "lessons learned")

- Delay Time Percentage = Delay Time / Project Duration *100
- Average Delay Time (%) = ∑ Delay Time Percentage / ∑ Number of Projects
- Delay Cost Percentage = Delay Cost / Project Budget *100
- Average Delay Cost (%) = ∑ Delay Cost Percentage / ∑ Number of Projects
- Responsibilities of the Delay (mode - descending order)
- Delayed Activities (mode - descending order)

Learning Potential Estimation: "Learning potential is the indicator value for the projects providing high learning opportunity as a measure for strategic assessment". Thus, the questionnaire should ask the learning potential creation of the following opportunities:

- To enter a new country
- To gain experience in a new project type
- To work with a new client
- To use a new construction technology
- To work with a new contract type
- To work with a new project delivery system (design-build, build-operate-transfer, etc.)
- To work with a new project partner

The weights that will be obtained for these attributes were decided to be called as "learning attributes" and assigned to other learning related concepts such as attributes to be used in measuring the "learning dependency":

- Country type
- Project type
- Client
- Construction technology
- Contract type
- Project delivery system (turnkey, build-operate-transfer, etc.)

- Project partner

Learning potential calculation is based on a similar calculation algorithm with "similarity calculation". After the matching is calculated for each attribute as a percentage, these values will be multiplied by the contribution ratings of the learning potential, which will be obtained through the questionnaire, and the weighted average of the match percentage will be obtained. It is expected that the learning potential of the project will be obtained by subtracting this value from 100, since matching value and learning potential are inversely proportional.

- Percentage of match (weighted average) (%) = X%
- Learning potential (%) = (100 - X)%

Project Dependency Calculation: "Dependency exists between projects if execution or success of one project is dependent on the other project". Dependency calculation is also based on a similar calculation algorithm with "similarity calculation". After the attribute matching between two projects is calculated as a percentage, these values will be multiplied by the importance of each attribute identified for the specific dependency type, which will be obtained through the questionnaire, and the weighted average of the match percentage will be obtained as magnitude of the dependency type in question. The questionnaire will also question the importance of each dependency type considering its effect to project risk. Once the weights of each dependency type is established, weighted average of the all dependencies will provide the overall dependency magnitude between the project pair.

- Percentage of match for a dependency type (weighted average) (%) = Dependency Magnitude (%)
- Weighted average of all dependencies between the project pair (%) = Overall Dependency Magnitude (%)

In addition to visualization of dependencies through network maps, the calculated dependencies for each pair of project should be presented in a matrix as follows where LD: Learning Dependency, RD: Resource Dependency, FD: Financial Dependency and “x” stands for the dependency magnitude (Table 4.3).

Table 4.3: Dependency Matrix

	Project 1			Project 2			Project 3			Project 4		
Project 1												
Project 2	LD x	RD x	FD x									
Project 3	LD x	RD x	FD x	LD x	RD x	FD x						
Project 4	LD x	RD x	FD x	LD x	RD x	FD x	LD x	RD x	FD x			
Project 5	LD x	RD x	FD x	LD x	RD x	FD x	LD x	RD x	FD x	LD x	RD x	FD x

Project Risk Assessment: The identified initial factors in needs analysis, which provides two-levelled analysis of factors, to be used in assessing risks are simplified to one level of factors as follows to minimize the effort required in the analysis.

- Economic risk (changes in exchange rates, cash flow risk, inflation, etc.),
- Political risks (changes in government, changes in international relations, etc.),
- Technical risks (delays due to technical problems, etc.),
- Resource risk (risks due to quality/availability of material, manpower, machinery and equipment, etc.),
- Design risk (deficiency/changes in design, etc.),
- Contractual risk (ambiguity in conditions, insufficient definitions, strict requirements/constraints, etc.),
- Owner-initiated risks (insufficient experience, delays in payments, etc.),
- Bureaucratic risks (delays in permissions, etc.),
- Project management risks (poor planning, insufficient experience, etc.),
- Risks due to weather conditions,

- Risks due to ground conditions, and
- Environmental risks (social and environmental factors).

The additional factors will be determined through the questionnaire. The participants will evaluate the effect of the risk factors to a construction project in case of their occurrences. These ratings will be used as "impacts" of the factors in risk assessment where their "probabilities" will be assigned by the user.

- Project Risk = f ("probability", "impact") = ∑ User Rating * Weight

Portfolio Risk: "The total value of the risks of each project that constitutes the portfolio and the risks arising from the relationships between those projects". A risk premium that meets the change in risk due to the dependencies between projects (risk premium) is assigned as "Delta Risk" (ΔR). This value will be the change in total risk rating of the portfolio at the end of the evaluation process. The "Delta R" value will be calculated as the properties of the dependency network map, as centrality of the nodes and density of the network. Centrality of a project indicates the "criticality of a project" in a portfolio, whereas density of a network indicates the "complexity of a portfolio" between different portfolio alternatives which may also evaluated as the dependency effect (ΔR) in a specific portfolio. Project centrality is based on the ratio of dependencies of a project to the total dependencies in a portfolio, and network density is based on the ratio of "actual connections" to "potential connections" in the network. Therefore, the following calculations will be done for all portfolio alternatives regarding the risk analysis of the portfolio.

- Average Risk Score = Total Risk Scores / Number of Projects [0,100]
- Portfolio Risk = Average Risk Score * (Dependency Effect)
- Dependency Effect = ΔR = Network Density = Current Relations / All Possible Relations [0,1]
- Centrality of a Project = $\frac{\#\ of\ the\ relationships\ of\ a\ project}{\#\ total\ relationships\ in\ the\ network}$
- Density of the Network = $\frac{\#\ of\ the\ existing\ relationships}{\#\ total\ possible\ relationships}$

- Portfolio Risk = $\frac{\sum Project\ Risk\ Ratings}{\sum Project\ Number} \times (1 + \Delta R)$
- Portfolio Risk = Average Risk Score * (1 + Network Density) [0,200] (updated by adjusting the portfolio risk range to [0,100])

Project Strategic Assessment: The identified initial factors for assessment of strategic fit in needs analysis are improved with division of “profit maximization” as “short-term” and “long-term”.

- Maximization of Short Term Profitability
- Maximization of Long Term Profitability
- Gaining Reputation
- Achievement of Learning / Gaining Experience
- Risk Minimization
- Entering New Markets

The additional factors as strategic objectives will be determined through the questionnaire. The participants will evaluate the importance of these strategic factors in the overall company strategy. These ratings will be used as “importance weights” of the factors in strategic assessment where their “fit with the purpose” will be assigned by the user.

- Project Strategic Fit = f (“importance”, “fit with the purpose”) = ∑ User Rating * Weight

Portfolio Strategic Fit: “The average value that indicates that the projects that make up the portfolio as well as the portfolio conforms to the targets set by the company”. The following calculation will be done for all portfolio alternatives.

- Average Strategic Fit Score = Total Strategic Fit Scores / Number of Projects [0,100]

The calculated average strategic fit score will indicate the strategic fit of the portfolio.

- Portfolio Strategic Fit = Average Strategic Fit

Portfolio Value: “The value that will be determined by taking into account the effect of projects to portfolio risk and strategic fit and to be used in comparing portfolio alternatives”. The following calculation will be done for all possible portfolio alternatives.

- Inverse of Portfolio Risk = Portfolio Success = 1 - Portfolio Risk / 200 (updated to match between the interval [0,100])
- Portfolio Value = Portfolio Success * Portfolio Strategic Fit Score
- Portfolio Value = $\left(1-\frac{\text{Portfolio Risk}}{200}\right)\times\left(\frac{\sum Strategic\ Fit\ Ratings}{\sum Project\ Number}\right)$
- Portfolio Value = (1 - Portfolio Risk / 200) * (Portfolio Strategic Fit Score) [0,100] (updated as summation of the two figures where they both range between [0,100])

Portfolio Formation: The tool will automatically create the portfolios. The current “on-going projects” of the company will constitute the “existing portfolio”. “Portfolio alternatives” will be obtained as addition of combinations of the “potential projects” to the set of current “on-going projects” (the inclusion of “potential projects” updated with a limit on evaluation of “four projects” in the analysis at once).

Portfolio Visualization: Visualization was decided to be provided at two levels as “project level” and “portfolio level” where further investigation of the projects in the portfolio are to be provided once portfolio analysis is performed with the support of the visualizations at portfolio level.

Project Level: Main visualizations at the project level (i.e., investigating the projects within the specified portfolio) were identified as depiction of dependencies through the “network map” where a project symbol was decided to be created for using as nodes in the map. The map should include “nodes” indicating the projects in the portfolio and “bi-directional relations” for depiction of the dependencies. The nodes of more central projects (having higher interconnectivity) should be relatively bigger in size. Dependencies can be visualized in different colors to indicate different types of dependencies and with different thicknesses indicating the relative magnitudes of dependencies. Thus, the user can easily capture the information about the dependencies between the projects, understand the relative importance of different types of dependencies and identify critical projects by looking at the network map. Additionally “risk vs strategic fit bubble diagram” was selected for identification of groups of projects in the safer zone of the bubble chart, which is left upper side of the diagram when risk is on the x-axis and strategic fit is on the y-axis. Sizes of the bubbles were identified to be the “expected/adapted profits” of the projects. The project symbol was agreed to be decided later according the figures that would be identified through numerical analysis of the model.

- Dependency Network Map
- Bubble Diagram for Project Risk Rating vs. Project Strategic Fit Rating

Portfolio Level: Visualization at the portfolio level namely the main portfolio analysis results were based on comparison of the portfolios on first the bubble diagram for identification of the safer portfolios as in the project level bubble diagrams. Additional bar chart was provided for visually separating the content of the portfolio value as “strategic fit” and “success” for comparison of portfolio values that would be akin to each other. Profits of the portfolios were integrated to the analysis through “change in value” and “change in profit” bar chart, since evaluation of value only or profit only may be misleading when they are set as both criterion. Therefore, to bring all the portfolios to an equal footing all of them were decided to be compared where current portfolio is set as the reference. The current portfolio is located at the (0,0) point and the other portfolios are scattered according to their level of change to the profit and value of the current portfolio. As an alternative the change graph was decided to be presented also through bar chart.

- Bubble Diagram for Portfolio Risk vs. Portfolio Strategic Fit
- Bar Chart for Portfolio Value where Stacked Column indicating Portfolio Strategic Fit and Portfolio Success

- Bubble Diagram for Change in Value vs. Change in Profit
- Bar Chart for Change in Value vs. Change in Profit

For calculation of the change is value and change in profit the following formulae were identified.

- Change in Value (%) = (Portfolio Alternative Value - Current Portfolio Value) / Current Portfolio Value * 100
- Change in Profit (%) = (Portfolio Alternative Profit - Current Portfolio Profit) / Current Portfolio Profit * 100

Warnings: “Warnings are provided by the tool for management and selection of the portfolios based on the dependencies and past project data”. The following warnings were identified as presentable considerations to the user:

- Criticality of the project based on the project with maximum dependencies,
- Criticality of the portfolio based on the portfolio with maximum density,
- Critical dependencies that need attention based on limit values set for each dependency type, and
- Critical figures that may be obtained from predictions.

The questionnaire survey was designed to respond investigation of the mentioned additional factors and their weights to obtain “default values” that will be provided within the tool. The figures were also incorporated into the numerical example to provide a complete numerical assessment of the process.

4.2.2. Questionnaire Survey (Survey 3)

A questionnaire survey was conducted to confirm the identified project characteristics and determine the numerical figures to be used in the overall process, which would establish the foundations for the design of the tool. In line with this, the questionnaire primarily includes questions about strategic assessment, risk assessment, and similarity assessment. Therefore, the questionnaire consists of three sections as:

- Section 1: Strategic Objectives,
- Section 2: Risk Assessment, and
- Section 3: Similarity Assessment.

The designed questionnaire was prepared as “online” and sent via e-mail to 280 company employees from Turkish construction companies working in the international market. The questionnaire was shared through the following web address:

- http://koc.qualtrics.com/se/?sıd=sv_9gqdovmh0tetjxf

General structure of the survey is as summarized follows while the survey itself is presented in Appendix C:

- Personal Information,
- Section 1: Strategic Objectives,
  - Importance of Strategic Objectives: Determining the level importance of strategic objectives to be used in evaluating the importance / value of a new project for the portfolio,
  - Learning Potential: Determining the potential of the factors for creation of learning opportunity,
- Section 2: Risk Assessment,
  - Effect of the Risk Factors: Determining the level of impact of the risk factors on construction projects in case of their occurrences,
  - Project Dependencies,
    - Importance of Project Dependencies: Determining the importance of dependencies between the projects when calculating the portfolio risk,

        - Measurement of Project Dependencies: Determining the importance of the factors to be used in measuring dependencies,
- Section 3: Similarity Assessment,
    - Significance of Criteria: determining the significance of the criteria for measuring the similarity of two projects.

As a result, the survey was answered by 108 people that indicates a 38.57% return in the overall. The accepted answers exceeded the stated limit of "80 answers" as the success criteria. The distribution of the information of survey participants and their companies are presented as follows together with the results obtained for each section of the questionnaire.

4.2.2.1. Profile of the Respondents

Majority of the respondents, approximately two third of them, are highly educated with the reported degrees of MSc (59%) and PhD (7%). Commonly observed titles within the respondents can be listed as "directors" (24%), "technical office staff and experts" (17%), "planning department employees" (16%), and "general managers" (14%). Approximately half of the respondents have at least "11 years" of professional experience where 16% of the overall respondents state at least "21 years" of experience. The professionals within the first "10 years" of their professional experience are sharing the "28%" of the overall with "0-5 years" experience and "23%" of the overall with "6-10 years". The "level of knowledge on PPM" self-reported by the respondents is obtained as "medium" in majority (42%), where the rest is equally reported as "low" and "high" (29% each). This constitutes a "71%" "medium - high" knowledge in the area. Considering the companies that the respondents have been currently working for, it is seen that majority are "contractor" companies (62%), which is followed by "client" (22%), "consultancy" (10%), and "design" or "other" companies (3% each). Half of the companies (51%) has at least

"31 years" of existence where "41%" of the overall companies has at least 41 years of existence. For the rest of the companies, ages degrading by "10 years" has the shares of "17%", "14%", "18%" (in the descending order of company ages). More than half of the companies (58%) have at least "500 million TL" annual return, where the rest have the shares of "18%" for "100-500 million TL" and "24%" for "0-100 million TL". Field of activity is selected as "commercial buildings", "transportation structures", and "housing" in majority which is followed by "industrial plants", "energy structures", "water structures" and "state buildings" as provided in the following figure (Figure 4.6).

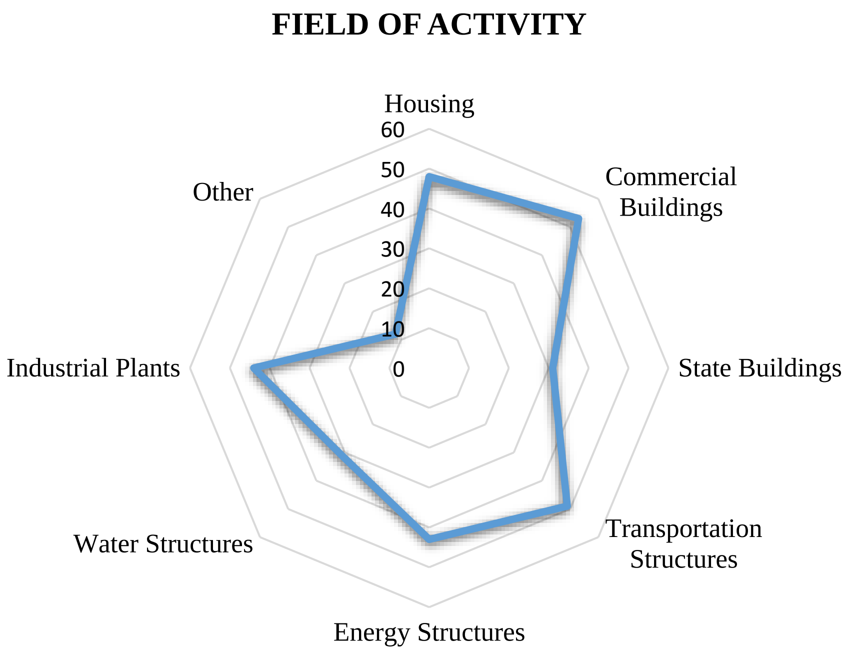


Figure 4.6: Radar Chart for Activity Field Breakdown of the Companies

4.2.2.2. Findings from the Survey

As a result of the survey, the weights were obtained as follows:

- Relative importance of the strategic objectives while determining the importance / value of a new project for the portfolio:
  - Maximization of Short Term Profitability: 15.32%
  - Maximization of Long Term Profitability: 18.65%
  - Gaining Reputation: 17.26%
  - Achievement of Learning / Gaining Experience: 15.95%
  - Risk Minimization: 16.28%
  - Entering New Markets: 16.54%
- Relative importance of the factors for creation of learning opportunity:
  - To enter a new country: 15.40%
  - To gain experience in a new project type: 15.72%
  - To work with a new client: 13.25%
  - To use a new construction technology: 15.02%
  - To work with a new contract type: 13.50%
  - To work with a new project delivery system (design-build, build-operate-transfer, etc.): 14.06%
  - To work with a new project partner: 13.01%
- Relative importance of effect of the risk factors (in terms of duration, cost) in case of their occurrence:
  - Economic risk (changes in exchange rates, cash flow risk, inflation, etc.): 9.47%
  - Political risks (changes in government, changes in international relations, etc.): 9.10%
  - Technical risks (delays due to technical problems, etc.): 8.36%
  - Resource risk (risks due to quality/availability of material, manpower, machinery and equipment, etc.): 8.34%
  - Design risk (deficiency/changes in design, etc.): 8.86%
  - Contractual risk (ambiguity in conditions, insufficient definitions, strict requirements/constraints, etc.): 9.06%
  - Owner initiated risks (insufficient experience, delays in payments, etc.): 8.77%

    - Bureaucratic risks (delays in permissions, etc.): 8.71%
    - Project management risks (poor planning, insufficient experience, etc.): 9.08%
    - Risks due to weather conditions: 6.51%
    - Risks due to ground conditions: 7.08%
    - Environmental risks (social and environmental factors): 6.60%
- Relative importance of the dependencies in calculating portfolio risk:
    - Financial Dependency: 27.10%
    - Resource Dependency: 27.04%
    - Learning Dependency: 22.32%
    - Outcome Dependency: 23.52%
- Relative importance of the factors in measuring financial and resource dependencies:
    - Financial Dependency
        - Client: 53.18%
        - Currency: 46.81%
    - Resource Dependency
        - Construction Materials: 21.94%
        - Critical Machinery and Equipment: 25.69%
        - Manpower: 24.46%
        - Qualified Personnel (Project Management): 27.90%
- Relative importance of the criteria for measuring the similarity of two projects:
    - Being in the same / similar country: 20.87%
    - Same / similar project type (housing, infrastructure, etc.): 22.07%
    - Having the same / similar client: 19.56%
    - Use of the same construction technology: 19.46%
    - Having the same contract type: 18.01%

The obtained numerical values for the presented attributes are to be used as “default weights” in calculations required for “strategic assessment”, “risk assessment”, “dependency assessment”, and “similarity assessment”, which will be embedded in the process of the tool.

4.2.3. Paper Prototype: A Numerical Example

Paper prototype as fundamentals of the design of the tool was decided to establish a sound basis before codification of the tool through its final design. Therefore, this process was evaluated to be formative for the design of the tool, which would be much more sound to start structuring the details and generation of the tool following evaluation of the numerical example by the “research team” and also the “focus group”. Following evaluation and identification of the details on the model through the questionnaire, the paper prototype of the model was generated through a numerical example to realize the decisions by numerical analysis. Within this context, typical process required in the proposed was simulated with the numerical example on the data generated within the scenario of hypothetical projects. The numerical example was prepared using software where “Excel” was utilized to demonstrate how the procedure works both responding the formation of a typical “database” and performing “calculations”, “ORA Software” provided by Carnegie Mellon University was used to produce the expected dependency network maps. The first trial as the “initial model” revealed some unpractical considerations for capturing information and provided detailing of the visual representation. Alternative similarity calculation methods were also tested and selected through the initial numerical example and the model and its basic functions were improved in accordance with the points identified. Following this initial evaluation by the research team, the numerical example was updated to “final model” and presented to the “focus group” to obtain final comments before codification of the tool. The following sections present the details of the process models in terms of the content of the numerical examples generated and the evaluations made based on each version.

4.2.3.1. Paper Prototype: Initial Model

In order to validate the initial model of the, a numerical example summarizing the whole process and the data from the survey results was used. For this example, 20 completed, 3 on-going, and 2 potential theoretical projects were defined to apply the current model on these project examples. Within this context, “general project information”, “critical resource information”, “partnering information”, “financial information” and “project duration information” were primarily defined as the basic project information. Following that the information for “activities”, “people” and “companies” required for completing the information was defined. Lessons learned from the “construction process”, “financial changes”, “delays”, “claims” and “dispute resolution” processes and related details were entered for the knowledge database of the tool serving in terms of lessons learned and predictions parts. The process and visual characteristics of the tool are exemplified through the numerical example. Since the numerical example is further updated with the improvements considered, this section only summarizes what is done at this stage. The complete data and outputs obtained with the numerical example are only presented in the updated version (Section 4.3.4.2).

4.2.3.1.1. General Information

Within the context of the first numerical example following information were generated to provide a complete example of a portfolio.

General Project Information: Information of 20 “completed”, 3 “on-going” and 2 “to-be-started” project was entered to create a portfolio of projects were knowledge can also be extracted for evaluation of current projects. The project information was entered through “Project ID”, “Project Name”, “Project Status”, “Country”, “Project Type”, “Client Name”, Technology”, “Contract Type”, “Project Delivery System”, “Contract Payment Type”, “Currency”, “Start Date”, “Completion Date”, and “Scope of Project”.

Critical Resource Information: Critical resource information was entered with the related information of “Project ID”, “Resource ID”, “Resource Type”, and “Resource Name” with also indicating the “location” of the resource.

Partnering Information: Partner company information was entered into the related projects with the “Project ID”, “Partner Company Name”, and “Partnership Type”.

Financial Information: Financial information was entered as “expected” and “actual” amounts through separate columns of “Project ID”, “Budget”, “Expected Cost”, “Change in Budget”, and “Actual Cost”.

Project Duration Information: Project duration information was entered including “planned” and “actual” durations with the “total delay cost” through separate columns of “Project ID”, “Planned Duration”, “Change in Duration”, “Actual Duration”, and “Delay Cost”.

Activities: Activities were entered with “explanations” and “typical project type” information in which they are generally used through separate columns of “Activity ID”, “Activity Name”, “Activity Description”, and “Typical Project Types”.

Actors: Individuals were entered with their “company” and “contact” information through separate columns of “Company ID”, “Individual ID”, “Name”, “Title”, “Gender”, “E-mail”, and “Phone Number”.

Company Information: Companies were entered with their “roles”, “expertise” and “contact” information through separate columns of “Company ID”, “Company Name”, “Company Role”, “Company Expertise”, “E-mail”, “Phone Number”, “Street Address”, “City”, and “Country”.

4.2.3.1.2. Lessons Learned and Predictions

Information entered for the "lessons learned" and the further details for the "forecasting" ability of the tool are presented in this section.

Construction Experience Information: Lessons learned from the construction process were entered as "best practices" and "problems" together with their impact ratings through separate columns of "Project ID", "Activity ID", "Individual ID", "Experience ID", "Importance Level", "Best Practices" and "Problems". Column for "Best Practices" was further divided to columns of "Description", "Key Factors", "How it is Achieved?", "Saved Time", and "Saved Money". Similarly, "Problems" column was separated to columns of "What Happened?", "Applied Solution", "Possible Preventive Action", "Time Loss", and "Money Loss".

Lessons Learned from Financial Changes: Lessons learned from financial changes were entered including changes on "cost", "cash flow" and "budget" together with their impact ratings through separate columns of "Project ID", "Financial Change ID", "Responsible Company Name", "Change Reason", "Importance Level", "Cost", "Cash Flow", and "Budget". Column for "Cost" further divided to columns of "Amount", "Was it Inevitable?", and "Possible Prevention Strategy". Similarly, "Cash Flow" column was separated to columns of "Consequences", and "Recommendation", while "Budget" column was divided into columns of "Expected Amount", "Changed Amount", and "Recommendation".

Lessons Learned from Delays: Lessons learned from delays were entered with their "causes" and "responsibilities" including the "measures to reduce their impacts" through separate columns of "Project ID", "Delay ID", "Activity Name", "Responsible Company Name", "Reason", "Activity Duration", "Delay Duration", "Reason", "Mitigative Action", and "Recommendation".

Lessons Learned from Claim Process: Lessons learned from the "claim process" were entered along with their "reasons", "requests" and "results" through separate columns of "Claim ID", "Delay/Change/Problem Experience ID", "Related Cause

ID”, “Amount”, “Award/Result”, and “Recommendation”. Column for “Amount” was further divided to columns of “Cost”, “Duration”, and “Other”. Similarly, “Award/Result” column was separated to columns of “Cost”, “Duration”, and “Other”.

Lessons Learned from Dispute Resolution: Lessons learned from “dispute resolution process” were entered along with the “resolution type” and “duration” through separate columns of “Claim ID”, “Dispute ID”, “Resolution Type”, “Result”, “Encountered Problems”, “Recommendation”, and “Duration”.

4.2.3.1.3. Numerical and Visual Outputs

The rest of the example includes the remaining part of the process as numerical and visual outputs obtained. Since these measures are valid for the updated version, which is completely presented in “Section 4.3.4.2”, the rest will be presented in that version with minor changes in the results to prevent duplication of presentation. The following considerations were made through the investigation within the context of the example:

- Knowledge Retrieval:
    - Similarity search was made by assigning attribute similarities for “country”, “project type”, and “client” and similarities for all the projects were calculated.
    - Calculations were made for “expected profit”, “actual profit” and “profit risk” of the projects and average values together with the deviations were obtained for “actual profit” and “profit risk” based on selected attributes in different combinations of “country”, “project type” and “client”.
    - Learning potentials of the on-going and potential projects were calculated.
- Dependency Calculation:
    - Dependencies between each project pair were calculated for on-going and potential projects and presented in a matrix.

    - Overall dependencies between the project pairs were also calculated.
- Risk Assessment:
    - At the beginning of evaluation, the profit risk for each project was investigated together with extraction of the “average delay time”, “average delay cost”, “delayed activities” and “responsible parties” through different filtering.
    - Risk ratings were made in considering the obtained information and risk scores for each project were calculated.
- Strategic Assessment:
    - At the beginning of evaluation, the profit risk for each project was investigated through different filtering for evaluation of profit maximization objective.
    - Learning potential of each project was investigated for learning objective.
    - Strategic fit ratings were made in considering the obtained information and strategic fit scores for each project were calculated.
- Portfolio Analysis:
    - Network densities and centrality of each project in each portfolio alternatives were calculated. Additionally following formulae were used for further measures in portfolio analysis;
        - Average Risk Rating (%): [Average Risk Rating]
        - Portfolio Risk (%): [Average Risk Rating * (1 + network density)/2]
        - Portfolio Success (%): [100 – Portfolio Risk]
        - Average Strategic Fit Rating (%): [Average Strategic Fit Rating]
        - Portfolio Value (%): [Portfolio Success + Average Strategic Fit Rating]
        - Expected Profit (million $)
    - Dependencies were visualized according to the obtained values through the tool “ORA” provided by CASOS.
    - Project Risk vs. Strategic Fit bubble diagrams were drawn through the charts provided in Excel for each portfolio alternative.

    - Portfolio Risk vs. Strategic Fit bubble diagram was drawn through the charts provided in Excel for the portfolio alternatives.
    - Portfolio Value bar chart indicating the Portfolio Strategic Fit and Portfolio Success was drawn through the charts provided in Excel for the portfolio alternatives.
    - Change in Value vs. Change in Profit bubble diagram and bar chart were drawn through the charts provided in Excel for the portfolio alternatives.
- Portfolio Selection
    - Different portfolios were selected considering their portfolio values, risks and strategic fits.
    - The portfolio providing highest expected positive change in the profit was selected considering the change diagrams.
    - The critical projects in each portfolio alternative were investigated through the obtained maximum centrality values.
    - Regarding the dependencies, share of financial resources and knowledge, resource planning, and outcome dependency were evaluated for the critical project pairs.

4.2.3.2. Paper Prototype: Evaluation by Research Team (Initial Evaluation of the Conceptual/Process Model)

As a result of the numerical example provided, model operation was generally found to be applicable; however, some details were decided to be changed to minimize the effort required while providing an intended level of usability for the tool. Main decisions through evaluation of numerical example can be summarized as below where further details are provided in the following sections.

- In the light of the numerical example, the method used to calculate the similarity was applied on the sample consisting of hypothetical projects and the same projects were also used for clustering analysis as an alternative method. As a result of the comparison, the “similarity calculation method” was verified and decided to be the integrated in the tool instead of “clustering method”. Details are provided in “4.2.3.2.1: Evaluation on Similarity Analysis”.

- The current structure for codification of the lessons learned in terms of different headings was evaluated to be ineffective. A single and common “entry form” for all of the lessons was generated instead, which was supported with a “tagging system” to provide the flexibility in information entry and retrieval of different kinds of lessons. Therefore, the “database structure” was updated and the “taxonomy required” for the selected tagging method was established. It was thought that it would be more meaningful to enter the learned lessons together with “project impact” and “financial impact” instead of sole “importance ratings” of the overall lesson. Rather than entry of all change or risky experience as it was proposed in the numerical example, the user was decided to enter only some “critical information” that may be provided in “predictions” for risky matters. Therefore, “predictions” was separated from lessons learned considerations and decided to be based on information of a different section of project information named as “Post Project Appraisal”. “Validation” of the proposed system as single entry form and tagging system was decided to be made through a separate study where face validation should be made at least by three company professionals for entry of lessons learned and evaluation of the content of the taxonomy. Details are provided in “4.2.3.2.2: Evaluation on Lessons Learned and Predictions”.
- The visual features of the tool were improved in the numerical example process and a figure was designed to be used in project display. It was thought that the project symbol to be used in visualizing the projects would be appropriate for the project to represent “status”, “profitability”, “risk score” and “strategic fit score” relative to other projects. It was also thought depicting the “percentage of completion” of the projects in the project symbol is to be helpful in the analysis. Additionally, generation of “summary cards” for depiction of the project information and lesson information were decided to

be valuable for quick evaluation of the projects and lessons learned. Details are provided in “4.2.3.2.3: Evaluation on Visualization”

- In line with the proposed single entry form and elimination of the data for predictions, it was also decided to develop a system for managerial suggestions (warnings/comments) that would respond to any situation that the tool may provide during the portfolio evaluation process. This consideration and other details are provided in “4.2.3.2.4: Other Considerations”.

The details of the summarized evaluations are provided in the following sections.

4.2.3.2.1. Evaluation on Similarity Analysis

Both proposed methods were experimented within the context of numerical example and it was decided to use the original method based on attribute-based similarity calculation since it was expected that this method would be integrated more easily into the tool to be developed. The clustering analysis was abandoned due to the fact that there should be enough projects to be able to do the analysis, the factor weights cannot be directly reflected in the analysis, and a separate module must be designed to operate dynamically in the tool. Therefore, cluster analysis was used in the verification of the proposed similarity calculation method, and similar projects were included in the same groups as a result of this method (Özyurt et al., 2016).

Evaluation on Similarity Calculation: The numerical example was based on similarity calculation as follows where the attributes and their weights were undertaken as provided below (based on the values obtained from the current answers for the questionnaire at the time of analysis) (Table 4.4).

The project attributes that were used to calculate the similarities were as provided below (Table 4.5).

Table 4.4: Similarity Attributes and Their Weights

Attributes to Measure Similarity	Rating	Weight
Same/Similar Country	4.38	0.211
Same/Similar Project Type	4.48	0.216
Same/Similar Client	3.77	0.182
Same Technology	4.28	0.206
Same Contract Type	3.83	0.185

Table 4.5: Attributes used to Measure Similarities for P24 and P25

Project ID	Country	Project Type	Client ID	Technology	Contract Type
P1	Bulgaria	Building	Atez Group	Self-Climbing Formwork	FIDIC
P2	Russia	Building	Vegas Group	Self-Climbing Formwork	FIDIC
P3	Russia	Building	Vegas Group	Pre-stressed Concrete	FIDIC
P4	Bulgaria	Building	Zeta Group		
P5	Russia	Building	Vegas Group	Precast Concrete	
P6	Azerbaijan	Road	Ministry of Transportation (Azerbaijan)	Concrete Road	Joint Contracts Tribunal
P7	Azerbaijan	Building	Baku TRC College	Precast Concrete	Joint Contracts Tribunal
P8	Kazakhstan	Building	Nata Group		
P9	Turkey	Tunnel	Ministry of Transportation (Turkey)	Tunnel Boring Machine	Public Procurement Law
P10	Azerbaijan	Tunnel	Ministry of Transportation (Azerbaijan)	Tunnel Boring Machine	
P11	Russia	Road	Ministry of Transportation (Russia)		
P12	Turkey	Pipeline	Ministry of Energy and Natural Resources (Turkey)		Public Procurement Law
P13	Kazakhstan	Building	Live Group		
P14	Russia	Building	Metropolitan Group	Tunnel Formwork	FIDIC
P15	Turkey	Building	Ramada Group		
P16	Turkey	Bridge	Ministry of Transportation (Turkey)	Post-tension Concrete	Public Procurement Law
P17	Azerbaijan	Bridge	Ministry of Transportation (Azerbaijan)		
P18	Turkey	Bridge	Ministry of Transportation (Turkey)	Post-tension Concrete, Self-Climbing Formwork	Public Procurement Law
P19	Russia	Building	Petro Group		FIDIC
P20	Turkey	Building	Ramada Group	Tunnel Formwork	
P24	Russia	Building	Vegas Group	Pre-stressed Concrete	FIDIC
P25	Turkey	Bridge	Ministry of Transportation (Turkey)	Seismic Base Isolator	Public Procurement Law

Similar projects for Project 24 were obtained as follows in the ranking of their similarities (Table 4.6):

Table 4.6: Similar Projects for P24

Similarity		Projects	0.211	0.216	0.182	0.206	0.185
P24	**100.00%**	P3	100.00%	100.00%	100.00%	100.00%	100.00%
	79.40%	P2	100.00%	100.00%	100.00%	0.00%	100.00%
	75.76%	P14	100.00%	100.00%	80.00%	0.00%	100.00%
	73.94%	P19	100.00%	100.00%	70.00%	0.00%	100.00%
	60.90%	P5	100.00%	100.00%	100.00%	0.00%	0.00%
	40.10%	P1	0.00%	100.00%	0.00%	0.00%	100.00%
	32.15%	P8	50.00%	100.00%	0.00%	0.00%	0.00%
	30.70%	P15	0.00%	100.00%	50.00%	0.00%	0.00%
	30.70%	P20	0.00%	100.00%	50.00%	0.00%	0.00%
	21.60%	P4	0.00%	100.00%	0.00%	0.00%	0.00%
	21.60%	P7	0.00%	100.00%	0.00%	0.00%	0.00%
	21.10%	P11	100.00%	0.00%	0.00%	0.00%	0.00%
	10.55%	P13	50.00%	0.00%	0.00%	0.00%	0.00%
	0.00%	P6	0.00%	0.00%	0.00%	0.00%	0.00%
	0.00%	P9	0.00%	0.00%	0.00%	0.00%	0.00%
	0.00%	P10	0.00%	0.00%	0.00%	0.00%	0.00%
	0.00%	P12	0.00%	0.00%	0.00%	0.00%	0.00%
	0.00%	P16	0.00%	0.00%	0.00%	0.00%	0.00%
	0.00%	P17	0.00%	0.00%	0.00%	0.00%	0.00%
	0.00%	P18	0.00%	0.00%	0.00%	0.00%	0.00%

Similar projects for Project 25 were obtained as follows in the ranking of their similarities (Table 4.7):

Table 4.7: Similar Projects for P25

Similarity		Projects	0.211	0.216	0.182	0.206	0.185
P25	**79.40%**	P16	100.00%	100.00%	100.00%	0.00%	100.00%
	79.40%	P18	100.00%	100.00%	100.00%	0.00%	100.00%
	64.28%	P9	100.00%	30.00%	100.00%	0.00%	100.00%
	54.16%	P12	100.00%	0.00%	80.00%	0.00%	100.00%
	53.33%	P17	90.00%	100.00%	70.00%	0.00%	0.00%

Table 4.7: Similar Projects for P25 (continued)

Similarity		Projects	0.211	0.216	0.182	0.206	0.185
P25	**40.37%**	P6	90.00%	40.00%	70.00%	0.00%	0.00%
	38.21%	P10	90.00%	30.00%	70.00%	0.00%	0.00%
	21.10%	P15	100.00%	0.00%	0.00%	0.00%	0.00%
	21.10%	P20	100.00%	0.00%	0.00%	0.00%	0.00%
	18.99%	P7	90.00%	0.00%	0.00%	0.00%	0.00%
	10.55%	P1	50.00%	0.00%	0.00%	0.00%	0.00%
	10.55%	P4	50.00%	0.00%	0.00%	0.00%	0.00%
	8.64%	P11	0.00%	40.00%	0.00%	0.00%	0.00%
	0.00%	P2	0.00%	0.00%	0.00%	0.00%	0.00%
	0.00%	P3	0.00%	0.00%	0.00%	0.00%	0.00%
	0.00%	P5	0.00%	0.00%	0.00%	0.00%	0.00%
	0.00%	P8	0.00%	0.00%	0.00%	0.00%	0.00%
	0.00%	P13	0.00%	0.00%	0.00%	0.00%	0.00%
	0.00%	P14	0.00%	0.00%	0.00%	0.00%	0.00%
	0.00%	P19	0.00%	0.00%	0.00%	0.00%	0.00%

Clustering analysis was handled for grouping of the projects as an alternative method to the current one, where the two methods were basically used to verify each other and their integration within the tool. The method identified to calculate the similarities of the projects was applied on the numerical example using information of theoretical projects and the same procedure was also applied by clustering analysis as an alternative method. As a result of the clustering analysis, clusters including the projects with high similarity percentages were to be investigated. For clustering analysis, hierarchical clustering methods were tested using SPSS (Statistical Package for the Social Sciences) package program. Project properties used during the analysis were selected as “Country”, “Project Type”, “Employer”, “Construction Technology” and “Contract Type” as they were used in the numerical example. To meet the similarities determined by the user in the numerical example, the “Country” attribute was entered through ten different criteria, and the items were selected in the same category as long as they would meet the assigned similarity rate between the attributes. The most appropriate clustering method ("Between Groups Linkage") and distance/closeness measure ("Minkowski") to be used to determine project similarities were selected by testing among the existing methods and criteria. In addition, verification methods to be used in selecting the appropriate clustering method were also identified. The specified methods and criteria will also be tested in the clustering analysis to be applied on the actual data and the selection will be made with the validated methods. During the analysis process, the similarities between the potential project and the completed projects were examined and it was determined that the projects with high similarity percentages obtained through the first method were in the same cluster.

In addition to the similarities between the potential project and the completed projects, the pairwise similarities between the completed projects between each other were also obtained as a result of the analysis. The percentages of similarities, which were requested to be entered by the user in the similarity analysis with the first method, were not for the completed project pairs but only for evaluation of the similarities of the potential project with the completed projects. In the clustering analysis, the similarities of all projects with each other could be investigated. Within the scope of the study clustering analysis was applied between the following project groups:

- Completed projects
- Completed projects and “Project 24”
- Completed projects and “Project 25”
- Completed projects, “Project 24” and “Project 25”

The locations of “Project 24” and “Project 25” as a result of the cluster analysis were compared with the numerical results of the first method. The cluster results obtained for the analysis of completed projects and “Project 24” are presented in the following dendrogram (Figure 4.7). As it is seen in the dendrogram, “Project 2”, “Project 3”, “Project 5” and “Project 1” have the highest similarities (over 40%) to “Project 21” (which constitutes the “Project 24” in the numerical example) when the number of clusters is determined as “5”. Due to the binary similarities between the projects themselves, “Project 14” and “Project 19” form a different cluster. It is seen that

"Project 12", "Project 16", "Project 17" and "Project 18", where the project similarities were obtained as the least with the first method, are co-existing in a different cluster.

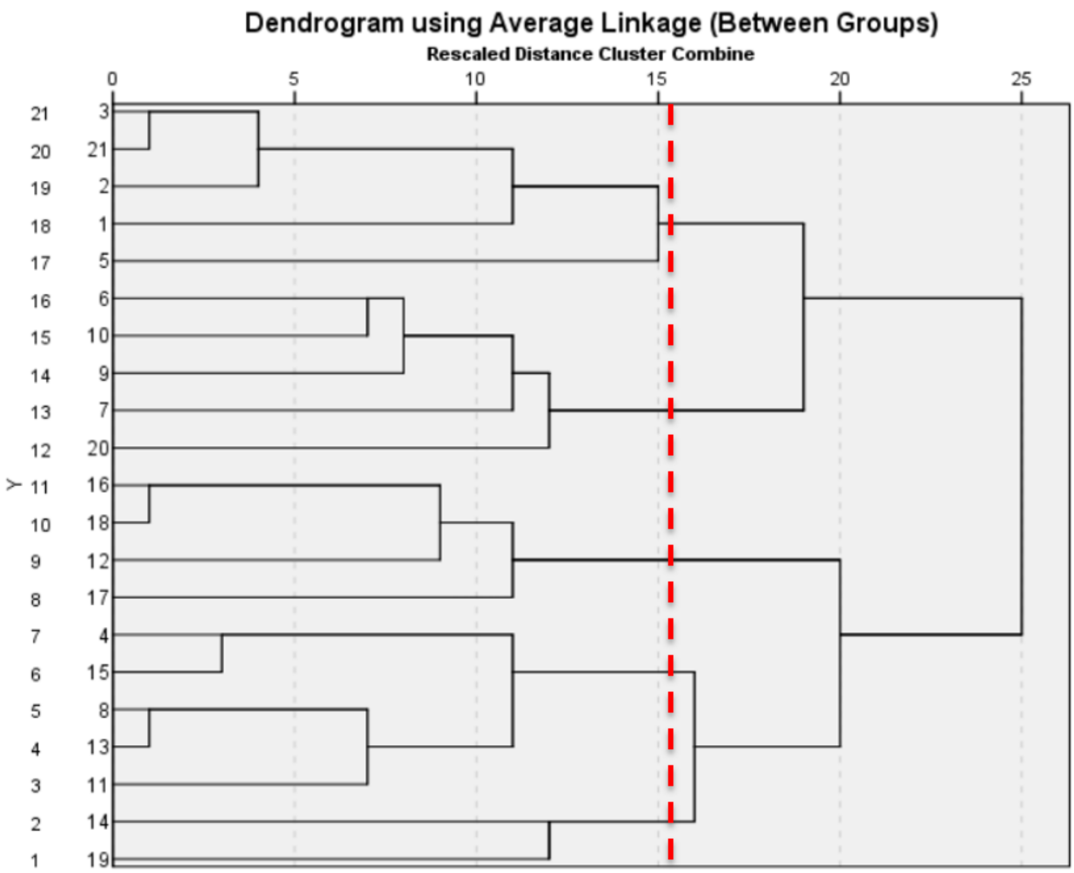


Figure 4.7: Dendrogram for Completed Projects and "Project 24"

As a result of the study, the similarity calculation method was verified and decided to be the integrated in the tool due to its easy adaptability and calculation of similarities for the project in question rather than all project pairs as in clustering analysis.

4.2.3.2.2. Evaluation on Lessons Learned and Predictions

The numerical example was based on hypothetical cases entered by the research team. The hypothetical cases also revealed some problems that may be encountered in actual utilization of the tool. The current consideration on designing different forms and entering lessons learned from “construction experience”, “financial changes”, etc. separately was abandoned due to inconsistency that may be a disadvantage due to both increasing the effort and also decreasing the flexibility of the user. Therefore, the structure is simplified to a common “entry form” for all of the lessons where flexibility in information entry may be supported through a “tag-based classification system” for management and retrieval of the entered lessons. Additionally, the current model was requiring entry of all financial changes, delays, and claim requests to be entered one by one which was also intended to serve for “risk estimation” process. Therefore, the current information may be entered as in the form of only the “critical information” where the user eliminates the excessive data and only enters the eliminated cases instead of entry of all cases, which may be further presented in “predictions” as consideration of the risky factors. Details of this section are as presented below.

Evaluation on Lessons Learned Management: Following the numerical example study, within the context of the joint study of Eken (2017), the current version of lesson entry through different headings and attributes specific to each heading was evaluated to be ineffective and overwhelming. This version could require an extra effort to fit the specific case into these predetermined lesson learned structures. It could also limit the user in entry of different kinds of lessons in different kinds of projects since it enforces constant structure for entry of lessons as follows where LL: “Lessons Learned”:

- Field Experience

    - LL for Best Practice: Importance Level, Description, Related Activity, Related Person/Party, Key Factors, How It is Achieved, Saved Time, Saved Money
    - LL for Problem: Importance Level, Description, Related Activity, Responsible Person/Party, Applied Solution, Possible Preventive Action, Time Loss, Money Loss
- Cost Control Experience
    - LL for Change in Cost: Importance Level, Amount, Reason, Responsible Person/Party, Possible Prevention Strategy:
    - LL for Cash Flow Fluctuation: Importance Level, Reason, Responsible Person/Party, Consequences, Recommendation
- Time Control Experience
    - Delay Information: Delayed Activity, Reason, Responsible Person/Party, Activity Duration, Delay Duration, Mitigative Action, Recommendation
- Claim Management Experience
    - Claim Information: Claim Reason, Claimed Cost, Claimed Time Extension, Other Claims, Awarded Cost, Awarded Time, Results of Other Claims, Encountered Problems during the Claim Procedure, Recommendation
    - Dispute Information: Related Claim, Resolution Type, Result, Duration, Encountered Problems during the Dispute Procedure, Recommendation
- Other Experiences
    - LL for Others: Importance Level, Description

Therefore, the method should both provide a unification in the entry process also should provide some level of flexibility to meet different requirements in entry of different lessons learned. It is appreciated that there is no standard technique for learning, it has both company specific and project specific considerations as follows:

- **Company Specific:** way of the organization to capture learning (Karna and Junnonen, 2005), which is structured with the deep seated values of the company affects learning (Kululanga et al., 1999), and

- **Project Specific:** different projects require different learning approaches (Knauseder et al., 2007).

Regarding codification of experiences, the work provided by Graham and Thomas (2007) presents an outline for codification while capturing related data through accessible world files with links. This outline both unifies the entry process and provides flexibility in codification through classification based on construction work in terms of "trade/subcontract". In this work, best or worst experiences are captured through:

- Title,
- Description,
- Contact details of individuals involved, and
- Classification based on trade/subcontract: cladding, glazing, foundations, etc.

Therefore, learning in the portfolio tool was decided to be codified through defining the project specific learning contribution by selecting concepts already defined or by editing/adding concepts through a "taxonomy" for classification of the lessons. It was decided that the information captured for the lessons learned could be supported through the information integrated through the taxonomy, which provides flexibility both in codification and retrieval of the lessons learned. It was planned that the "tagging method" and "data entry" using this taxonomy could be as follows.

Tagging Method: It was decided to develop a method that will enable the user to select a relevant concept through the taxonomy to be presented in the tool and story to be tagged and scanned through the assigned tags in the search results (Arditi et al., 2010). A literature survey was made for the development of the taxonomy within the context of the study held by Eken (2017) and a taxonomy was prepared to ensure that the lesson stories are labeled in this way. The taxonomy development was based on the main concepts of “project”, “process”, “actor” and “resource” as presented in the work of El-Diraby et al. (2005). In the continuation of the study, various “construction management” books (Chudley and Greeno, 2010; Dykstra, 2011; Fewings, 2013; Hendrickson, 2000; Kerzner, 2006; Peurifoy et al., 2006; Sears et al., 2008) were investigated as the major contributors. Additionally, “EuroStat” (1997) mainly served for identification of the “project types”, “Project Management Institute” (2003) was investigated for “construction management” main headings and “MasterFormat” (2015) was reviewed for detailing of “construction works”. The main titles of the developed taxonomy and the first stage sub-concepts defined are partially presented in the table below (Table 4.8). The final version of the taxonomy in the extended form to all levels is presented in the work of Eken (2017).

Common Entry Form for Lessons Learned: Following the selection of the tagging method, it was envisaged to design a common entry screen instead of having different data entry screens according to the type of “lessons learned”, as it was initially tried in the numerical example. Since the provided “tagging method” was evaluated to support the expected retrieval mechanism as the search functions, it was decided to limit the required information for a lesson with entry of “story” as what happened, its “effect” and “suggestion” for its reoccurrence/prevention. It was also evaluated that it would be more meaningful in the lesson retrieval for a user to investigate the “impact on project duration” and “financial impact” instead of searching only “importance ratings” of the lessons. Therefore, entry of a typical lesson learned should be in terms of following attributes (Eken, 2017):

- Main categorization as “best practice” or “problem”,
- Description of the event/lesson,
- Related recommendation,
- Impact on duration,
- Impact on cost, and
- Detailed categorization through assigned tags.

The new decisions with entry of lessons learned further led the consideration of the "predictions" to be separately handled within the tool through integration of a "Post Project Appraisal (PPA)" section as provided below. Moreover, the potential of the management of lessons learned within a construction company was evaluated to have an utilization potential by the companies that do not require adoption of portfolio management initiatives. Therefore, generation of a separate tool was aimed, which would also completely be integrated in the portfolio management tool with minor changes for its adaptation. The further considerations on lessons learned was generated as the joint effort provided by study of Eken (2017).

Table 4.8: Partial Tag Tree Taxonomy

Category	Reference
Project	(El-Diraby et al., 2005)
Buildings	(Eurostat, 1997)
Civil Engineering Works	(Eurostat, 1997)
Process	(El-Diraby et al., 2005)
Feasibility	(Dykstra, 2011)
Design	(El-Diraby et al., 2005)
Contract Formation	(Hughes and Murdoch, 2001)
Management	(El-Diraby et al., 2005)
Integration Management	(PMI, 2003)
Scope Management	(PMI, 2003)
Time Management	(Kerzner, 2006; PMI, 2003; Sears et al., 2008)
Cost Management	(PMI, 2003; Sears et al., 2008)
Quality Management	(Fewings, 2013; Hendrickson, 2000; Kerzner, 2006; PMI, 2003)
Human Resource Management	(PMI, 2003; Sears et al., 2008)
Communications Management	(Fewings, 2013; PMI, 2003)
Risk Management	(Fewings, 2013; Kerzner, 2006; PMI, 2003)
(continued)	
Construction	(El-Diraby et al., 2005)
Site Works	(Chudley and Greeno, 2010)
Construction Works	(CSI, 2015)
Furnishings	(CSI, 2015)
Conveying Equipment	(CSI, 2015)
Earthwork	(CSI, 2015)
(continued)	
Actor	(El-Diraby et al., 2005)
Client	(Hughes and Murdoch, 2001)
Constructors	(Hughes and Murdoch, 2001)
Dispute Resolvers	(Hughes and Murdoch, 2001)
Regulators	(Hughes and Murdoch, 2001)
Staff	(Hughes and Murdoch, 2001)
Resource	(El-Diraby et al., 2005)
Personnel	(El-Diraby et al., 2005)
Manpower	(Hendrickson, 2000; El-Diraby et al., 2005)
Machinery and Equipment	(Hendrickson, 2000; El-Diraby et al., 2005)
Material	(Hendrickson, 2000; El-Diraby et al., 2005)
Subcontractor	(El-Diraby et al., 2005)
Software	(El-Diraby et al., 2005)

Post Project Appraisal for Predictions: Following simplification of the lesson entry forms, some part of the data that may be captured in lessons learned was decided to be included as "summary values" that may be presented in "predictions". Therefore, rather than elimination of some critical figures embedded in the excessive lessons learned, user may initially enter some values in PPA section that would easily be presented within the "predictions" provided. Thus, predictions were separated from lessons learned differently from the initial consideration and decided to be based on the information that would be captured in "Post Project Appraisal" section for the "completed projects". It was expected that the average values obtained from the projects can be grouped under PPA section. Typical PPA entry was decided to include the main attributes provided as follows:

- Planned and Actual Cost
- Planned and Actual Duration
- Delay and Delay Penalty or Early Completion Incentive
- Critical Actors, Work Packages, and Delay Causes
- Claimed Duration and Cost
- Awarded Duration and Cost

Validation Study for Lessons Learned: Following decisions on simplification of lessons learned and separation of predictions and more importantly the provision of special focus on lessons learned through a joint study (Eken, 2017), validation of lessons learned was decided to be held within the context of the other study through special investigation of the management of lessons learned, which may otherwise be underestimated within validation studies of the portfolio management tool. It was decided to carry out validation for handling of lessons learned through one-to-one interviews with at least three company professionals considering the validity of the method, captured project information, entry form and context of the "tag tree". Company professionals were first to be asked to enter information for a project into the database, and then lesson entry and retrieval mechanisms were to be tested through entry of different lessons learned by investigation and utilization of the tag tree. Details of the final version of the applied validation method is presented in the study of Eken (2017).

4.2.3.2.3. Evaluation on Visualization

It was expected that visualization of the project and portfolio characteristics would be helpful for the user through dependency network maps, bubble diagrams and bar charts as they were tested in the numerical example. In addition to provided versions in the example, the versions within the tool environment were expected to provide some descriptive information such as values appearing when the related section of the maps/charts are selected. Additionally, a project symbol was decided to be integrated to the graphs, especially to the network map, as the one provided in the study of Rauch et al. (2013). Finally, “summary cards” for the “project” and “lesson learned” information were decided to be provided to enable easy review of the entered information, which may also be integrated to different sections of the tool.

Project Symbol: Details of the project symbol that would be used for depiction of the projects as “nodes” in visualizations in portfolio analysis with possible use in dependency networks were identified as follows following the numerical figures investigated in the analysis. The figure was decided to be a “circle” including a “middle liner” to summarize the statuses of the projects at a glance as the “on-going” and “potential” projects. The current status of on-going projects can be shown on the lane as a percentage of the completion rate. On-going projects can be presented in “green” color while potential projects can be in “yellow”. The figure was decided to include an outer circle portion as “doughnut”, which can be further divided into three to indicate different status bars indicating different measures for the project in addition to “project status”. Initial decision for these measures was made to be the profitability of the project (“blue”), its risk score (“pink”) and its strategic fit score (“purple”) where they are presented with filling ratio that would provide relative comparison to each project existing on the dependency map/portfolio. “Project name” and “project type” were also decided to be indicated on the figure. The initial drawing of the figure was made as it is presented in Figure 4.8 (figure further used in project cards where direction can be provided through double clicking of nodes on the dependency network diagrams).

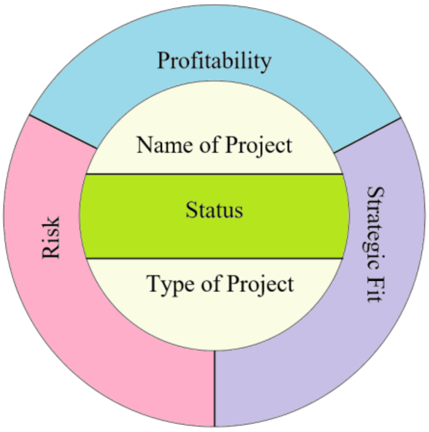


Figure 4.8: Representation of a Project (Project Symbol)

Calculations were needed for numerical depiction in terms of “occupancy rates” of the sections on the figure. “Risk” and “strategic fit” values were decided to be calculated through score limits of “100”, which may be depicted through occupancy rate in “percentages (%)”. Calculation of the “profitability” of projects was needed and decided to be also based on “percentages” as follows:

- Profitability for Completed Projects = (“Actual Profit” / “Actual Cost”) * 100
- Profitability for On-going and Potential Projects = (“Adapted Profit” / “Expected Cost”) * 100

Summary Cards: A “project card” that would summarize all the entered information and some additional calculations was decided to be integrated in different visualization sections of the tool where quick review of the project information was needed together with presentation of some calculated figures for the projects such as "adapted profit", "learning potential", etc. Similarly, a "lesson card" was also required to provide the entered information for quick review of the lessons while investigating different lessons learned retrieved through a search mechanism.

4.2.3.2.4. Other Considerations

Other considerations taken into account through numerical example were as provided below:

- The provided single entry form and predictions were usable by all type of projects. In line with these, it was also decided to develop a system for managerial suggestions (warnings/comments) that would respond to any case obtained during the portfolio evaluation process. Regarding improvement required for the management suggestions/warnings, the identified "critical information" can also be provided to the user in warnings in addition to the network map measures and dependencies.
- Rather than entry of "professional" and "company" information separately, the process was decided to be unified through an "actor entry form" to simplify the entry process only by indicating the "actor type" as "individual/corporation".
- Prediction calculations based on projects obtained through similarity were decided to be based on the data of "50% or more" similar projects only to obtain the data of similar projects, since similarity analysis ranks the projects between the range of [0,100%] where the similarities "below 50%" can be regarded as "very low" for calculation of predictions.
- In the initial decisions on calculations including "contract price", it was seen that the "change in budget" was underestimated. Therefore, all the related calculations were decided to be updated including consideration of the "change in contract price".

- Regarding “adapted profit” calculations, it was decided that profit should be recalculated in accordance of the values obtained through automatic filtering of the “completed projects” for “Country” and “Project Type” matching with the project in question. Since it was realized in the example that sometimes user may not obtain any projects through this filtering in some of the cases, update in the calculation was required. Therefore, it was decided that in such cases no adaptation is required, only the “Expected Profit” should be provided. Therefore, “Expected Profit” should substitute the “Adapted Profit” as long as it is required. However, the “Adapted Profit” value should be automatically used in priority and presented in the portfolio analysis and diagrams as long as it is applicable.
- Since the tool was decided to be creating all the possible portfolio alternatives as combinations of the potential projects, it was evaluated that it would be impossible for a user to make a sound decision-making with un-limited numbers of alternatives. Thus, the user was enforced to include at most “four potential project alternatives” at once in the analysis, which would provide “sixteen portfolio alternatives” to be evaluated.
- Direct use of the generated figure as nodes on the network map was abandoned since the nodes were evaluated to be relatively sized according to profits of the projects, some of the nodes may fall short to clearly depict the content of the project symbol. Therefore, project symbol was decided to be opened in the project cards through selection of the nodes which were decided to be represented in different colors for “on-going” and “potential” projects.
- Identification of the projects mainly as “completed”, “on-going”, and “potential” was decided to be limiting the user in entry of project information. Therefore, additional project statuses for other projects as “suspended”, “eliminated”, and “cancelled" was decided to be reserved together with “project cards” where project status colors (middle bars of the project symbol) were to be assigned as “purple”, “light gray” and “gray” respectively.

- During the analysis it was noticed that a “common currency” unit may be required to find a common ground for different portfolio alternatives, so alternatives should be evaluated through a shared currency.
- Short-code identification for the projects was required to make them representative in the tables/figures where it was not easy-to-follow the projects in full-name.
- Within the process of the analysis on the model, the tool to be generated was decided to be named as “COnstruction Project Portfolio MANagement” tool with the abbreviation of “COPPMAN” in the light of the expected service of the model, and so the tool.

4.2.3.3. Paper Prototype: Final Model

In accordance with the considerations made through the evaluation of the “initial model”, the numerical example was updated to the “final model” to be further tested by the “focus group” as validation of the model before generation of the tool. The final model was structured within the outline provided below and presented to the “focus group” including the improvements identified in the previous section. The initial numerical example was updated as follows through the outlined considerations for “data entry”, “calculations”, “search options”, and “portfolio analysis”:

- **Data Entry**
    - General Project Information
    - Critical Resource and Partner Company Information
    - Duration, Financial, Outcome Dependency and Technology Information
    - Post Project Appraisal Information
    - Lessons Learned Information
- **Calculations**
    - Financial calculations including “profitability”, “profit deviation”, and “adapted profit”,

    - Delay and claim calculations including “delay time”, “delay cost”, “claim success” in terms of “duration” and “cost”,
    - Similarity calculation assigning similarities to “country”, “project type”, and “client” attributes,
    - Learning potential calculation,
    - Risk assessment,
    - Strategic fit assessment,
    - Dependency calculation,
- **Search Options**
    - Predictions based on filtering of the attributes,
    - Predictions based on similarity including only 50% and more similar projects,
- **Portfolio Analysis**
    - Portfolio visualization through “dependency network”, “bubble diagrams” and “bar charts”
    - Calculation of portfolio analysis measures as “network density”, “centrality of projects”, “portfolio risk”, “portfolio success”, “portfolio strategic fit”, “portfolio value”, “portfolio expected profit”, “change in value”, and “change in profit”,
    - Portfolio selection considering “portfolio value”, “portfolio strategic fit”, “portfolio risk”, and “portfolio profits”

The numerical example was continuously used to verify the updated models of the tool throughout its development. Therefore, the details with the numerical example will be presented in the final version in comparison to the outputs obtained from the tool in “Section 4.3.4.2: Charrette Test with Paper Prototype: Numerical Example”. The following section handles the evaluation of the process model through investigation provided by the “focus group” on the current version of the numerical example (“final model”) as the last evaluation obtained before generation of the tool.

4.2.3.4. Paper Prototype: Evaluation of Process Model by Construction Firm (Survey 4 - Section 1)

The models of the tool were decided to be evaluated to ensure the accuracy and reliability of the developed pre-models by making the necessary improvements in order to overcome the identified deficiencies and errors. In addition, the evaluation of the model by the developer team as the research team, it was also intended to be evaluated in the light of the experience of the company's executives in past projects and their knowledge about different projects. Therefore, evaluation of the current model was also made by participation of the same three professionals from the power systems company ("focus group" who also participated in Survey 1 and 2) in a combined survey (Survey 4 in two sections), which also includes evaluation of the "modules" and the final "requirement specification" (Survey 4: Section 2) generated based on the process model. The survey (Survey 4: Section 1) includes open questions on general evaluation of the model through the presented prototype (Appendix D). The result of the evaluation as the comments of the "focus group" is as presented below:

- The model well suits with the identified requirements, and quantification formulae are reasonable.
- It is very beneficial that the model encapsulates different considerations of different departments such as strategic and risk assessment, lessons learned, similar projects, predictions, etc.
- Variety in retrieval options such as filtering and similarity based search is also successful to serve for benchmarking.
- It would be much better to investigate the model through the tool, because model would serve best when it is enhanced with capabilities of the tool. The case example as paper prototype is reasonable, but it is also important that how the tool reports the case to the user, reporting would also be important. The model is suitable to serve as a basis for generation of the first prototype of the tool. There is no current limitation regarding the model. The model

should also be supported with a usable tool. It should not need considerable effort to utilize at least to serve for this kind of a company.

In the light of the accepted version of the process model, the “final model and the algorithm” of the tool were identified and summarized in the following sections, which was also provided to the software development company as a reference to generation of the tool together with the supportive considerations as the “modules” and “requirement specification” generated in the light of the approved final model of the tool.

4.2.4. Modules and Requirement Specification

The model details were finalized through development and evaluation of the “modules” and “requirement specification” as a transition between the development processes of the “model” and the “tool” where “process model” is more formalized with the investigation of “modules” and the “requirement specification”.

4.2.4.1. Modules

According to the provided conceptual framework and the initial investigations made through numerical examples as paper prototype of the model, the architecture of the tool was decided to be designed with “five main modules” as building blocks of the required main system serving for the identified model as presented in the following figure (Figure 4.9). The modules and their roles in the proposed system are as presented below.

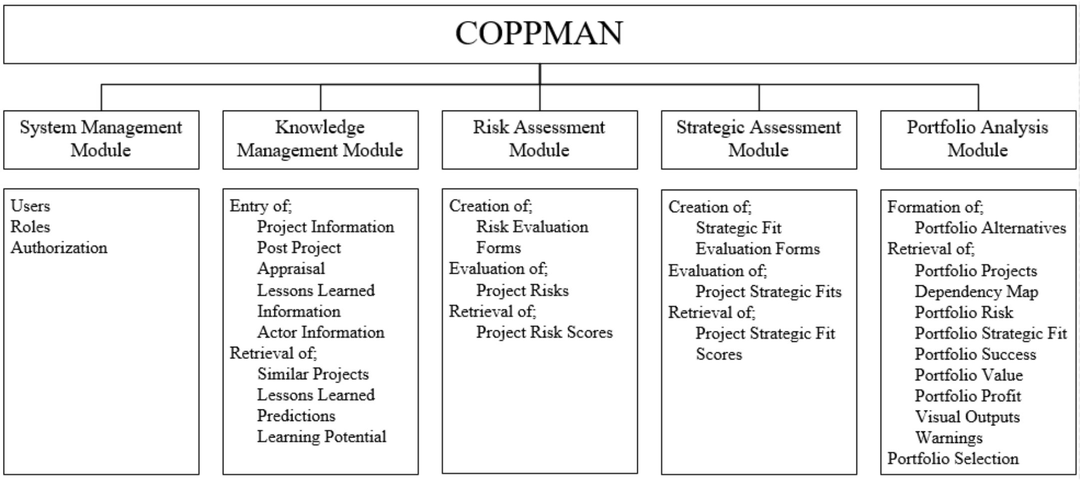


Figure 4.9: Modules (Bilgin et al., 2018)

Details of the proposed modules are as follows:

- **System Management Module:** is required to establish a user management system that would serve for the different evaluation and analysis processes identified within the process model. The system should include defining specific roles, users and their authorization to support establishment of a system to successfully utilize the tool.
- **Knowledge Management Module:** encapsulates the requirements for managing both explicit and tacit knowledge for the construction company. Therefore, all the project data, the lessons learned and data used in predictions are unified under this module, including the retrieval of related information that would support the analysis process. Various data retrieval options are to be provided as predictions for specific project (based on PPA information) and the related lessons learned. Further information of similar projects and learning potential of each project are to be provided within the context of this module for investigation before assessment of projects.
- **Risk Assessment Module:** provides customizable risk evaluation forms to assess risk scores of each project where the risk scores are to be further utilized in calculation of portfolio risk. Risk evaluation histories of projects

should also be stored under this module for evaluation of the change upon request and a system for keeping risk evaluations up-to-date at the time of analysis should also be included (i.e., evaluations should be at most “3 months” old).

- **Strategic Assessment Module:** provides customizable strategic fit evaluation forms to assess strategic fit of each project as in the risk assessment module. Similarly, the obtained strategic fit scores are to be further utilized in calculation of portfolio strategic fit and strategic fit evaluation histories of projects should also be stored for evaluation upon request.
- **Portfolio Analysis Module:** enables automatic formation of portfolios while providing visualization for project and portfolio properties through tables, bubble diagrams and bar charts, together with dependency maps of each portfolio, where warnings on portfolios upon either selection or management of portfolios are also obtained as a support for decision-making.

4.2.4.2. Evaluation of Modules (Survey 4 - Section 2.1)

Modules were evaluated as a part of second section of Survey 4, which also investigates the model in Section 1. Section 2 was designed for evaluation of the “modules” and the final “requirement specification” (Survey 4: Section 2). The survey (Survey 4: Section 2.1) includes investigation of the capacity of modules designed to be included in the tool to figure out any module based attention to modify the current system. Adequateness of the modules was evaluated on a Seven-Point Likert Scale ranging from “strongly disagree (1)” to “strongly agree (7)” (Appendix D). The result of the evaluation is presented below in terms of average rating for each statement (Table 4.9):

Table 4.9: Evaluation of Modules

Modules	Rating
1. The structure of the "system management module" is adequate for a construction project portfolio management tool.	5.00
2. The structure of the "knowledge management module" is adequate for a construction project portfolio management tool.	6.33
3. The structure of the "risk assessment module" is adequate for a construction project portfolio management tool.	5.33
4. The structure of the "strategic assessment module" is adequate for a construction project portfolio management tool.	5.67
5. The structure of the "portfolio analysis module" is adequate for a construction project portfolio management tool.	6.00

Adequacy of all the modules were approved through the evaluation where indication of at least "somewhat agree" is provided for the "system management module". The modules with high potential for the tool were identified as the "knowledge management" and "portfolio analysis" modules as they are expected to be powerful. "Strategic assessment" and "risk assessment" modules were also found valuable comparatively. "System management" module got the approval with lowest degree, which may be the least critical point of the model and would be improved with capabilities of the tool. The evaluation process did not report a module that needs critical attention for further consideration.

4.2.4.3. Requirements Specification

In the light of the established "model" and the "modules", the identified "initial requirements" were transformed to "requirement specification" as more detailed and certain requirements. The requirements for successful operation of the modules and meeting expected properties of the tool were identified as below together with the related "design principles" and "modules" as follows (Table 4.10):

Table 4.10: Requirements with Related Design Principles and Modules

Requirement	Design Principle	Module
Identification of different users in tool with different accessibility options to the tool menu/operations.	Multi-users	System Management Module
Menu for entry of different types of projects, together with view and query options.	Multi-projects	Knowledge Management Module
Identification of ready-to-use project inputs.	Pre-defined Attributes	Knowledge Management Module
Calculation and presentation of predictions for the on-going and potential projects through use of information of completed projects.	Post Project Appraisal	Knowledge Management Module
Menu for entry of lessons learned, together with view and query options.	Lessons Learned Management	Knowledge Management Module
Tagging system for entry of lessons learned, including editing options for the tag tree and tag-based query.	Lesson Classification	Knowledge Management Module
Calculation and presentation of learning potentials for the on-going and potential projects.	Learning Potential Assessment	Knowledge Management Module
Establishment of project similarity based search and calculation capabilities.	Similarity Assessment	Knowledge Management Module
Establishment of filtering based search and calculation capabilities.	Filtering Capability	Knowledge Management Module
Menu for evaluation of risk and strategic fit factors, including editing of the factors and calculation of scores.	Risk and Strategic Fit Analysis	Risk and Strategic Assessment Modules
Calculation of dependencies between projects and visualization of dependencies with a dependency map.	Dependency Assessment	Portfolio Analysis Module
Development of a project symbol to be used in visualizations.	Visualization of Projects	Portfolio Analysis Module
Automatic formation of the portfolio alternatives through addition of potential project combinations to on-going projects.	Portfolio Formation / Scenario Analysis	Portfolio Analysis Module
Calculation of portfolio attributes and depiction of results through tables, bubble diagrams and bar charts.	Visualization of Portfolios	Portfolio Analysis Module
Establishment of an automatic warning system for current portfolios.	Warnings	Portfolio Analysis Module

4.2.4.4. Evaluation of Requirements Specification (Survey 4 - Section 2.2)

The identified “requirements specification” was evaluated as the second part of second section of Survey 4. The survey (Survey 4: Section 2.2) includes evaluation of the importance of the features of the tool to figure out the criticality of each requirement in the development of the tool as the major requirements to be developed. The importance of the requirements was evaluated on a Seven-Point Likert Scale ranging from "strongly disagree (1)" to "strongly agree (7)" (Appendix D). The result of the evaluation is presented below in terms of average rating for each statement (Table 4.11):

Table 4.11: Evaluation of Requirement Specification

Requirement	**Rating**
1. Identification of different users in tool with different accessibility options to the tool menu/operations is an important feature	6.00
2. Menu for entry of different types of projects, together with view and query options is an important feature	6.33
3. Identification of ready-to-use project inputs is an important feature	5.67
4. Calculation and presentation of predictions for the on-going and potential projects through use of information of completed projects is an important feature	6.67
5. Menu for entry of lessons learned, together with view and query options is an important feature	7.00
6. Tagging system for entry of lessons learned, including editing options for the tag tree and tag-based query is an important feature	6.67
7. Calculation and presentation of learning potentials for the on-going and potential projects is an important feature	5.33
8. Establishment of project similarity based search and calculation capabilities is an important feature	6.67
9. Establishment of filtering based search and calculation capabilities is an important feature	6.33
10. Menu for evaluation of risk and strategic fit factors, including editing of the factors and calculation of scores is an important feature	6.67
11. Calculation of dependencies between projects and visualization of dependencies with a dependency map is an important feature	7.00
12. Development of a project representation to be used in visualizations is an important feature	5.67
13. Automatic formation of the portfolio alternatives through addition of potential project combinations to on-going projects is an important feature	6.00
14. Calculation of portfolio attributes and depiction of results through tables, bubble diagrams and bar charts is an important feature	6.33
15. Establishment of an automatic warning system for current portfolios is an important feature	6.00

As it can be seen from the ratings obtained, all of the requirements can be deemed important; however, the most important requirements were identified as the ones related with "lessons learned" and "handling project dependencies". Following that requirements for "predictions", "tagging system", "similarity assessment", and "risk and strategic assessments" were evaluated to be the second most important requirements of the tool as it was expected. The other requirements that serve for portfolio analysis as “accessibility options for different users”, “entry of different project types”, “filtering based capabilities”, “automatic portfolio formation”, “visualization of portfolio properties” and “automatic warnings” were the other group of important requirements. The supportive requirements as “ready-to-use project inputs” and “project symbol” got the least scores in the overall requirements for portfolio tool.

4.2.5. Details of the Final Model and Algorithm

As presented, the conceptual/process model and basic functions of the tool was tested with numerical examples and was to be transferred to the software company with the identified requirements. It was decided to continue with the precise details of the model according to the improvement that will be achieved during the design of the tool. The following section clarifies the details that were delivered to the software company as the further details of the SRS document. This section also includes the final versions of the formulae identified for the algorithm of the tool and the decisions on the overall structure of the menu and operations at the outline level required for the overall structure of the tool design.

4.2.5.1. Initial Settings

There will be ready-to-use project inputs to be identified before entering the project information to ease the entry process. User would be able to make some adjustments in the preferences available within the tool (Table 4.12).

Table 4.12: Inputs and Settings

Ready-to-use Input for Projects:	Settings for:
▪ Project Types ▪ Project Delivery Systems ▪ Contract Types ▪ Contract Payment Types ▪ Resource Types ▪ Project Partnership Types ▪ Critical Work Packages ▪ Critical Delay Causes ▪ Technologies ▪ Actors	▪ Tag Tree ▪ Evaluation Factors ▪ Constants used in Calculations ▪ Exchange Rate Constants ▪ Users ▪ Access and Authorization

4.2.5.2. Project Information and Operations

The required project information according to each project status will be as follows. The differences in required information are provided in “red” color (Table 4.13).

More information is required for “completed projects” for the “Post Project Appraisal” section of the tool as provided below (Table 4.14).

Operations for projects are identified as follows where the differences in operations are provided in “red” color (Table 4.15).

Learning Potential Calculation: The percentage matching of the contribution of learning of each project can be subtracted from “100” and the obtained value can be used as indication the learning potential of the project. Thus, the matching percentages of each attribute is calculated first, and then the weighted average is subtracted from “100” to measure the learning potential. The following table indicates details of the calculation process for different attributes with different entry options as “optional”, “single-mandatory” or “multiple” entries where “NA” stands for “Not Applicable” (Table 4.16).

Table 4.13: Required Project Information

PROJECT ENTRY INFORMATION		
Completed Project	**On-Going Project**	**Potential Project**
General Project Information ▪ Project Name ▪ Project Type ▪ Project Scope ▪ Client ▪ Country ▪ Project Delivery System ▪ Short Code ▪ Contract Type ▪ Contract Payment Type ▪ Currency ▪ Start Date ▪ End Date Critical Resource Information ▪ Resource Type ▪ Resource Name Partnership Information ▪ Partnership Type ▪ Partner Company Duration Information ▪ Planned Project Duration Financial Information ▪ Contract Price ▪ Expected Cost Dependent Projects Technologies	General Project Information ▪ Project Name ▪ Project Type ▪ Project Scope ▪ Client ▪ Country ▪ Project Delivery System ▪ Short Code ▪ Contract Type ▪ Contract Payment Type ▪ Currency ▪ Start Date ▪ Planned End Date Critical Resource Information ▪ Resource Type ▪ Resource Name Partnership Information ▪ Partnership Type ▪ Partner Company Duration Information ▪ Planned Project Duration ▪ Completion Percentage Financial Information ▪ Contract Price ▪ Expected Cost Dependent Projects Technologies	General Project Information ▪ Project Name ▪ Project Type ▪ Project Scope ▪ Client ▪ Country ▪ Project Delivery System ▪ Short Code ▪ Contract Type ▪ Contract Payment Type ▪ Currency ▪ Planned Start Date ▪ Planned End Date Critical Resource Information ▪ Resource Type ▪ Resource Name Partnership Information ▪ Partnership Type ▪ Partner Company Duration Information ▪ Planned Project Duration Financial Information ▪ Estimated Contract Price ▪ Expected Cost Dependent Projects Technologies

Table 4.14: Required Post Project Appraisal Information for Completed Projects

POST PROJECT APPRAISAL FORM FOR A COMPLETED PROJECT
Evaluation Information ▪ Actual Project Duration ▪ Extension of Time ▪ Delay ▪ Actual Cost ▪ Change in Contract Price ▪ Delay Cost ▪ Delay Penalty ▪ Early Completion Incentive Claim Information ▪ Claimed Duration ▪ Duration Awarded ▪ Claimed Payment ▪ Payment Awarded

Table 4.14: Required Post Project Appraisal Information for Completed Projects (continued)

POST PROJECT APPRAISAL FORM FOR A COMPLETED PROJECT
Critical Causes of Delay ▪ Critical Delay Cause ▪ Effect Level Critical Actors ▪ Critical Actor ▪ Effect Level Critical Work Packages ▪ Critical Work Package ▪ Effect Level

Table 4.15: Project Operations

OPERATIONS FOR PROJECTS		
Completed Project	**On-Going Project**	**Potential Project**
Operations ▪ Edit ▪ Lesson Learned Entry ▪ Remove ▪ View Project Card	Supportive Information ▪ Display Similar Projects ▪ Display Lessons Learned ▪ Display Predictions ▪ Display Learning Potential Operations ▪ Edit ▪ Risk Assessment ▪ Strategic Fit Assessment ▪ Remove ▪ View Project Card	Supportive Information ▪ Display Similar Projects ▪ Display Lessons Learned ▪ Display Predictions ▪ Display Learning Potential Operations ▪ Edit ▪ Risk Assessment ▪ Strategic Fit Assessment ▪ Remove ▪ View Project Card
Lessons Learned information is expected to be entered at least for completed projects. It is not provided in the standard operations menu for on-going and potential projects since it is not an obligatory operation to perform analysis; however, it can also be entered for these projects from "Corporate Memory" function.		

Table 4.16: Details of Attribute Matching for Learning Potential Calculation

ATTRIBUTE MATCHING CALCULATION			
Attribute	**In Case of "1" Data Entry (%)**	**In Case of "more than 1" Data Entry (%)**	**In Case of "No" Data Entry (%)**
Country	Matching Count/Project Count	NA	NA
Project Type	Matching Count/Project Count	NA	NA
Client	Matching Count/Project Count	NA	NA

Table 4.16: Details of Attribute Matching for Learning Potential Calculation (continued)

ATTRIBUTE MATCHING CALCULATION			
Attribute	**In Case of "1" Data Entry (%)**	**In Case of "more than 1" Data Entry (%)**	**In Case of "No" Data Entry (%)**
Technology	Matching Count/Project Count	Average (Matching Count/Project Count)	Matching 100%, Learning Potential 0%
Contract Type	Matching Count/Project Count	NA	Matching 100%, Learning Potential 0%
Project Delivery System	Matching Count/Project Count	NA	NA
Partner Company	Matching Count/Project Count	Average (Matching Count/Project Count)	Matching 100%, Learning Potential 0%

Weighted Average Matching (%) = X % = $\sum$ (Attribute Matching)$_i$ * (Attribute Weight)$_i$ for i = each "Learning Potential Attribute"

Learning Potential (%) = (100 – X) %

All the entered project information will be visible in the "projects cards" that would be specific to each project status with a "project symbol". There will also be some calculated information on the project cards/figures according to the entered information. Profit information is calculated and presented in the "Project Cards" according to the following formulae:

- Actual Profit (for completed projects) = "Contract Price" + "Change in Contract Price" – "Actual Cost"
- Expected Profit (for all types of projects) = "Contract Price" – "Expected Cost"
- Adapted Profit (for on-going and potential projects): details are provided below

Adapted Profit = ("Expected Profit") * (1 + "Average Deviation in Profit")

- Average Deviation in Profit: "Country" and "Project Type" filter for the Project in hand will be made between "Completed Projects" and only filtered projects will be used in calculation.
- If no projects are obtained through filtering projects, "Adapted Profit" would be equal to "Expected Profit"
- Deviation in Profit = [("Actual Profit" – "Expected Profit") / ("Expected Profit")] * 100
  - Actual Profit = "Contract Price" + "Change in Contract Price" – "Actual Cost"
  - Expected Profit = ("Contract Price" – "Expected Cost")

Information provided through the "Project Symbols" are as follows:

- Project Name: (written)
- Project Type: (written)
- Risk Score over 100: Light Pink
- Strategic Fit Score over 100: Lilac
- Profitability Percentage: Light Blue (details are provided below)
- Project Status:
  - Blue (for completed projects)
  - Green (for on-going projects) also indication of "Completion Percentage"
  - Yellow (for potential projects)

Profitability (for completed projects) = ("Actual Profit" / "Actual Cost") * 100

Profitability (for on-going/potential projects) = ("Adapted Profit" / "Expected Cost") * 100

4.2.5.3. Corporate Memory

Details of the “Corporate Memory” are handled in the study of Eken (2017), whereas as a summary, the required lesson learned information will be as follows (Table 4.17):

Table 4.17: Required Lesson Learned Information

LESSON LEARNED ENTRY
Lesson Learned Information ▪ Project (select) ▪ Lesson Learned Name (enter) ▪ Best Practice (or not) (tick box) ▪ Event Description (enter) ▪ Recommendations (enter) Effect on Duration (tick box) (5-Scale Rating: Very Low - Very High) Effect Amount (enter) (if it is known) Effect on Cost (tick box) (5-Scale Rating: Very Low - Very High) Effect Amount (enter) (if it is known) Tags (right click to assign) ▪ Project (extendable list) ▪ Process (extendable list) ▪ Actor (extendable list) ▪ Resource (extendable list)

Lessons Learned should be displayed according to three query options as: “filtering”, “similarity-based” and “tag-based” search (Table 4.18).

$$\text{Similarity (\%)} = \sum (\text{Attribute Matching})_i * (\text{Attribute Weight})_i$$

for i = each “Similarity Attribute”

$(\text{Attribute Matching})_{\text{All Similarity Attributes}}$ = 100% for exact matching

$(\text{Attribute Matching})_{\text{Country, Project Type, Client}}$ = [0, 100]% according to the assignment by the user

“Lesson Cards” will be displayed following the query process including depiction of all the entered information.

Table 4.18: Lesson Learned Retrieval through Different Query Options

DISPLAY LESSON LEARNED	
Filtering ▪ Country (select) ▪ Project Type (select) ▪ Contract Type (select) ▪ Client (keyword search) ▪ Partner Company (keyword search)	Following the filtering process lessons learned obtained can be further filtered by the assigned tags.
Similarity-Based Search ▪ Country (select) (user will be asked to indicate similarity of countries) ▪ Project Type (select) (user will be asked to indicate similarity of project types) ▪ Client (keyword search) (user will be asked to indicate similarity of clients) ▪ Technology (select) (exact matching of the attribute) ▪ Contract Type (select) (exact matching of the attribute)	**Similarity-Based Search:** Percent matching of the weighted attributes of a project pair constitutes the similarity between the projects. Exact matching of "technology" and "contract type" is searched for this calculation. However, user can assign some similarity at the attribute level for the attributes of "country", "project type" and "client". Similarity calculation is provided below.
Tag-Based Search	**Tag-Based Search:** Assignment of a tag also provides automatic assignment of generalized tags in the tag tree. This enables search with upper level tags in the hierarchy even if the event is tagged only with a specific tag at lower levels.

4.2.5.4. Predictions

Predictions will be based on information entered in the Post Project Appraisal section of "completed" project entry. Predictions would be presented based on the information obtained through two query options as "filtering" and "similarity-based search" as they are also included in the "lesson retrieval". Differently from the "similarity-based search" for "lesson retrieval", the information of projects with "50%" or "higher" similarity values will be used in calculation of "predictions". Calculation of similarity will be proceeded in the same way. Calculations required for "predictions" are as follows:

- Average Deviation in Profit = $\sum[\{(\text{Actual Profit})_i - (\text{Expected Profit})_i\} / (\text{Expected Profit})_i * 100] / n$

for i = each obtained project, n = total project count

    - Actual Profit = “Contract Price” + “Change in Contract Price” – “Actual Cost”
    - Expected Profit = (“Contract Price” – “Expected Cost”)

- Average Profitability = $\sum[(\text{Profitability})_i] / n$

  for i = each obtained project, n = total project count

- Average Delay Duration = $\sum[(\text{Delay Duration})_i / (\text{Actual Duration})_i * 100] / n$

  for i = each obtained project, n = total project count

- Average Delay Cost = $\sum[(\text{Delay Cost})_i / (\text{Actual Cost})_i * 100] / n$

  for i = each obtained project, n = total project count

- Average Claim Success (Duration) = $\sum[(\text{Duration Awarded})_I / (\text{Claimed Duration})_i * 100] / n$

  for i = each obtained project, n = total project count

- Average Claim Success (Cost) = $\sum[(\text{Payment Awarded})_i / (\text{Claimed Payment})_i * 100] / n$

  for i = each obtained project, n = total project count

- Critical Actors = mode counted considering effects
- Critical Work Packages = mode counted considering effects
- Critical Delay Causes = mode counted considering effects

4.2.5.5. Portfolio Management

In this section dependency analysis used in portfolio analysis section will be presented with the portfolio analysis results.

4.2.5.5.1. Dependency Analysis

The identified dependencies and their attributes for their measurement are as in the following table (Table 4.19).

Table 4.19: Dependencies and Attributes to Measure Dependencies

Dependency Type	Attributes
Financial Dependency: Problems that may be encountered in one project due to some financial attributes may affect the other project that is using the same attributes. For example, problems with a client in one project may affect the other project with the same client.	▪ Client ▪ Currency
Resource Dependency: Any inconveniency due to a resource in one project may affect the other project using the same resources. For example, any failure in special equipment used in one project may affect the other project that is using the same equipment.	▪ Personnel ▪ Manpower ▪ Machinery and Equipment ▪ Material
Learning Dependency: Every project has some contribution to learning at different levels. If the projects have the same learning attributes, problems encountered in one project that affects the knowledge gained during execution of the project may affect the knowledge to be gained in the other project that is using same new process. For example, problem that may be encountered in training of personnel in one project may affect the other project that needs the same training process.	▪ Country ▪ Project Type ▪ Client ▪ Technology ▪ Contract Type ▪ Partnering Company
Outcome Dependency: If the outcome produced in one project is to be used in the other project, there exists an outcome dependency between the projects. Additionally, any special dependency may be defined with an outcome dependency. For example, if a special condition is required for wining of a project; namely awarding of a project is dependent on successful completion of a project with the same client, then an outcome dependency may be defined between these projects.	▪ User is asked to identify

Overall Dependency Calculation: Dependencies are calculated through weighted attribute matching process. Further dependencies are normalized with dependency weights.

Dependency = [$\sum$ (Attribute Matching)$_i$ * (Attribute Weight)$_i$] * Dependency Weight

for i = each “Dependency Attribute”

Measuring Dependencies: Once the user defines projects within the tool, dependencies will be automatically calculated using the project data when the user defines the projects, except for the "outcome dependency" for which the user is asked to assign existence of the "outcome dependency" while entering project information (updated with also quantification of "outcome dependency" through entering a value between [0,100%] by the user).

By using the attributes and the assigned weights, overall dependency between the projects {X, Y} as D(X, Y) are calculated according to the following formulae:

$$D(X,Y)\ [0{,}100\%] = \sum_{i=1}^{4} D_i\ (X,Y) * w_i \quad i = \{dependency\ types\}$$

$$D_i(X,Y) = \sum_{k=1}^{n_k} w_k * S_k(X_k,Y_k)$$

$$S_k(X_k,Y_k) = \begin{cases} 100\% & if\ X_k = Y_k \\ 0 & otherwise \end{cases} \quad k = 1,\dots,n_k$$

where; X and Y are projects, $D_i\ (X,Y)$ is the dependency measure for dependency i, w_i is the overall weight for dependency i, w_k is the attribute weight for attribute k, $S_k(X_k,Y_k)$ is the per-attribute similarity, and n_k is the maximum number of the attributes for measuring dependency i.

Through the properties of the dependency network map, the critical projects and the intensity of dependencies can be quantified by using the below formulae:

$$P_C(X)\ [0{,}100\%] = \frac{\sum_{i=1}^{n_p} D(X,Y_i)}{\sum_{i=1}^{n_p} D(X,Y_i) + \sum_{i<j} D(Y_i,Y_j)} \quad Port = \{X, Y_1, \dots, Y_{n_p}\}$$

where; $P_C(X)$ is the centrality of the project X, $\sum_{i=1}^{n_p} D(X,Y_i)$ is the total dependency of the Project X, $\sum_{i=1}^{n_p} D(X,Y_i) + \sum_{i<j} D(Y_i,Y_j)$ is the total dependencies between the projects of the portfolio $\{X, Y_1, \dots, Y_{n_p}\}$.

$$Port_{ND}\ [0{,}1] = \frac{\sum_{i<j} D(X_i,X_j)}{\binom{n_p}{2} * 100\%} \quad Port = \{X_1, \dots, X_{n_p}\}$$

where; $Port_{ND}$ is the network density of the portfolio, $\sum_{i<j} D(X_i,X_j)$ is the total of dependencies between the projects of the portfolio $\{X_1, \dots, X_{n_p}\}$ and $\binom{n_p}{2}$ is the possible dependencies of the network as binary combination count of the projects in the portfolio.

Following identification of network density, portfolio risk is obtained by grossing the average portfolio risk with the network density as the dependency effect due to the level of complexity within the portfolio.

$Port_R\ [0{,}100] = \bar{X}(P_R) * \frac{1+Port_{ND}}{2}$

where; $Port_R$ is the portfolio risk and $\bar{X}(P_R)$ is the average risk score of the projects in the portfolio (Bilgin et al., 2017).

4.2.5.5.2. Portfolio Analysis Results

Portfolio analysis results are first presented in tables including some "portfolio" or "project" properties. Portfolio level presentation should include the information of:

- Portfolio Name
- Average Risk Score [0,100] = Average of the Risk Scores of the Projects within the Portfolio
- Average Strategic Fit Score [0,100] = Average of the Strategic Fit Scores of the Projects within the Portfolio
- Network Density [0,1] = "Total of the Weighted Dependencies between the Projects within the Portfolio" / ("Binary Combination Count of the Projects within the Portfolio" *100) = Total Dependencies / (C(n,2) * 100)
  where n = number of projects in the portfolio
- Portfolio Risk [0,100] = ("Average Risk Score of the Portfolio Alternative") * (1 + "Network Density") / 2
- Portfolio Success (%) [0,100] = 100 – "Portfolio Risk"
- Portfolio Value [0,200] = "Average Strategic Fit" + "Portfolio Success"
- Portfolio Profit (in the selected currency) = Total "Adapted Profit" Value of the Projects within the Portfolio

Whereas, information of the projects included in the portfolio alternative will be presented as follows:

- Project Name
- Start Date
- End Date
- Project Status
- Risk Score = $\sum$ (Factor Score)$_i$ * (Factor Weight)$_i$
  for i = each "Risk Evaluation Factor"
- Strategic Fit Score = $\sum$ (Factor Score)$_i$ * (Factor Weight)$_i$
  for i = each "Strategic Fit Evaluation Factor"
- Centrality Value = "Total of Dependencies (Multiplied with Weights) Entering the Project Node that the Centrality Calculation will be Made" / Total of Dependencies (Multiplied with Weights) between the Projects in the Portfolio"

Following the tables, diagrams will be presented. These diagrams would be obtained once for the obtained portfolios in the analysis. Diagrams presented at the portfolio level will be as follows ("sizes of bubbles" in the "bubble diagrams" would indicate the "adapted profits" of the portfolios):

- Portfolio Strategic Fit vs. Portfolio Risk Bubble Diagram
- Portfolio Success vs. Portfolio Strategic Fit Bar Chart
- Change in Profit vs. Change in Value Bubble Diagram
- Change in Profit vs. Change in Value Bar Chart

Change in Value = ("Value of the Portfolio Alternative" – "Value of the Current Portfolio") / "Value of the Current Portfolio"

Change in Profit = ("Profit of the Portfolio Alternative" – "Profit of the Current Portfolio") / "Profit of the Current Portfolio"

Project level diagrams will be presented for each portfolio alternative. Diagrams presented at project level will be as follows ("sizes of bubbles" in the "bubble diagram" would indicate the "adapted profits" of the projects):

- Project Strategic Fit Score vs. Project Risk Score Bubble Diagram
- Dependency Map (further properties of the diagram would be as follows):
  - Double-click on Project nodes opens "Project Card" where "Project Symbol" is located together with the summarized information
  - Colors of the nodes indicate project status
  - Colors of the dependencies indicate different relations
  - Thickness of the dependencies indicate values of the dependencies
  - Double-click on dependencies display details of attributes and dependency values
  - Print Matrix Table button at the upper right of the table provides export of the dependencies in a matrix table format

Warnings will also be represented in the portfolio analysis results. The warnings are presented with their existence conditions and related statements as in the following table (Table 4.20).

Table 4.20: Warning Conditions and Statements

WARNINGS	
Portfolio Alternative ▪ Network Density > 0.2	"Dependency network of the projects in the portfolio is at critical level, therefore investigation of the dependencies between projects and attention to these dependencies during management of the projects are suggested."
Projects within the Portfolio Alternative ▪ Project Centrality > 0.5	Due to centrality of the @projects in the portfolio, the situation of the projects is at the level of affecting the portfolio situation.
Projects within the Portfolio Alternative ▪ Project Completion > 80%	It is suggested to take into consideration that the effect of the @projects in the portfolio can be disappeared in a short time since they have 80% or more completion percentages.
Projects within the Portfolio Alternative ▪ Profitability < 5%	The @projects in the portfolio are low profit projects, possible cost increases to be encountered in these projects may entail damage risk to the portfolio.
Projects within the Portfolio Alternative ▪ Risk Score > 70%	The @projects in the portfolio are evaluated as high risky projects, generation of risk management strategies for these projects is suggested.
Clients assigned to the Projects within the Portfolio Alternative ▪ Critical Actor	The @criticalActor assigned to the @project has been defined as critical actor @times times, evaluation of issues generated by this actor in the previous projects is suggested.

Table 4.20: Warning Conditions and Statements (continued)

WARNINGS	
Partner companies assigned to the Projects within the Portfolio Alternative ▪ Critical Actor	The @criticalActor assigned to the @project has been defined as critical actor @times times, evaluation of issues generated by this partner company in the previous projects is suggested.
Financial dependency of the Projects within the Portfolio Alternative ▪ Currency Ratio > 45%	Portfolio profit is dependent on @currency at @percentage percentage. Fluctuations in this currency would effect the portfolio seriously. Taking into consideration of this situation and making expenses in the same currency as far as possible to reduce the financial risk are suggested. **Percentage Calculation:** (total profit in one currency) / (total profit of the portfolio) * 100
Financial dependency of the Projects within the Portfolio Alternative ▪ Client > 45%	Portfolio profit is @percentage percentage financed by the Client: @employer. High dependency of the portfolio profit to this client entails financial risk. **Percentage Calculation:** (total profit by one client) / (total profit of the portfolio) * 100
Resource dependency of the Projects within the Portfolio Alternative ▪ Personnel	The same personnel @personnel has been assigned to the @projects in the portfolio, therefore revision of the work load and consideration of the possible problems are suggested.
Resource dependency of the Projects within the Portfolio Alternative ▪ Manpower	The same manpower of @manPower has been tasked with the same @projects in the portfolio, therefore revision of the work plan and consideration of the possible problems are suggested.
Resource dependency of the Projects within the Portfolio Alternative ▪ Material	The @projects in the portfolio are sharing the same critical material @material, therefore careful procurement planning of this material is suggested.
Resource dependency of the Projects within the Portfolio Alternative ▪ Machinery and Equipment	The @projects in the portfolio, are using the same machinery/equipment of @machineryEquipment, therefore doing work planning in a way to provide share of this machinery/equipment is suggested.
Learning dependency of the Projects within the Portfolio Alternative ▪ Dependency > 40% ▪ Weighted Dependency > weight*40%	There is high learning dependency between the projects @projects in the portfolio, establishment of the information transfer between these projects is suggested.
Outcome dependency of the Projects within the Portfolio Alternative	Successes of the @projects in the portfolio are dependent to each other since they include a result required for each other, consideration of this situation in management is suggested.
Portfolio Selection ▪ Change in Value < 0 for all of the portfolio alternatives	Regarding the profit-value equilibrium the most advantageous portfolio option is @portfolio. **Calculation of Advantageous Portfolio:** the portfolio alternative that has the maximum value of "Change in Profit" / │"Change in Value"│

In the “portfolio selection” option, portfolio alternatives will be sorted according to the selected criteria and the selected ordering style (ascending/descending) including following options:

- Risk based selection
- Strategic fit based selection
- Portfolio value based selection
- Profitability based selection

4.2.5.6. Library

The tool should include an editable library that will at least have sections for:

- Tool Process Summary
- Roadmap (Figure 5.6: Roadmap Flowchart)
- Glossary (Appendix H)
- Calculation Details (4.2.5: Details of the Final Model and Algorithm)

4.2.5.7. Feedback Mechanism

The tool should provide feedback for “correct”, “wrong” or “forthcoming” user actions as in the following table (Table 4.21).

Table 4.21: Feedback Mechanism

SITUATION	FEEDBACK
When wrong user information is entered:	You entered an invalid user name or password.
While actions for password change:	User name must be a valid email address. Password cannot be left empty, minimum 6 characters are required. Passwords do not match, please check.
When an information is saved:	Saved successfully.
When an information is edited:	Updated successfully.
When an information is deleted:	Deleted successfully.

Table 4.21: Feedback Mechanism (continued)

SITUATION	FEEDBACK
When coefficient constants are not normalized:	Total of coefficients must be equal to 1.
When an obligatory information is missing while saving:	“The item” cannot be left empty.
When a factor set evaluated for a project is to be deleted:	Cannot be deleted because it is linked to a project.
When the risk evaluation is outdated:	There has been no risk evaluation during past three months. Please update your evaluation.
When risk assessment is not made:	Risk assessment has not been made.
When strategic fit assessment is not made:	Strategic fit assessment has not been made.
Warnings about factor weights:	Factor weight should be within the range of [0,1]. Sum of the factor weights is not equal 1. Please control and update the factor weights.
When a completed project is saved:	Lessons learned regarding with the project are needed to be entered from Project Operations section.
When an on-going or potential project is saved:	Risk and Strategic Fit evaluation of projects are needed to be made from Project Operations section.
When the operations page for an on-going or potential project is opened:	Review of Supportive Information before Risk and Strategic Fit evaluation is suggested.
While making a lesson learned entry without selection of a project:	Please choose a project to create a lesson learned.
When a tag is to be assigned to a lesson learned, at the bottom of the tag tree:	Right click on the structure to take action...
When the portfolio analysis page is opened:	Please choose potential projects that you want them to be taken into analysis.
When more than four potential projects are to be added to analysis:	You cannot add more than four projects to analyze at once!
When the portfolio analysis results page is opened:	You can access to the details of the portfolio alternatives with Display Portfolio option.
Over the dependency map:	Double-click on the node to view the project details.

4.2.6. Summary on Process Model Development

The process summary is as follows:

1. A questionnaire was designed and answered by the company's professionals so that the above-mentioned methods can be used and the required values can be determined in order to be able to calculate the criteria.

2. The survey results were examined and the default attributes and weights required for the model were determined.
3. Numerical modeling (example) with hypothetical projects was carried out to examine the operation of the model as validation studies of the current model and related updates were provided to the model operation.
4. Projects of the numerical example were grouped by clustering analysis in the sense to test the reliability of project similarities calculated in the numerical example and to provide an alternative method for calculation. However, it was decided that the integration of the clustering method would not be appropriate and practical for the tool architecture and should only be considered as verification work.
5. The database structure was updated considering the lessons learned and predictions where PPA section and tagging method and its taxonomy are integrated to the current model. As a result of the changes made, a method for validation of the lessons learned as the study of corporate memory to be generated in another study (Eken, 2017) considering the individual potential of the corporate memory when it is distinguished from the portfolio management tool.
6. The visual characteristics of the tool was improved as a result of the numerical example process and a figure to be used in project displays was designed.
7. Finally, the conceptual model and basic functions of the tool were tested through a two-phased analysis provided by the research team and the focus group where required updates were provided.
8. As a result of the overall process the process model was validated as the basis of tool architecture and it was supported further through generation of the modules and the requirement specification while finalizing the required algorithms.

In the light of the summarized study on process model development, visual representation of the process model of the tool, which was generated using IDEF0 in terms of the current functions, can be provided in the figure below (Figure 4.10). The figure is further updated to overall process model indicating main functions of the tool as it is presented later in “Section 5.2.1: COPPMAN Framework” (Figure 5.3: Overall Process Model).

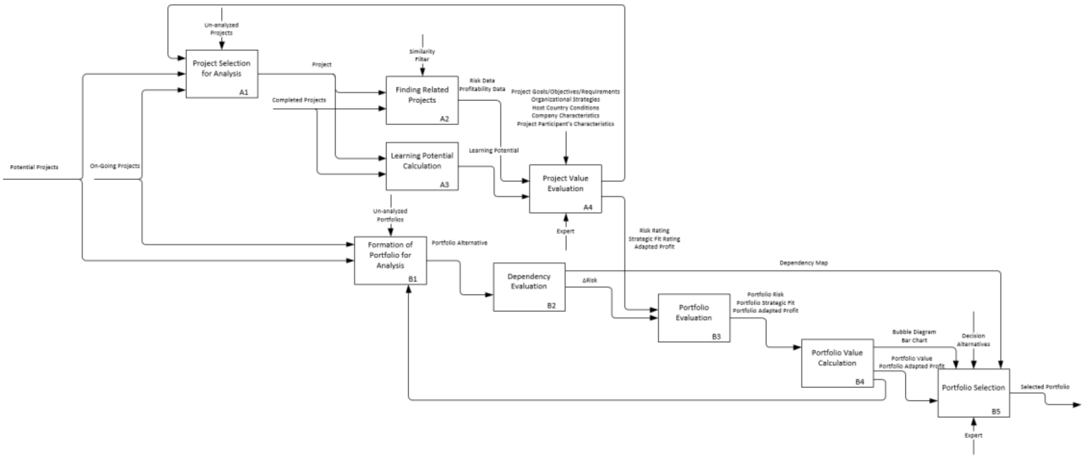


Figure 4.10: Phased Process Model (Detailed with Functions)

4.3. Tool Development Process

The structured details of the tool was presented to ten different software developer companies and the one promising expected solutions was selected for proceeding with development of the tool. The process was proceeded in delivery of the completed sections of the tool through “5 sprints” where bilateral meetings were continuously held to discuss possibilities and provide further explanations on the requirements. Commencement of the development process revealed some details that would not be easily considered through the prototypes. The options were evaluated through discussions between the developer company and the research team, while also correcting the identified failures in the generated sections of the tool. The development of the tool was continuously verified by the research team through the numerical example for the overall process and some particular tests investigating detailed features by utilizing random data. At the end of the development process where the evaluations and related updates in generation of the tool were provided throughout the process, the first completely operating version of the tool (alpha version) as representing the "feature functionality" was released for further investigation through professionals outside the research team and developer company. The following sections present the development process where evaluations and updates are provided for each evolution step.

4.3.1. The First Release (Alpha Version)

The "alpha version" of the tool was successfully released responding all the identified requirements, which were further supported with decisions made during codification of the model. This version was verified with the outcomes of the "paper prototype" as entering the same set of projects and obtaining the same results from the tool. The first release was evaluated for its "functional features" and updated in the light of the evaluation obtained through "expert panel" as presented in the following section. Then verification with paper prototype was made once again for the updated version of the tool. Therefore results of the verification testing will be presented in its final form for verification of the "updated alpha version" in "Section 4.3.4.2: Charrette Test with Paper Prototype: Numerical Example". Additionally the tool (COPPMAN) will also be presented in its updated version (beta version) in "Chapter 5: COPPMAN".

4.3.2. Evaluation of the Alpha Version: Expert Panel (Survey 5)

Expert panel provides the evaluation of the results of the while also investigating whether the approach and the results are reliable and the important concepts in the domain are covered adequately or not (Fischer, 2006). Therefore, an expert panel consisting of academicians and professionals from construction and software industry was established. The panel was consisting of four civil engineers as follows:

- Academician: Prof. Dr. in Construction Engineering and Management Division
- Academician: Asst. Prof. Dr. in Construction Engineering and Management Division
- Professional from Construction Industry: “Executive Assistant to CEO” in one of the leading construction companies in Turkey
- Professional from Software Industry: “Product Manager” in a civil engineering software firm in Turkey

Thus, the first version of the tool was evaluated from the perspective of model and the methodology undertaken, content and performance of the tool by resulting in the first update of the alpha version.

4.3.2.1. Test Process

The current version of the numerical example was provided as the base model within the body of the tool to reflect the “mental image” of the model. Access links to the tool interface and the example was provided to each expert “10 days” before the meeting and they were asked to make analysis on basic functions of the tool while navigating in the tool. In addition to access to the tool, a report introducing the tool and is development in detail was prepared and presented to the experts. In addition, the criteria to be used in evaluating the tool and content of the questionnaire were also shared. It was decided that the experts to be interviewed together in a single session in order to enable sharing of the ideas. On the day of the meeting, a presentation was made firstly and the questions of the experts were answered following the presentation. Later on, discussions with the experts were undertaken as a meeting and the evaluation questionnaire was carried out (Appendix E).

The questionnaire includes a section on "background of the expert" as indication of the conformity of the expert for the evaluation as follows:

- Title
- Education
- Experience
- Use of Company Specific Tools
- Knowledge in Information Technology
- Knowledge in Portfolio Management

The questionnaire was further designed to be in two sections as ratings for the statements provided and open ended questions as follows:

1. **Section 1 - Ratings:** This section includes ratings of the experts on the statements provided through 7-point Likert scale ranging between "strongly disagree" (1) and "strongly agree" (7) (Sauro and Dumas, 2009). Statements were adapted from the studies as successful examples of evaluation process such as, Shen and Marks (2016), Lee and Rojas (2013), and Chong et al. (2013) in addition to some other studies on usability testing (Lund, 2001; Rubin and Chisnell, 2008; Seffah et al., 2006; Yıldız, 2012; Sauro and Dumas, 2009; Chin et al., 1988). The statements are grouped under following main headings/metrics of:
    - Completeness/Coverage,
    - Suitability/Accuracy,
    - Usefulness,
    - Usability,
    - Receptiveness, and
    - Overall.
2. **Section 2 - Open-Ended Questions:** questions are provided as further probing through the questions asked for changes that could be done in the tool, as well as requesting features that the experts liked and disliked in order to get general opinions as follows:

- Please indicate your general comments about the tool. What did you like most? What did not you like most?
- Please indicate any item/property that needs to be changed in the tool or be added to the tool.

The evaluations and comments obtained as a result of the questionnaire, and the updates made in the light of them are presented below.

4.3.2.2. Evaluation and Comments

As a result of the questionnaire, the average score of the tool was obtained to be "6.045" out of "7" from all the experts, and the scores on the basis of the criteria are presented in the table below (Table 4.22):

Table 4.22: Survey Results for Expert Panel

	Completeness / Coverage	Suitability / Accuracy	Usefulness	Usability	Receptiveness	Overall	Average
Expert 1	5.64	5.75	6.00	5.67	5.80	6.14	5.833
Expert 2	6.14	6.50	7.00	6.00	6.00	6.14	6.297
Expert 3	6.36	5.92	7.00	6.44	6.80	6.14	6.443
Expert 4	5.64	5.67	5.80	5.89	5.20	5.43	5.605
Average	5.945	5.960	6.450	6.000	5.950	5.963	6.045

The evaluations of open-ended questions during the meeting and at the end of the questionnaire are as provided follows.

The Appreciated Features of the Tool:

- Since the tools available in the literature are inadequate to serve as a complete system it is a necessary tool for responding the need
- Detailed features of the tool in comparison to available tools
- Assisting the user in managing the portfolio during the purchase of new project

- Inter-project dependencies are calculated automatically in the tool so that they do not depend on the experiences and subjective evaluations of individuals
- Submission of numerical data for use in assessing risks to decision makers
- The familiarity of the tool interface, its up-to-date format, mobile compatibility and usefulness
- Tool graphics are useful and practical
- Detailed information required in the post project appraisal section
- Directing the user through the warnings
- The lessons learned management module existing in the tool can have a stand-alone value and be used as a separate tool
- Tool architecture can be applied to different sectors, such as information technology, with very small changes in its design

Inadequate Features of the Tool:

- The tool homepage should include some shortcut keys that will allow quick access to the most likely operations instead of depicting directly the current analysis.
- Since the actor field provided on the tag tree in lesson codification is mainly for categorization, the related actors should also be attached to the lessons learned from the identified "actor list" (which also includes the contact information) through lesson learned information entry in addition to assignment of the actor through tag tree. The lessons learned should be recorded including the "record time" and the "user" information. There should also addition of a system/button for approval of the lessons learned codified by different users. Authorization can be assigned to the selected users to ensure that lessons learned information can be verified. Therefore, lesson learned entries or the lesson card also includes the expression of "Approved/Not Approved" to indicate the verification status of the lesson.
- There should be a method to facilitate the search of the tags on the tag tree since it is comprehensive and difficult to manage the tags in its current version.

- The visual presentations of the tool should be presented more interactively. The usability of the graphs can be increased by providing an option to investigate the other graph while investigating the current one, or by enabling to see details of some section by double clicking on the graphs, etc. The similarity results or learning potential can be presented through the breakdown of the overall score.
- Rather than approving the existence of an outcome dependency through automatic assignment of "100%", the user should be able to define the magnitude of the outcome dependency through the [0,100%] interval.
- The limit values use for calculation of "warnings" should be adjustable by the user.

Future Work Recommendations:

- Resource management ability can be integrated with a future work.
- The preferable optimal portfolio alternative can be identified and directly presented to the user by using multi-criteria decision-making techniques or optimization methods for portfolio selection.
- The past portfolio selections of the company and the recommendations that may be obtained regarding these selections can be presented to the user.
- The tool can be adapted to different sectors (e.g., software) through the changes to be made in the tool architecture.

4.3.3. Update for the Alpha Version

As a result of the meeting, the following changes were made to the tool and the tool was updated by the software company through an additional development process:

- The homepage was designed to include four main section for the options of "adding project", "project operations", "portfolio analysis" and "library".

- Limit values on which the warnings are based on are provided to be changeable by the user.
- A button was created for the approval of the lesson learned information and the lessons can be displayed on the basis of their “approved / non-approved” statuses.
- The information of the user who has entered the lesson information and the date of entry of the lesson were provided to be recorded and presented together with the lesson information. It was also made possible to search for lessons learned based on dates of entries.
- The related actor was provided to be selectable through the identified actors while entering the lesson learned information and the lessons can be retrieved through search on the actor basis.
- The ability to search for lesson learned information was improved through further filtering on “best practice”, “financial impact” and “duration effect”.
- The breakdown of attribute-based similarities of an overall similarity score was also provided next to obtained lessons as a result of similarity-based search for the lessons learned.
- Searching mechanism through “free-text search” on the tag tree was provided for selection of tags in the assignment process where the tags including the searched text are filtered and listed in a simplified form (eliminated from unrelated tags) in their current hierarchy on the tag tree in “italic format” and “red font color”.
- The display option of the learning potential was improved through provision of the breakdown of the attributes and their contribution values that are adding up the total learning potential score.
- The display option of the similarity scores of the similar projects was improved through provision of the breakdown of the attributes and their contribution values that are adding up the total similarity score.
- Interactivity of the portfolio bubble graphs was increased by the ability of opening the details of the related portfolio alternative when the bubble representing the portfolio is double-clicked.

- Simplified form of the portfolio change bar chart was provided as the chart indicating the change in unit value through the button of “Changes in Unit Value” on the top right corner of the diagram.
- Access to the most complicated dependency network of the current analysis was provided through a button (“Most Crowded Network” button) located at the top right corner of the dependency maps of each portfolio alternative obtained through the analysis, so that the most intensive network map in the current analysis can be reviewed any time while investigating the other alternatives.

4.3.4. Verification of the Tool

Verification studies of the tool were contemporaneously held with the development process as long as the new properties are added to the tool. The main consideration was evaluations through some black-box testing where random checks are made for investigation of different properties and comparison of the overall process with the numerical example as “paper prototype”. The following sections presents the details with verification of the tool.

4.3.4.1. Black-Box Testing

In addition to checking the tool performance through numerical example, some black box testing methods were also used during evaluation as follows:

Requirements Testing: testing of which requirements are met in consideration of their priorities as H: “High”, M: “Medium”, and L: “Low” (all the requirements are met in the final design of the tool) (Table 4.23).

Table 4.23: Requirements Testing

Requirement No	Description	Priority (H/M/L)
R1	Identification of different users in tool with different accessibility options to the tool menu/operations is an important feature	M
R2	Menu for entry of different types of projects, together with view and query options is an important feature	M
R3	Identification of ready-to-use project inputs is an important feature	L
R4	Calculation and presentation of predictions for the on-going and potential projects through use of information of completed projects is an important feature	H
R5	Menu for entry of lessons learned, together with view and query options is an important feature	H
R6	Tagging system for entry of lessons learned, including editing options for the tag tree and tag-based query is an important feature	H
R7	Calculation and presentation of learning potentials for the on-going and potential projects is an important feature	L
R8	Establishment of project similarity based search and calculation capabilities is an important feature	H
R9	Establishment of filtering based search and calculation capabilities is an important feature	M
R10	Menu for evaluation of risk and strategic fit factors, including editing of the factors and calculation of scores is an important feature	H
R11	Calculation of dependencies between projects and visualization of dependencies with a dependency map is an important feature	H
R12	Development of a project representation to be used in visualizations is an important feature	L
R13	Automatic formation of the portfolio alternatives through addition of potential project combinations to on-going projects is an important feature	M
R14	Calculation of portfolio attributes and depiction of results through tables, bubble diagrams and bar charts is an important feature	M
R15	Establishment of an automatic warning system for current portfolios is an important feature	M

Positive and Negative Testing: as random checks of both cases (Table 4.24).

Table 4.24: Positive and Negative Testing Examples

Requirement	Input 1	Input 2	Current State	Expected Output
Calculation of adapted profit	No country matching	No client matching	Profit: Expected Profit	Displayed Profit: Expected Profit
Calculation of adapted profit	Country matching	No client matching	Profit: Expected Profit	Displayed Profit: Adapted Profit
Entry of factor weights	Total more than 1	-	-	Do not save factors
Entry of factor weights	Total equals to 1	-	-	Save factors

Decision Table: as conditional checking of different properties (Table 4.25).

Table 4.25: Decision Table Examples

Criteria	Condition 1	Result
Network Density	Over 0.2	Suggestion appears
Project Centrality	Over 0.5	Suggestion appears
Project Completion	Over 0.80	Suggestion appears

Compatibility Testing: as successful performance on different web server clients (Table 4.26).

Table 4.26: Compatibility Testing Examples

Server	Web Server	Client
Windows 10	IIS7.0	Mozilla Firefox (37.0)
Windows 10	IIS7.0	Google Chrome (42.0)
Windows 10	IIS7.0	Opera (29.0)
Windows 10	IIS7.0	Internet Explorer (11)

Performance Testing: as successful access to the tool by different users contemporaneously (Table 4.27).

Table 4.27: Performance Testing Examples

Activity	Number of users	Test Environment
Concurrent use	10	Chrome
Concurrent use	10	Internet Explorer

Black-box testing methods were held according to the special requirements for evaluation of the current versions of the tool.

4.3.4.2. Charrette Test with Paper Prototype: Numerical Example

The numerical example was used for testing the operation of the tool as in a "charrette test" where the outputs of a specific solution is compared with the "gold standard" serving for the same purpose. This section presents the latest version of the numerical example where the "updated alpha version", which is to be transformed to the "beta version” through minor changes in the up-coming sections of the study, is tested against the paper prototype (i.e., “the gold standard”). With the numerical case study presented, the operation of the tool was controlled through the predefined inputs and the expected output of these inputs. The calculation procedures of the tool were carried out on excel in a controlled manner and as a result of the comparison the functions of the tool were appreciated to be working as expected, which also constitutes the testing of codification of the tool.

The details of the numerical example are presented below, along with the information entered and the expected results to be obtained both through the example and also tool (as presented in the screenshots). At the end of the process, it was seen that the results obtained from the hypothetical data case study and the results of the tool were the same, and it was confirmed that “the tool works as expected”. In this context, the study details of the case study and related outputs of the tool are presented below under the main sections of “data entry”, “calculations”, “search options” and “portfolio analysis”.

4.3.4.2.1. Data Entry

General Project Information: Information of “25 projects” are entered as provided below where information is marked “blue” for “completed projects”, “green” for “on-going projects”, and “yellow” for “potential projects” (Table 4.28 and Table 4.29).

Table 4.28: General Project Information (1)

Project No	Project Status	Project Name	Project Type	Project Scope	Client
P1	Completed	High-Rise Office Building	Building	Construction of a 36-storey office building	Atez Group
P2	Completed	High-Rise Residential Building	Building	Construction of 6 blocks of 30 story buildings	Vegas Group
P3	Completed	Shopping Mall	Building	Construction of 4 story shopping mall at a size of 500x100m with 50m gallery openings	Vegas Group
P4	Completed	Shopping Mall	Building	Construction of a 3 story shopping mall	Zeta Group
P5	Completed	Shopping Mall	Building	Construction of 5 story shopping mall with 60m gallery openings	Vegas Group
P6	Completed	Highway	Road	Construction of 15 km concrete road	Ministry of Transportation (Azerbaijan)
P7	Completed	Library	Building	Construction of 3 story library including a cafeteria unit	Baku TRC College
P8	Completed	School	Building	Construction of a 5 story 4 school buildings including sports building and open sport-field	Nata Group
P9	Completed	Tunnel	Tunnel	Construction of 4 km long tunnel	Ministry of Transportation (Turkey)
P10	Completed	Tunnel	Tunnel	Construction of 5 km long tunnel	Ministry of Transportation (Azerbaijan)
P11	Completed	Highway	Road	Construction of 60 km asphalt road	Ministry of Transportation (Russia)
P12	Completed	Natural Gas Pipeline	Pipeline	Construction of 50 km natural gas pipeline	Ministry of Energy and Natural Resources (Turkey)
P13	Completed	Hospital	Building	Construction of 10 story hospital building with 3 blocks	Live Group
P14	Completed	High-Rise Office Building	Building	Construction of a 30-story office building with 2 blocks	Metropolitan Group
P15	Completed	High-Rise Office Building	Building	Construction of a 40-story office building	Ramada Group
P16	Completed	Viaduct	Bridge	Construction of 60 m high and 1 km long viaduct	Ministry of Transportation (Turkey)
P17	Completed	Viaduct	Bridge	Construction of 150 m high and 500 m long viaduct	Ministry of Transportation (Azerbaijan)
P18	Completed	Viaduct	Bridge	Construction of 80 m high and 1 km long viaduct	Ministry of Transportation (Turkey)
P19	Completed	Hotel	Building	Construction of a seaside hotel with aqua park	Petro Group
P20	Completed	Hotel	Building	Construction of a 5-star hotel with outdoor sports facilities	Ramada Group
P21	On-going	Highway	Road	Construction of 20 km concrete road	Ministry of Transportation (Greece)
P22	On-going	High-Rise Residential Building	Building	Construction of a 20-story residential building with 5 blocks	Vegas Group
P23	On-going	Thermal Power Plant	Power Plant	Construction of 200 MW capacity thermal plant	Ministry of Energy and Natural Resources (Turkey)
P24	Potential	Shopping Mall	Building	Construction of a 5 story shopping mall	Vegas Group
P25	Potential	Viaduct	Bridge	Construction of 100 m high and 900 m long viaduct	Ministry of Transportation (Turkey)

Table 4.29: General Project Information (2)

Project No	Country	Project Delivery System	Contract Type	Contract Payment Type	Currency	Start Date	End Date
P1	Bulgaria	Design-Bid-Build	FIDIC	Lump-Sum	Euro	2010	2012
P2	Russia	Design-Bid-Build	FIDIC	Unit-Price	US Dollar	2009	2012
P3	Russia	Design-Build	FIDIC	Unit-Price	US Dollar	2012	2014
P4	Bulgaria	Design-Bid-Build		Lump-Sum	Euro	2008	2009
P5	Russia	Design-Bid-Build		Lump-Sum	Euro	2010	2012
P6	Azerbaijan	Build-Operate-Transfer	Joint Contracts Tribunal	Unit-Price	US Dollar	2008	2009
P7	Azerbaijan	Design-Bid-Build	Joint Contracts Tribunal	Lump-Sum	US Dollar	2003	2003
P8	Kazakhstan	Design-Bid-Build		Lump-Sum	US Dollar	2005	2006
P9	Turkey	Design-Build	Public Procurement Law	Unit-Price	Turkish Lira	2009	2010
P10	Azerbaijan	Design-Build		Unit-Price	Euro	2006	2008
P11	Russia	Design-Build		Unit-Price	Euro	2002	2003
P12	Turkey	Design-Build	Public Procurement Law	Unit-Price	Turkish Lira	2008	2010
P13	Kazakhstan	Design-Build		Lump-Sum	US Dollar	2006	2007
P14	Russia	Design-Bid-Build	FIDIC	Unit-Price	US Dollar	2011	2013
P15	Turkey	Design-Bid-Build		Lump-Sum	Turkish Lira	2008	2010
P16	Turkey	Build-Operate-Transfer	Public Procurement Law	Unit-Price	Turkish Lira	2013	2014
P17	Azerbaijan	Design-Build		Lump-Sum	US Dollar	2006	2008
P18	Turkey	Build-Operate-Transfer	Public Procurement Law	Lump-Sum	Turkish Lira	2012	2013
P19	Russia	Design-Build	FIDIC	Unit-Price	US Dollar	2002	2004
P20	Turkey	Design-Bid-Build		Unit-Price	Turkish Lira	2005	2007
P21	Greece	Build-Operate-Transfer		Unit-Price	US Dollar	2015	2017
P22	Russia	Design-Bid-Build	FIDIC	Lump-Sum	US Dollar	2014	2017
P23	Turkey	Design-Build	Public Procurement Law	Unit Price	Turkish Lira	2016	2020
P24	Russia	Design-Build	FIDIC	Unit-Price	US Dollar	2016	2018
P25	Turkey	Design-Build	Public Procurement Law	Unit-Price	Turkish Lira	2016	2019

Critical Resource and Partner Company Information: Critical resource information was entered with the "resource type" and "resource location" information where partnership information was entered with the "partnership type" as follows (Table 4.30).

Table 4.30: Critical Resource and Partner Company Information

Project No	Resource Type	Resource Name	Partnership Type	Partner Company
P1	Material	Curtain Wall (window film)	Consortium	Kasktas A.S.
	Machinery and Equipment	Tower Crane	Consortium	Metros Construction
P2	Machinery and Equipment	Tower Crane	Joint Venture	Metros Construction
P3	Material	Marble		
	Machinery and Equipment	Tower Crane		
P4	Material	Marble		
P5	Material	Precast Concrete Elements		
P6	Machinery and Equipment	Concrete Plant		
P7	Material	Precast Concrete Elements		
	Material	Marble		
P8	Material	Window Door Framing		
P9	Machinery and Equipment	Tunnel Boring Machine	Joint Venture	Astaldi
P10	Machinery and Equipment	Tunnel Boring Machine	Joint Venture	Astaldi
P11	Machinery and Equipment	Excavator		
P12	Machinery and Equipment	Excavator	Consortium	Borusan
P13	Material	Marble	Joint Venture	Leighton Construction
P14	Material	Curtain Wall (window film)	Joint Venture	Metros Construction
	Machinery and Equipment	Tower Crane		
P15	Material	Curtain Wall (window film)	Consortium	Kasktas A.S.
	Machinery and Equipment	Tower Crane		
P16	Material	Post-tension Concrete Elements	Consortium	Kasktas A.S.
	Machinery and Equipment	Formwork System		
P17	Machinery and Equipment	Formwork System		
P18	Material	Post-tension Concrete Elements	Consortium	Kasktas A.S.
	Machinery and Equipment	Formwork System		
P19	Material	Marble		
P20	Material	Curtain Wall (window film)		
P21	Personnel	Planner (Dep1)		
P22	Material	Curtain Wall (window film) (Russia)	Consortium	Kasktas A.S.
	Machinery and Equipment	Formwork System (Russia)		
P23	Personnel	Planner (Dep1)	Joint Venture	Kolin Construction
	Personnel	Mechanical Designer (Dep3)		
P24	Material	Curtain Wall (window film) (Russia)	Consortium	Kasktas A.S.
	Machinery and Equipment	Formwork System (Russia)		
	Personnel	Mechanical Designer (Dep3)		
P25	Material	Bridgestone Seismic Isolator (Japan)	Consortium	Sendai Construction
	Machinery and Equipment	Formwork System (Russia)		

Duration, Financial, Outcome Dependency and Technology Information: Project duration information was entered as “planned” and “completion percentages”. In addition, the entered “contract price”, “expected cost”, “outcome dependency” and necessary “construction technology” information were entered as shown in the table below (Table 4.31).

Table 4.31: Duration, Financial, Outcome Dependency and Technology Information

Project No	Planned Project Duration	Completion Percentage	Contract Price	Expected Cost	Outcome Dependency	Construction Technology
P1	560	100%	€ 106,000,000	€ 95,000,000		Self-Climbing Formwork
P2	840	100%	$95,000,000	$85,000,000		Self-Climbing Formwork
P3	720	100%	$85,000,000	$79,000,000		Pre-stressed Concrete
P4	450	100%	€ 80,000,000	€ 72,000,000		
P5	740	100%	€ 90,000,000	€ 80,000,000		Precast Concrete
P6	450	100%	$45,000,000	$39,000,000		Concrete Road
P7	300	100%	$20,000,000	$17,000,000		Precast Concrete
P8	430	100%	$50,000,000	$45,000,000		
P9	400	100%	40,000,000 TL	34,000,000 TL		Tunnel Boring Machine
P10	600	100%	€ 40,000,000	€ 35,000,000		Tunnel Boring Machine
P11	500	100%	€ 50,000,000	€ 42,000,000		
P12	750	100%	120,000,000 TL	105,000,000 TL		
P13	450	100%	$90,000,000	$80,000,000		
P14	560	100%	$80,000,000	$72,000,000		Tunnel Formwork
P15	860	100%	80,000,000 TL	70,000,000 TL		
P16	400	100%	100,000,000 TL	85,000,000 TL		Post-tension Concrete
P17	700	100%	$100,000,000	$85,000,000		
P18	500	100%	100,000,000 TL	85,000,000 TL		Post-tension Concrete Self-Climbing Formwork
P19	650	100%	$90,000,000	$80,000,000		
P20	460	100%	75,000,000 TL	70,000,000 TL		Tunnel Formwork
P21	730	60%	$60,000,000	$51,000,000		Concrete Road
P22	1095	40%	$65,000,000	$53,000,000	P24	Tunnel Formwork Seismic Base Isolator
P23	1460	6%	130,000,000 TL	118,000,000 TL		Pre-stressed Concrete
P24	730	0%	$75,000,000	$67,000,000	P22	Pre-stressed Concrete
P25	1095	0%	110,000,000 TL	90,000,000 TL		Seismic Base Isolator

Post Project Appraisal Information: The completed project information was entered as shown in the following tables, including the “actual duration”, “time extension”, “delay duration”, “actual cost”, “change in contract price”, “delay cost”, “claimed/awarded duration/payment”, and the critical information as “critical delay cause”, “critical actor” and “critical work package” information (Table 4.32 - Table 4.34).

Table 4.32: Post Project Appraisal Information (1)

Project No	Actual Project Duration	Extension of Time	Delay	Actual Cost	Change in Contract Price
P1	595	25	35	€ 96,100,000	€ 1,000,000
P2	900	30	60	$89,100,000	$3,000,000
P3	830	0	110	$82,000,000	$0
P4	525	60	75	€ 73,040,000	€ 800,000
P5	760	20	20	€ 80,500,000	€ 0
P6	472	22	22	$39,120,000	$60,000
P7	330	10	30	$16,540,000	$10,000
P8	465	15	35	$45,250,000	$100,000
P9	430	0	30	35,400,000 TL	0 TL
P10	620	0	20	€ 35,500,000	€ 0
P11	530	10	30	€ 42,250,000	€ 100,000
P12	800	50	50	105,900,000 TL	400,000 TL
P13	515	35	65	$80,950,000	$200,000
P14	590	0	30	$72,300,000	$0
P15	875	15	15	71,200,000 TL	0 TL
P16	420	10	20	86,400,000 TL	0 TL
P17	720	20	20	$85,950,000	$0
P18	530	0	30	86,500,000 TL	0 TL
P19	685	35	35	$80,550,000	$250,000
P20	470	10	10	71,300,000 TL	0 TL

Table 4.33: Post Project Appraisal Information (2)

Project No	Delay Cost	Delay Penalty	Early Completion Incentive	Claimed Duration	Duration Awarded	Claimed Payment	Payment Awarded
P1	€ 1,050,000	-	-	25	25	€ 1,000,000	€ 1,000,000
P2	$3,600,000	-	-	30	30	$3,000,000	$3,000,000
P3	$3,000,000	-	-	50	50	-	-
P4	€ 1,000,000	-	-	75	60	€ 1,000,000	€ 800,000
P5	€ 500,000	-	-	20	20	-	-
P6	$100,000	-	-	22	22	$40,000	$40,000
P7	$40,000	-	-	10	10	$10,000	$10,000
P8	$250,000	-	-	15	15	$100,000	$100,000
P9	600,000 TL	-	-	-	-	-	-
P10	€ 500,000	-	-	-	-	-	-
P11	€ 250,000	-	-	10	10	€ 100,000	€ 100,000
P12	900,000 TL	-	-	50	50	400,000 TL	400,000 TL
P13	$950,000	-	-	45	35	$200,000	$200,000
P14	$300,000	-	-	-	-	-	-
P15	600,000 TL	-	-	15	15	-	-
P16	1,400,000 TL	-	-	10	10	-	-
P17	$950,000	-	-	20	20	-	-
P18	1,000,000 TL	-	-	-	-	-	-
P19	$550,000	-	-	35	35	$250,000	$250,000
P20	500,000 TL	-	-	10	10	-	-

Table 4.34: Post Project Appraisal Information (3)

Project No	Critical Delay Cause	Critical Actor	Critical Work Package
P1	Delay in payments for material, Unavailability of qualified labor	Atez Group, Subcontractor - Prozone Construction	Facade, Ceramic Tiling
P2	Scope change, Unavailability of qualified labor	Vegas Group, GBG Construction	Interior Wall, Fire System Installation
P3	Unforeseen ground conditions, Late material delivery	GBG Construction, Supplier - Ceramateria	Foundation, Floor Covering
P4	Delay in payments for material, Deficiency in design	Zeta Group, Designer - CentralHVAC Design	Floor Covering, Mechanical Installation
P5	Adverse weather conditions	GBG Construction	Foundation
P6	Failure to give access to site, Unforeseen ground conditions	Ministry of Transportation (Azerbaijan), GBG Construction	Mobilization, Excavation
P7	Failure to give access to site, Late material delivery	Baku TRC College, Supplier - Marbaku	Mobilization, Floor Covering
P8	Delay in payments for material, Unavailability of qualified labor	Nata Group, Subcontractor - Windoor Construction	Interior Wall, Window Door Framing
P9	Unavailability of machinery - broken TBM machine due to unavailability of spare part	GBG Construction	Boring
P10	Unavailability of machinery - late delivery of TBM machine	GBG Construction	Boring
P11	Failure to give access to site, Unavailability of machinery - excavators	Ministry of Transportation (Russia), GBG Construction	Mobilization, Excavation
P12	Unforeseen ground conditions, Failure to give access to site	GBG Construction, Ministry of Energy and Natural Resources (Turkey)	Excavation, Excavation
P13	Delay in payments for material, Unavailability of qualified labor, Adverse weather conditions	Zeta Group, GBG Construction, GBG Construction	Floor Covering, Mechanical Installation, Facade
P14	Adverse weather conditions, Poor scheduling - omission of natural holidays	GBG Construction, GBG Construction	Structural Framing, Facade
P15	Unforeseen ground conditions	GBG Construction	Foundation
P16	Unforeseen ground conditions, Unavailability of qualified labor	GBG Construction, GBG Construction	Excavation, Installation of Post-Tension Elements
P17	Unforeseen ground conditions	GBG Construction	Excavation
P18	Unavailability of material	Supplier - PrePostConcrete	Structural Framing
P19	Delay in payments for material, Adverse weather conditions	Petro Group, GBG Construction	Ceramic Tiling, Structural Framing
P20	Unforeseen ground conditions	GBG Construction	Foundation

Lessons Learned Information: The lessons learned information was entered into the related projects without a story, and randomly searched tags, critical actors and impact ratings were assigned. Details of these hypothetical lessons are not shared under numerical example, since the “corporate memory” will be separately tested (Section 4.3.5: Validation of Corporate Memory).

4.3.4.2.2. Calculations

Financial Calculations: Estimates are presented to the user for on-going and new projects based on the data of past projects captured through the PPA section. Within this context, firstly calculations were made on how the expected profit of the project would be changed. In Table 4.35, the "deviation" and "profitability" values are calculated from the "expected profit" and "actual profit" information entered for the completed projects. The following formulae were used for calculation of profitability of the completed projects and the profit deviations.

- Profitability (Completed Project) = ("Actual Profit" / "Actual Cost") * 100
- Profit Deviation = [("Actual Profit" - "Expected Profit") / ("Expected Profit")] * 100

The "adapted profit" and "average deviation in profit" estimation values for on-going and potential projects given in Table 4.36 were calculated as the result of using the calculated values for the completed projects in Table 4.35 in the estimation for the. The following formulae were used for calculating these values:

- Adapted Profit = ("Expected Profit") * (1+ "Average Profit Deviation")
    - Average Profit Deviation: For the project under review, "Country" and "Project Type" will be filtered through "Completed Projects" and the filtered projects will be used in the calculation.
    - If the project cannot be achieved as a result of the filtering, the "Adapted Profit" value will be equal to the "Expected Profit" value.
    - Profit Deviation = [("Actual Profit" - "Expected Profit") / ("Expected Profit")] * 100

Table 4.35: Financial Calculations (1)

Project No	Exchange Rate	Expected Profit (Contractual Currency)	Expected Profit (TL Equivalent)	Actual Profit (Contractual Currency)	Profit Deviation	Profitability
P1	3.522	11,000,000.00	38,742,000.00	10,900,000.00	-0.91%	11.34%
P2	2.9	10,000,000.00	29,000,000.00	8,900,000.00	-11.00%	9.99%
P3	2.9	6,000,000.00	17,400,000.00	3,000,000.00	-50.00%	3.66%
P4	3.522	8,000,000.00	28,176,000.00	7,760,000.00	-3.00%	10.62%
P5	3.522	10,000,000.00	35,220,000.00	9,500,000.00	-5.00%	11.80%
P6	2.9	6,000,000.00	17,400,000.00	5,940,000.00	-1.00%	15.18%
P7	2.9	3,000,000.00	8,700,000.00	3,470,000.00	15.67%	20.98%
P8	2.9	5,000,000.00	14,500,000.00	4,850,000.00	-3.00%	10.72%
P9	1	6,000,000.00	6,000,000.00	4,600,000.00	-23.33%	12.99%
P10	3.522	5,000,000.00	17,610,000.00	4,500,000.00	-10.00%	12.68%
P11	3.522	8,000,000.00	28,176,000.00	7,850,000.00	-1.88%	18.58%
P12	1	15,000,000.00	15,000,000.00	14,500,000.00	-3.33%	13.69%
P13	2.9	10,000,000.00	29,000,000.00	9,250,000.00	-7.50%	11.43%
P14	2.9	8,000,000.00	23,200,000.00	7,700,000.00	-3.75%	10.65%
P15	1	10,000,000.00	10,000,000.00	8,800,000.00	-12.00%	12.36%
P16	1	15,000,000.00	15,000,000.00	13,600,000.00	-9.33%	15.74%
P17	2.9	15,000,000.00	43,500,000.00	14,050,000.00	-6.33%	16.35%
P18	1	15,000,000.00	15,000,000.00	13,500,000.00	-10.00%	15.61%
P19	2.9	10,000,000.00	29,000,000.00	9,700,000.00	-3.00%	12.04%
P20	1	5,000,000.00	5,000,000.00	3,700,000.00	-26.00%	5.19%
P21	2.9	9,000,000.00	26,100,000.00			
P22	2.9	12,000,000.00	34,800,000.00			
P23	1	12,000,000.00	12,000,000.00			
P24	2.9	8,000,000.00	23,200,000.00			
P25	1	20,000,000.00	20,000,000.00			

Profitability calculations for on-going and potential projects were made through the formula:

- Profitability (On-going / Potential Project) = ("Adapted Profit" / "Expected Cost") * 100

Table 4.36: Financial Calculations (2)

Project No	Average Deviation in Profit	Adapted Profit (Contractual Currency)	Adapted Profit (TL Equivalent)	Profitability
P21	-	9,000,000.00	26,100,000.00	17.65%
P22	-14.55%	10,254,000.00	29,736,600.00	19.35%
P23	-	12,000,000.00	12,000,000.00	10.17%
P24	-14.55%	6,836,000.00	19,824,400.00	10.20%
P25	-9.67%	18,066,666.67	18,066,666.67	20.07%

The profitability calculations of the generated portfolio alternatives were made by using the data obtained in Table 4.36 for on-going and potential projects and are presented in Table 4.37. The following formulae were used for calculation of “changes in profit” while collecting the related profit values of the projects in the portfolio.

- Change in Profit = ("Portfolio Alternative Profit" - "Current Portfolio Profit") / "Current Portfolio Profit"
- Change in Adapted Profit = ("Adapted Portfolio Alternative Profit" - "Adapted Existing Portfolio Profit") / "Adapted Existing Portfolio Profit"

Table 4.37: Financial Calculations (3)

	Portfolio Projects	Portfolio Profit	Adapted Portfolio Profit	Change in Profit (According to the Current Portfolio)	Change in Adapted Profit (According to the Current Portfolio)
Alternative 1	P-21-22-23	72,900,000.00	67,836,600.00	0.00%	0.00%
Alternative 2	P-21-22-23-24	96,100,000.00	87,661,000.00	31.82%	29.22%
Alternative 3	P-21-22-23-25	92,900,000.00	85,903,266.67	27.43%	26.63%
Alternative 4	P-21-22-23-24-25	116,100,000.00	105,727,666.67	59.26%	55.86%

Delay and Claim Calculations: Delay and claim percentages were calculated for each completed project based on the delay and claim information entered for the completed projects. This information is presented in Table 4.38 and the calculation formulae are given below.

- Delay Time = (Delay Time) / (Actual Time) * 100

- Delay Cost = (Delay Cost) / (Actual Cost) * 100
- Claim Success (Duration) = (Awarded Duration) / (Claimed Duration) * 100
- Claim Success (Cost) = (Awarded Cost) / (Claimed Cost) * 100

Table 4.38: Delay and Claim Calculations

Project No	Delay Duration Percentage	Delay Cost Percentage	Claim Success (Duration)	Claim Success (Cost)
P1	5.88%	1.09%	100.00%	100.00%
P2	6.67%	4.04%	100.00%	100.00%
P3	13.25%	3.66%	100.00%	
P4	14.29%	1.37%	80.00%	80.00%
P5	2.63%	0.62%	100.00%	
P6	4.66%	0.26%	100.00%	100.00%
P7	9.09%	0.24%	100.00%	100.00%
P8	7.53%	0.55%	100.00%	100.00%
P9	6.98%	1.69%		
P10	3.23%	1.41%		
P11	5.66%	0.59%	100.00%	100.00%
P12	6.25%	0.85%	100.00%	100.00%
P13	12.62%	1.17%	77.78%	100.00%
P14	5.08%	0.41%		
P15	1.71%	0.84%	100.00%	
P16	4.76%	1.62%	100.00%	
P17	2.78%	1.11%	100.00%	
P18	5.66%	1.16%		
P19	5.11%	0.68%	100.00%	100.00%
P20	2.13%	0.70%	100.00%	

Similarity Search: Scores and weights obtained according to the survey responses for project attributes used in similarity measurement are as presented in the table below (Table 4.39).

Table 4.39: Weights used in Similarity Calculation

Attributes used to Measure Similarity	Points	Weight
Same/Similar Country	4.18	0.209
Same/Similar Project Type	4.42	0.221
Same/Similar Client	3.90	0.195
Same Construction Technology	3.89	0.195
Same Contract Type	3.58	0.179

The attributes used to calculate similarities are shown in the table below (Table 4.40).

Table 4.40: Attributes used in Similarity Calculation

Project No	Country	Project Type	Client	Technology	Contract Type	Project Delivery System	Partner Company
P1	Bulgaria	Building	Atez Group	Self-Climbing Formwork	FIDIC	Design-Bid-Build	Kasktas A.S. Metros Construction
P2	Russia	Building	Vegas Group	Self-Climbing Formwork	FIDIC	Design-Bid-Build	Metros Construction
P3	Russia	Building	Vegas Group	Pre-stressed Concrete	FIDIC	Design-Build	
P4	Bulgaria	Building	Zeta Group			Design-Bid-Build	
P5	Russia	Building	Vegas Group	Precast Concrete		Design-Bid-Build	
P6	Azerbaijan	Road	Ministry of Transportation (Azerbaijan)	Concrete Road	Joint Contracts Tribunal	Build-Operate-Transfer	
P7	Azerbaijan	Building	Baku TRC College	Precast Concrete	Joint Contracts Tribunal	Design-Bid-Build	
P8	Kazakhstan	Building	Nata Group			Design-Bid-Build	
P9	Turkey	Tunnel	Ministry of Transportation (Turkey)	Tunnel Boring Machine	Public Procurement Law	Design-Build	Astaldi
P10	Azerbaijan	Tunnel	Ministry of Transportation (Azerbaijan)	Tunnel Boring Machine		Design-Build	Astaldi
P11	Russia	Road	Ministry of Transportation (Russia)			Design-Build	
P12	Turkey	Pipeline	Ministry of Energy and Natural Resources (Turkey)		Public Procurement Law	Design-Build	Borusan
P13	Kazakhstan	Building	Live Group			Design-Build	Leighton Construction
P14	Russia	Building	Metropolitan Group	Tunnel Formwork	FIDIC	Design-Bid-Build	Metros Construction
P15	Turkey	Building	Ramada Group			Design-Bid-Build	Kasktas A.S.
P16	Turkey	Bridge	Ministry of Transportation (Turkey)	Post-tension Concrete	Public Procurement Law	Build-Operate-Transfer	Kasktas A.S.
P17	Azerbaijan	Bridge	Ministry of Transportation (Azerbaijan)			Design-Build	
P18	Turkey	Bridge	Ministry of Transportation (Turkey)	Post-tension Concrete Self-Climbing Formwork	Public Procurement Law	Build-Operate-Transfer	Kasktas A.S.
P19	Russia	Building	Petro Group		FIDIC	Design-Build	
P20	Turkey	Building	Ramada Group	Tunnel Formwork		Design-Bid-Build	
P21	Greece	Road	Ministry of Transportation (Greece)	Concrete Road		Build-Operate-Transfer	
P22	Russia	Building	Vegas Group	Tunnel Formwork Seismic Base Isolator	FIDIC	Design-Bid-Build	Kasktas A.S. Borusan

Table 4.40: Attributes used in Similarity Calculation (continued)

Project No	Country	Project Type	Client	Technology	Contract Type	Project Delivery System	Partner Company
P23	Turkey	Power Plant	Ministry of Energy and Natural Resources (Turkey)	Pre-stressed Concrete	Public Procurement Law	Design-Build	Kolin Construction
P24	Russia	Building	Vegas Group	Pre-stressed Concrete	FIDIC	Design-Build	Kasktas A.S.
P25	Turkey	Bridge	Ministry of Transportation (Turkey)	Seismic Base Isolator	Public Procurement Law	Design-Build	Sendai Construction

Identification of similar attributes: Similar attributes entered for "Project 24": Similar attributes for "country", "project type", and "client" were assigned as follows:

- Country "Russia": similar country "Kazakhstan" similarity degree "0.50"
- Project Type "Building": no similar project type is defined
- Client "Vegas Group": similar client "Metropolitan Group" similarity degree "0.80", similar client "Petro Group" similarity degree "0.70", similar client "Ramada Group" similarity degree "0.50"

The search for similarity was made as follows in the tool.

Project similarities were obtained as matching ratings of the following project attributes and the project similarities were obtained as follows (Table 4.41):

Table 4.41: Similar Projects

		Project No	Country	Project Type	Client	Technology	Contract Type
Similarity		Projects	0.209	0.221	0.195	0.195	0.179
P24	**100.00%**	P3	100.00%	100.00%	100.00%	100.00%	100.00%
	80.52%	P2	100.00%	100.00%	100.00%	0.00%	100.00%
	76.61%	P14	100.00%	100.00%	80.00%	0.00%	100.00%
	74.66%	P19	100.00%	100.00%	70.00%	0.00%	100.00%
	62.59%	P5	100.00%	100.00%	100.00%	0.00%	0.00%
	40.06%	P1	0.00%	100.00%	0.00%	0.00%	100.00%
	32.60%	P8	50.00%	100.00%	0.00%	0.00%	0.00%
	32.60%	P13	50.00%	100.00%	0.00%	0.00%	0.00%
	31.90%	P15	0.00%	100.00%	50.00%	0.00%	0.00%
	31.90%	P20	0.00%	100.00%	50.00%	0.00%	0.00%
	22.13%	P4	0.00%	100.00%	0.00%	0.00%	0.00%
	22.13%	P7	0.00%	100.00%	0.00%	0.00%	0.00%
	20.93%	P11	100.00%	0.00%	0.00%	0.00%	0.00%
	0.00%	P6	0.00%	0.00%	0.00%	0.00%	0.00%
	0.00%	P9	0.00%	0.00%	0.00%	0.00%	0.00%

Table 4.41: Similar Projects (continued)

Similarity		Project No / Projects	Country 0.209	Project Type 0.221	Client 0.195	Technology 0.195	Contract Type 0.179
P24	**0.00%**	P10	0.00%	0.00%	0.00%	0.00%	0.00%
	0.00%	P12	0.00%	0.00%	0.00%	0.00%	0.00%
	0.00%	P16	0.00%	0.00%	0.00%	0.00%	0.00%
	0.00%	P17	0.00%	0.00%	0.00%	0.00%	0.00%
	0.00%	P18	0.00%	0.00%	0.00%	0.00%	0.00%

The results of the similarity search made in the tool were also obtained as the same with the numerical example.

Learning Potential: The attributes used in measuring the learning potential and the weights according to the survey responses are presented in the table below (Table 4.42).

Table 4.42: Weights used in Learning Potential Calculation

Attributes used to Measure Learning Potential	Points	Weight
To enter a new country	4.38	0.154
To gain experience in a new project type	4.48	0.157
To work with a new client	3.77	0.133
To use a new construction technology	4.28	0.150
To work with a new contract type	3.83	0.135
To work with a new project delivery system (design-build, build-operate-transfer, etc.)	4.01	0.141
To work with a new project partner	3.70	0.130

The calculation of the learning potentials was made through investigation of how much the submitted attributes of the projects that are likely to be taken were matching with the completed projects based on the assumption of the increase in number of matches reduces the learning potential (Table 4.43):

Table 4.43: Calculation of Learning Potential

			Country	Project Type	Client	Technology	Contract Type	Project Delivery System	Partner Company
Learning Potential		Weight	0.154	0.157	0.133	0.150	0.135	0.141	0.130
P21	69.07 %	Matching	0.00 %	10.00%	0.00 %	5.00%	100.00%	15.00%	100.00%
		Learning Potential	100.00%	90.00%	100.00%	95.00%	0.00%	85.00%	0.00%
		Weighted L.P.	15.40 %	14.13%	13.30 %	14.25%	0.00%	11.99%	0.00%
P22	70.90 %	Matching	30.00 %	60.00%	15.00 %	5.00%	25.00%	45.00%	20.00%
		Learning Potential	70.00 %	40.00%	85.00 %	95.00%	75.00%	55.00%	80.00%
		Weighted L.P.	10.78 %	6.28%	11.31 %	14.25%	10.13%	7.76%	10.40%
P23	85.63 %	Matching	30.00 %	0.00%	5.00 %	5.00%	20.00%	40.00%	0.00%
		Learning Potential	70.00 %	100.00%	95.00 %	95.00%	80.00%	60.00%	100.00%
		Weighted L.P.	10.78 %	15.70%	12.64 %	14.25%	10.80%	8.46%	13.00%
P24	71.60 %	Matching	30.00 %	60.00%	15.00 %	5.00%	25.00%	40.00%	20.00%
		Learning Potential	70.00 %	40.00%	85.00 %	95.00%	75.00%	60.00%	80.00%
		Weighted L.P.	10.78 %	6.28%	11.31 %	14.25%	10.13%	8.46%	10.40%
P25	82.69 %	Matching	30.00 %	15.00%	15.00 %	0.00%	20.00%	40.00%	0.00%
		Learning Potential	70.00 %	85.00%	85.00 %	100.00 %	80.00%	60.00%	100.00%
		Weighted L.P.	10.78 %	13.35%	11.31 %	15.00%	10.80%	8.46%	13.00%

For example, for "Project 22" it was seen that the result was the same when the learning potential was also queried within the tool.

Risk Assessment: The factors used in the risk assessment and the weights obtained by the survey results are presented in the table below (Table 4.44).

Existing risk factors were assessed for each project as much as possible by supporting project characteristics and data from the database, and a risk score for each project was obtained as follows (Table 4.45).

Table 4.44: Weights of the Risk Factors

Risk Factors	Points	Weight
Economic risk (changes in exchange rates, cash flow risk, inflation, etc.)	4.39	0.095
Political risks (changes in government, changes in international relations, etc.)	4.19	0.091
Technical risks (delays due to technical problems, etc.)	3.89	0.084
Resource risk (risks due to quality/availability of material, manpower, machinery and equipment, etc.)	3.85	0.083
Design risk (deficiency/changes in design, etc.)	4.09	0.089
Contractual risk (ambiguity in conditions, insufficient definitions, strict requirements/constraints, etc.)	4.17	0.090
Owner initiated risks (insufficient experience, delays in payments, etc.)	4.05	0.088
Bureaucratic risks (delays in permissions, etc.)	4.02	0.087
Project management risks (poor planning, insufficient experience, etc.)	4.18	0.091
Risks due to weather conditions	3.00	0.065
Risks due to ground conditions	3.26	0.071
Environmental risks (social and environmental factors)	3.04	0.066

Table 4.45: Risk Scores

	Project 21		Project 22		Project 23		Project 24		Project 25	
Risk Factors	**Probability**	**P x E***	**Prob.**	**P x E**	**Prob.**	**P x E**	**Prob.**	**P x E**	**Prob.**	**P x E**
Economic risk	80	7.61	40	3.81	70	6.66	30	2.85	80	7.61
Political risks	50	4.54	60	5.45	30	2.72	60	5.45	30	2.72
Technical risks	40	3.37	50	4.22	50	4.22	50	4.22	80	6.75
Resource risk	20	1.67	30	2.50	30	2.50	60	5.01	60	5.01
Design risk	30	2.66	30	2.66	60	5.32	20	1.77	40	3.55
Contractual risk	20	1.81	30	2.71	80	7.23	70	6.33	40	3.62
Owner initiated risks	20	1.76	40	3.51	70	6.15	60	5.27	80	7.02
Bureaucratic risks	10	0.87	40	3.49	50	4.36	50	4.36	50	4.36
Project management risks	20	1.81	20	1.81	40	3.62	70	6.34	60	5.44
Risks due to weather conditions	10	0.65	30	1.95	80	5.20	70	4.55	30	1.95
Risks due to ground conditions	10	0.71	40	2.83	40	2.83	80	5.65	30	2.12
Environmental risks	20	1.32	80	5.27	50	3.30	30	1.98	40	2.64
Risk Score	**28.78**		**40.21**		**54.11**		**53.78**		**52.78**	

*P x E = Probability x Effect

Strategic Fit Assessment: The factors used in the evaluation of strategic fit and the weights obtained with the survey results are presented in the table below (Table 4.46).

Table 4.46: Weights of the Strategic Factors

Strategic Factors	Points	Weight
Maximization of Short Term Profitability	3.68	0.155
Maximization of Long Term Profitability	4.43	0.186
Gaining Reputation	4.10	0.172
Achievement of Learning / Gaining Experience	3.78	0.159
Risk Minimization	3.88	0.163
Entering New Markets	3.93	0.165

The existing strategic factors were assessed as much as possible for each project, supported by information from the database, and a strategic eligibility score for each project was obtained (Table 4.47).

Table 4.47: Strategic Fit Scores

	Project 21		Project 22		Project 23		Project 24		Project 25	
Strategic Factors	**Points**	**Score**	**Points**	**Score**	**Points**	**Score**	**Points**	**Score**	**Points**	**Score**
Maximization of Short Term Profitability	90	13.92	60	9.28	50	7.73	50	7.73	50	7.73
Maximization of Long Term Profitability	30	5.58	80	14.89	30	5.58	80	14.89	40	7.45
Gaining Reputation	10	1.72	60	10.34	90	15.50	30	5.17	50	8.61
Achievement of Learning / Gaining Experience	70	10.64	60	10.32	80	13.18	70	10.48	80	12.71
Risk Minimization	90	14.67	30	4.89	10	1.63	30	4.89	30	4.89
Entering New Markets	80	13.21	40	6.61	90	14.86	30	4.95	30	4.95
Strategic Fit Score	**60.22**		**55.53**		**58.02**		**48.75**		**46.34**	

The risk and strategic fit scores presented when the projects were filtered as "on-going" and "potential" in the tool were the same.

Dependency Calculation: The dependency weights used in the calculation of the total dependency were obtained according to the survey data as follows (Table 4.48). The relations were measured based on the matching ratios of the attributes defined for each dependency only where the "outcome dependency" was directly assigned.

Table 4.48: Weights of the Dependencies

Dependencies	Points	Weight
Financial Dependency	4.30	0.271
Resource Dependency	4.29	0.270
Learning Dependency	3.54	0.223
Outcome Dependency	3.76	0.237

Financial Dependency: The attributes and weights used in measuring the financial relationship (Table 4.49) and the financial relationships calculated between project pairs (Table 4.50) were as follows.

Table 4.49: Weights of the Attributes for Financial Dependency Calculation

Attributes used to Measure Financial Dependency	Points	Weight
Client	4.18	0.533
Currency	3.66	0.467

Table 4.50: Calculated Financial Dependencies between the Projects

		0.533	0.467
Financial Dependency		Client	Currency
P21 - P22	**46.70%**	0.00%	46.70%
P21 - P23	**0.00%**	0.00%	0.00%
P21 - P24	**46.70%**	0.00%	46.70%
P21 - P25	**0.00%**	0.00%	0.00%
P22 - P23	**0.00%**	0.00%	0.00%
P22 - P24	**100.00%**	53.30%	46.70%
P22 - P25	**0.00%**	0.00%	0.00%
P23 - P24	**0.00%**	0.00%	0.00%
P23 - P25	**46.70%**	0.00%	46.70%
P24 - P25	**0.00%**	0.00%	0.00%

Resource Dependency: The attributes and weights used in measuring the resource dependency (Table 4.51) and the resource dependencies calculated between the project pairs (Table 4.52) were as given below.

Table 4.51: Weights of the Attributes for Resource Dependency Calculation

Attributes used to Measure Resource Dependency	Points	Weight
Qualified Personnel (Project Management)	4.54	0.279
Manpower	3.99	0.245
Critical Machinery and Equipment	4.17	0.256
Construction Materials	3.58	0.220

Table 4.52: Calculated Resource Dependencies between the Projects

Resource Dependency		0.279 Personnel	0.245 Manpower	0.256 Machinery and Equipment	0.220 Material
P21 - P22	**0.00%**	0.00%	0.00%	0.00%	0.00%
P21 - P23	**27.90%**	27.90%	0.00%	0.00%	0.00%
P21 - P24	**0.00%**	0.00%	0.00%	0.00%	0.00%
P21 - P25	**0.00%**	0.00%	0.00%	0.00%	0.00%
P22 - P23	**0.00%**	0.00%	0.00%	0.00%	0.00%
P22 - P24	**47.60%**	0.00%	0.00%	25.60%	22.00%
P22 - P25	**25.60%**	0.00%	0.00%	25.60%	0.00%
P23 - P24	**27.90%**	27.90%	0.00%	0.00%	0.00%
P23 - P25	**0.00%**	0.00%	0.00%	0.00%	0.00%
P24 - P25	**25.60%**	0.00%	0.00%	25.60%	0.00%

Learning Dependency: The attributes and weights used in measuring the learning dependency (Table 4.53) and the learning dependencies calculated between project pairs (Table 4.54) were as provided below.

Table 4.53: Weights of the Attributes for Learning Dependency Calculation

Attributes used to Measure Learning Dependency	Points	Weight
Country	4.38	0.154
Project Type	4.48	0.157
Client	3.77	0.133
Construction Technology	4.28	0.150
Contract Type	3.83	0.135
Project Delivery System	4.01	0.141
Project Partner	3.70	0.130

Table 4.54: Calculated Learning Dependencies between the Projects

Learning Dependency		0.154 Country	0.157 Project Type	0.133 Client	0.150 Technology	0.135 Contract Type	0.141 Project Delivery System	0.130 Partner Company
P21 - P22	**0.00%**	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
P21 - P23	**0.00%**	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
P21 - P24	**0.00%**	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
P21 - P25	**0.00%**	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
P22 - P23	**0.00%**	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
P22 - P24	**70.90%**	15.40%	15.70%	13.30%	0.00%	13.50%	0.00%	13.00%
P22 - P25	**15.00%**	0.00%	0.00%	0.00%	15.00%	0.00%	0.00%	0.00%
P23 - P24	**29.10%**	0.00%	0.00%	0.00%	15.00%	0.00%	14.10%	0.00%
P23 - P25	**43.00%**	15.40%	0.00%	0.00%	0.00%	13.50%	14.10%	0.00%
P24 - P25	**14.10%**	0.00%	0.00%	0.00%	0.00%	0.00%	14.10%	0.00%

Outcome Dependency: The outcome dependency defined between the projects were as follows (Table 4.55).

Table 4.55: Identified Outcome Dependencies between the Projects

Outcome Dependency	
P21 - P22	**0.00%**
P21 - P23	**0.00%**
P21 - P24	**0.00%**
P21 - P25	**0.00%**
P22 - P23	**0.00%**
P22 - P24	**100.00%**
P22 - P25	**0.00%**
P23 - P24	**0.00%**
P23 - P25	**0.00%**
P24 - P25	**0.00%**

Total Dependencies: The values obtained by multiplying the dependencies between the project pairs by their weights are presented in light colors on the table (Table 4.56). The Financial Dependency (FD) is depicted in "green", the Resource Dependency (RD) is in "blue", the Learning Dependency (LD) is in "orange", and the Outcome Dependency (OD) is in "gray".

Table 4.56: Multiplication of the Dependencies with Weights

	FD	RD	LD	OD	FD	RD	LD	OD	FD	RD	LD	OD	FD	RD	LD	OD
	Project 21				Project 22				Project 23				Project 24			
P22	46.70%	0.00%	0.00%	0.00%												
	12.66%	0.00%	0.00%	0.00%												
P23	0.00%	27.90%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%								
	0.00%	7.53%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%								
P24	46.70%	0.00%	0.00%	0.00%	100.00%	47.60%	70.90%	100.00%	0.00%	27.90%	29.10%	0.00%				
	12.66%	0.00%	0.00%	0.00%	27.10%	12.85%	15.81%	23.70%	0.00%	7.53%	6.49%	0.00%				
P25	0.00%	0.00%	0.00%	0.00%	0.00%	25.60%	15.00%	0.00%	46.70%	0.00%	43.00%	0.00%	0.00%	25.60%	14.10%	0.00%
	0.00%	0.00%	0.00%	0.00%	0.00%	6.91%	3.35%	0.00%	12.66%	0.00%	9.59%	0.00%	0.00%	6.91%	3.14%	0.00%

The relationship matrix obtained in the tool was also parallel to the numerical example.

Relations obtained for each project pair are presented in the table below (Table 4.57).

Table 4.57: Dependencies between the Projects

Project Pairs	Financial Dependency	Resource Dependency	Learning Dependency	Outcome Dependency
P21 - P22	12.66%	0.00%	0.00%	0.00%
P21 - P23	0.00%	7.53%	0.00%	0.00%
P21 - P24	12.66%	0.00%	0.00%	0.00%
P21 - P25	0.00%	0.00%	0.00%	0.00%
P22 - P23	0.00%	0.00%	0.00%	0.00%
P22 - P24	27.10%	12.85%	15.81%	23.70%
P22 - P25	0.00%	6.91%	3.35%	0.00%
P23 - P24	0.00%	7.53%	6.49%	0.00%
P23 - P25	12.66%	0.00%	9.59%	0.00%
P24 - P25	0.00%	6.91%	3.14%	0.00%
P23 - P24	0.00%	7.53%	6.49%	0.00%
P23 - P25	12.66%	0.00%	9.59%	0.00%
P24 - P25	0.00%	6.91%	3.14%	0.00%

4.3.4.2.3. Search Options

The different search capabilities of the tool (similarity, filtering, and tag-based search) were tested on the basis of the expected results obtained on excel. It was seen that the tool provides accurate calculations based on the results obtained through the queries. In order to illustrate this process, the predictions obtained through different search mechanisms can be summarized as follows.

The predictions based on the obtained projects (P2, P3, P5, P14, and P19) from a sample filtering on the "project type" and "country" attributes for "Project 22" were obtained as follows (Table 4.58):

Table 4.58: Predictions for P22 based on Project Type and Country Filtering

Project No	Project Type	Country	Profit Deviation	Profitability	Delay Duration Percentage	Delay Cost Percentage	Claim Success (Duration)	Claim Success (Cost)
P2	Building	Russia	-11.00%	9.99%	6.67%	4.04%	100.00%	100.00%
P3	Building	Russia	-50.00%	3.66%	13.25%	3.66%	100.00%	
P5	Building	Russia	-5.00%	11.80%	2.63%	0.62%	100.00%	
P14	Building	Russia	-3.75%	10.65%	5.08%	0.41%		
P19	Building	Russia	-3.00%	12.04%	5.11%	0.68%	100.00%	100.00%
		AVERAGE	-14.55%	9.63%	6.55%	1.88%	100.00%	100.00%

The prediction results based on the same filtering for "Project 22" in the tool were the same with the obtained results from the numerical example.

For the predictions based on similarity analysis, the search made for "Project 24" was selected as a reference. Since the prediction calculation is based on the projects with similarities 50% and more the following projects were obtained to be taken into account in the calculation (Table 4.59).

Table 4.59: Similar Project Results for P24 with more than 50% Similarity Scores

		Project No	Country	Project Type	Client	Technology	Contract Type
Similarity		Projects	0.209	0.221	0.195	0.195	0.179
P24	100.00%	P3	100.00%	100.00%	100.00%	100.00%	100.00%
	80.52%	P2	100.00%	100.00%	100.00%	0.00%	100.00%
	76.61%	P14	100.00%	100.00%	80.00%	0.00%	100.00%
	74.66%	P19	100.00%	100.00%	70.00%	0.00%	100.00%
	62.59%	P5	100.00%	100.00%	100.00%	0.00%	0.00%

Since the same projects (P2, P3, P5, P14, and P19) with the case of filtering for predictions for "Project 22" were obtained for calculation of the predictions for "Project 24" through the filtering method, the prediction results should be same for the two cases.

The similarity search results obtained in the tool for "Project 24" were the same with the results obtained from the numerical example.

4.3.4.2.4. Portfolio Analysis

Portfolio analysis results were compared through the following considerations starting with investigation of a portfolio alternative in detail and them comparing different portfolio alternatives.

Review of the Portfolio Alternative ("Portfolio 3" / "Alternative 4"): The portfolio alternative that is including both of the potential projects was analyzed in detail for comparing the results obtained. The alternative was named as "Portfolio 3" within the numerical example, whereas it was automatically named as "Alternative 4 (Alt4)" within the analysis made in the tool.

Regarding the obtained results, the dependency network maps of the portfolio alternatives and related features are presented in the following figures and tables. The dependencies and network properties of the project through "network density" and "centrality" values were obtained as follows (Table 4.60, Table 4.61).

Table 4.60: Dependencies of the Projects in Portfolio 3 / Alternative 4

Portfolio 3: Dependencies of the Projects				
P21	**P22**	**P23**	**P24**	**P25**
Financial Dependency	Financial Dependency	Financial Dependency	Financial Dependency	Financial Dependency
25.31%	39.76%	12.66%	39.76%	12.66%
Resource Dependency	Resource Dependency	Resource Dependency	Resource Dependency	Resource Dependency
7.53%	19.76%	15.07%	27.30%	13.82%
Learning Dependency	Learning Dependency	Learning Dependency	Learning Dependency	Learning Dependency
0.00%	19.16%	16.08%	25.44%	16.08%
Outcome Dependency	Outcome Dependency	Outcome Dependency	Outcome Dependency	Outcome Dependency
0.00%	23.70%	0.00%	23.70%	0.00%
Total	Total	Total	Total	Total
32.84%	102.38%	43.80%	116.20%	42.56%

Table 4.61: Network Properties of Portfolio 3 / Alternative 4

Network Properties	
Network Density	**16.89%**
Centrality - Project 21	**19.45%**
Centrality - Project 22	**60.62%**
Centrality - Project 23	**25.93%**
Centrality - Project 24	**68.80%**
Centrality - Project 25	**25.20%**

The calculated relationships were digitally drawn through the software program named "ORA" provided by Carnegie Mellon University where, the financial dependencies are shown as "green", the resource dependencies as "blue", the learning dependencies as "orange", and the outcome dependencies as "gray" (Figure 4.11).

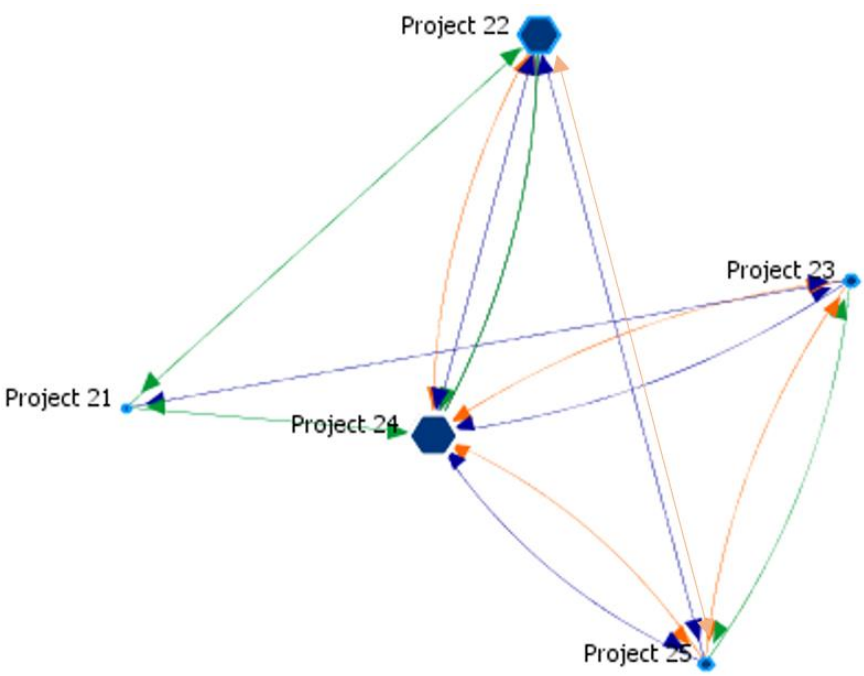


Figure 4.11: Dependency Network for Portfolio 3 / Alternative 4

The network map for the same portfolio in the tool indicating the project centrality for "Project 24" is as follows (Figure 4.12) and the nodes are in the expected scale when it is compared with the version in numerical example (Figure 4.11):

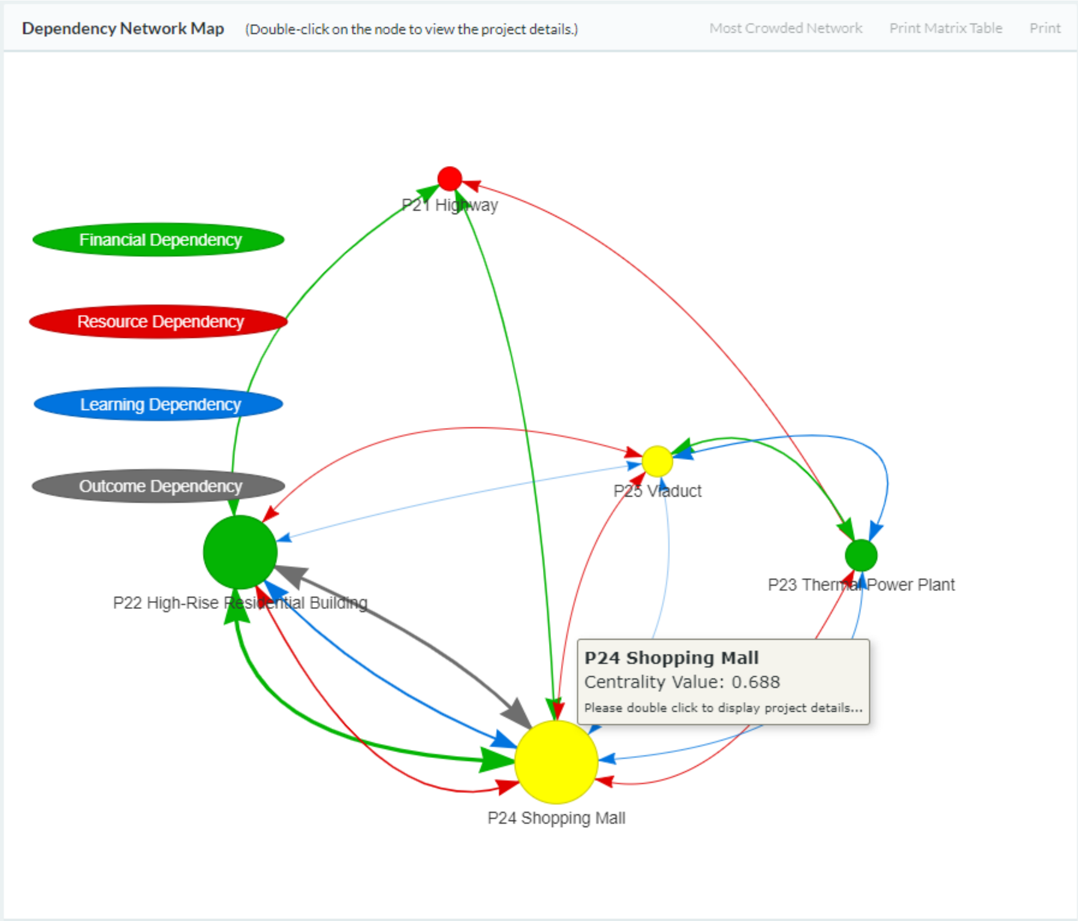


Figure 4.12: Dependency Network for Portfolio 3 / Alternative 4

Visualization of Portfolios: Bubble and bar diagrams were used in visualizing portfolios. Firstly, the projects in the portfolio (Figure 4.13 and Figure 4.14), then portfolio alternatives (Figure 4.15 - Figure 4.22) were visualized within the process.

The bubble sizes in the diagrams presented below represent “Adapted Profit” for projects and portfolios (Figure 4.13 - Figure 4.16, Figure 4.19 and Figure 4.20).

Figure 4.13: Graph of Portfolio 3

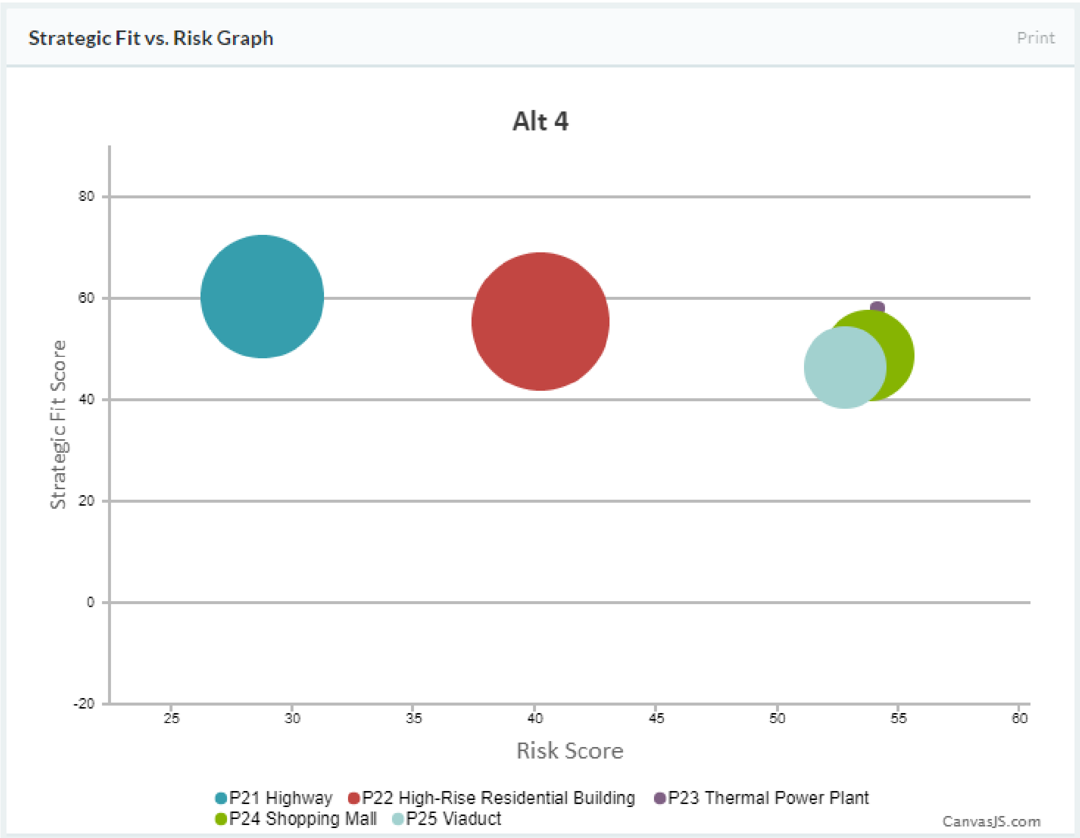


Figure 4.14: Graph of Portfolio 3

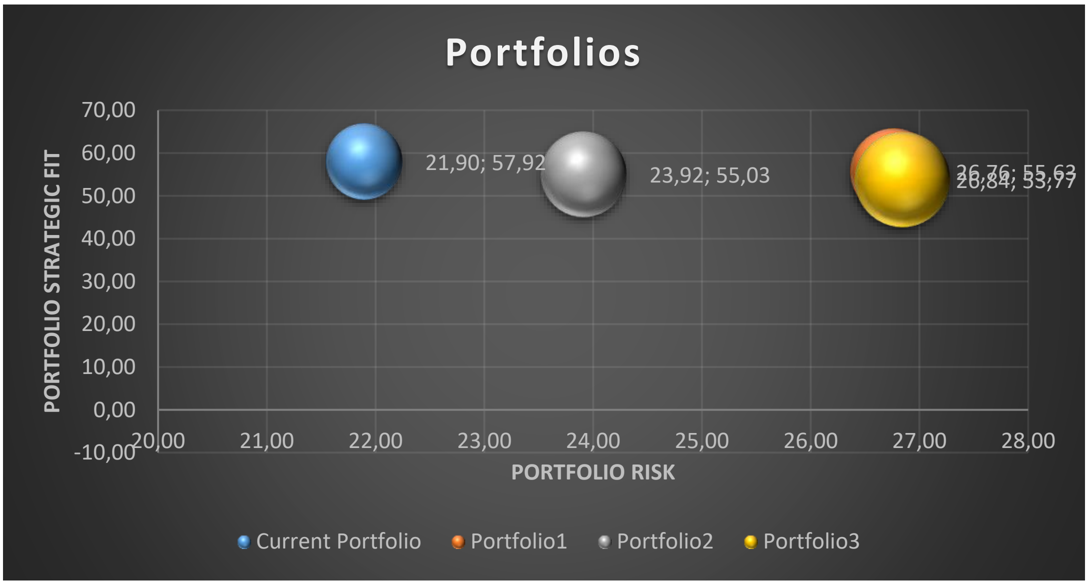


Figure 4.15: Bubble Graph of Portfolios

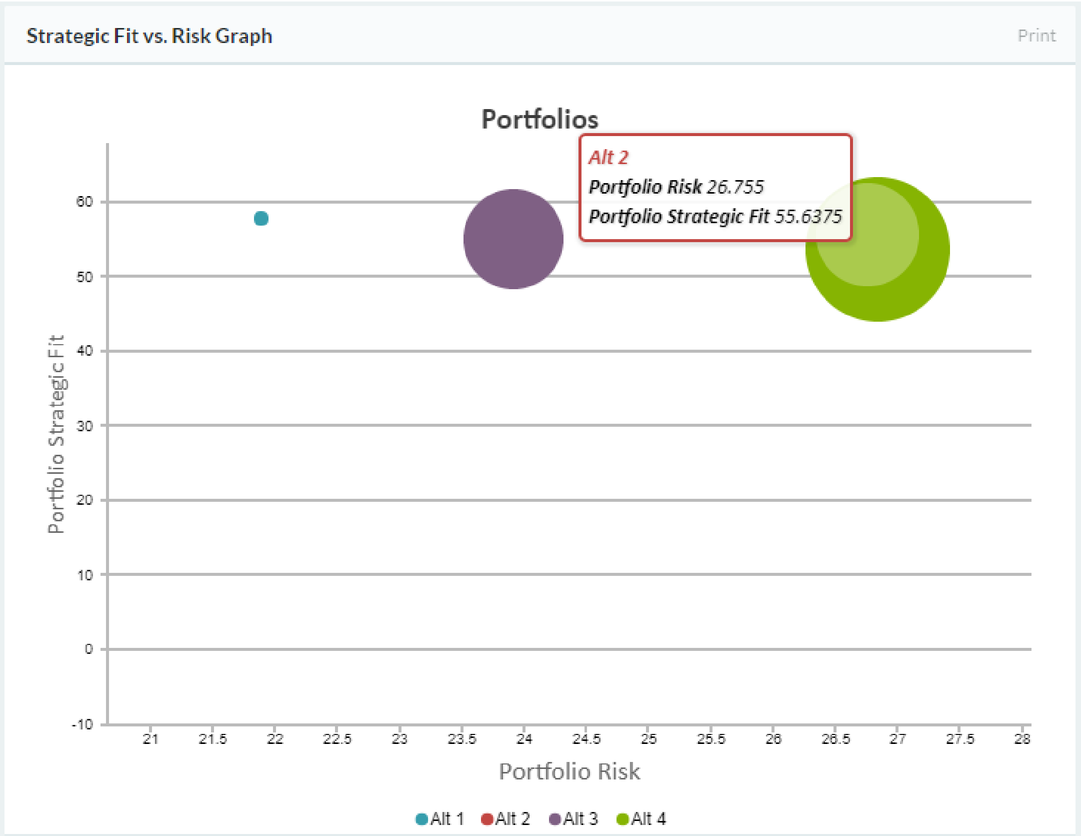


Figure 4.16: Bubble Graph of Portfolios

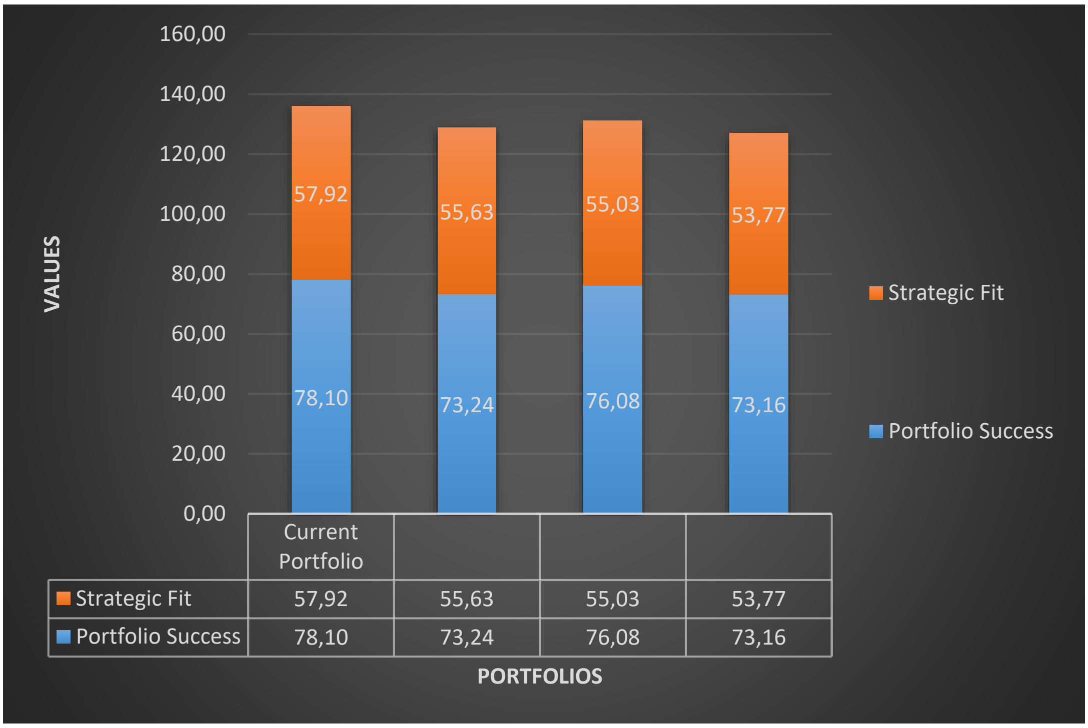


Figure 4.17: Bar Chart of Portfolios

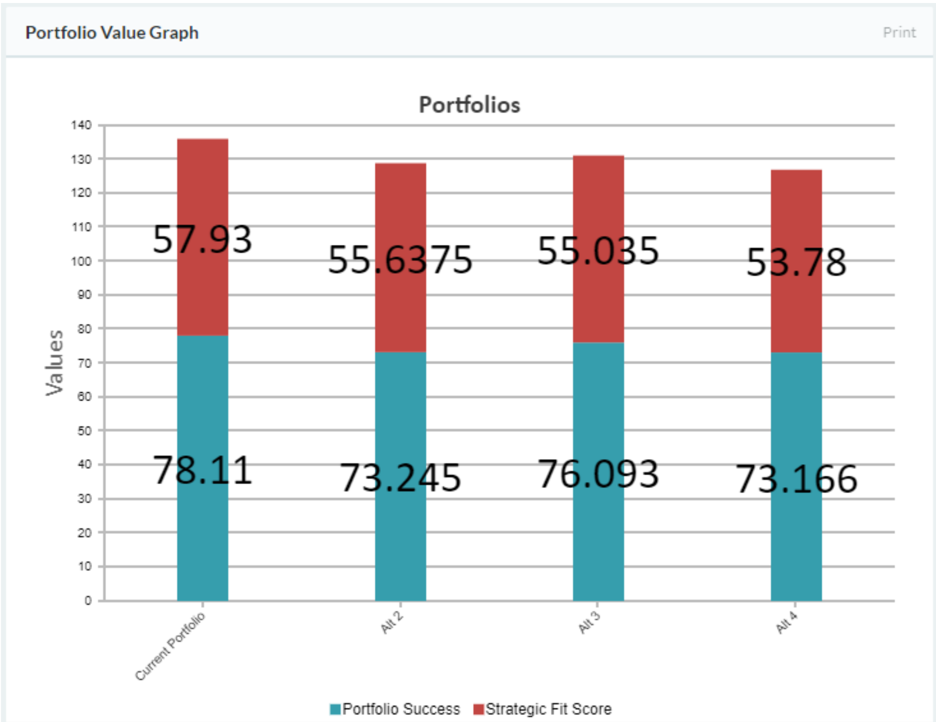


Figure 4.18: Bar Chart of Portfolios

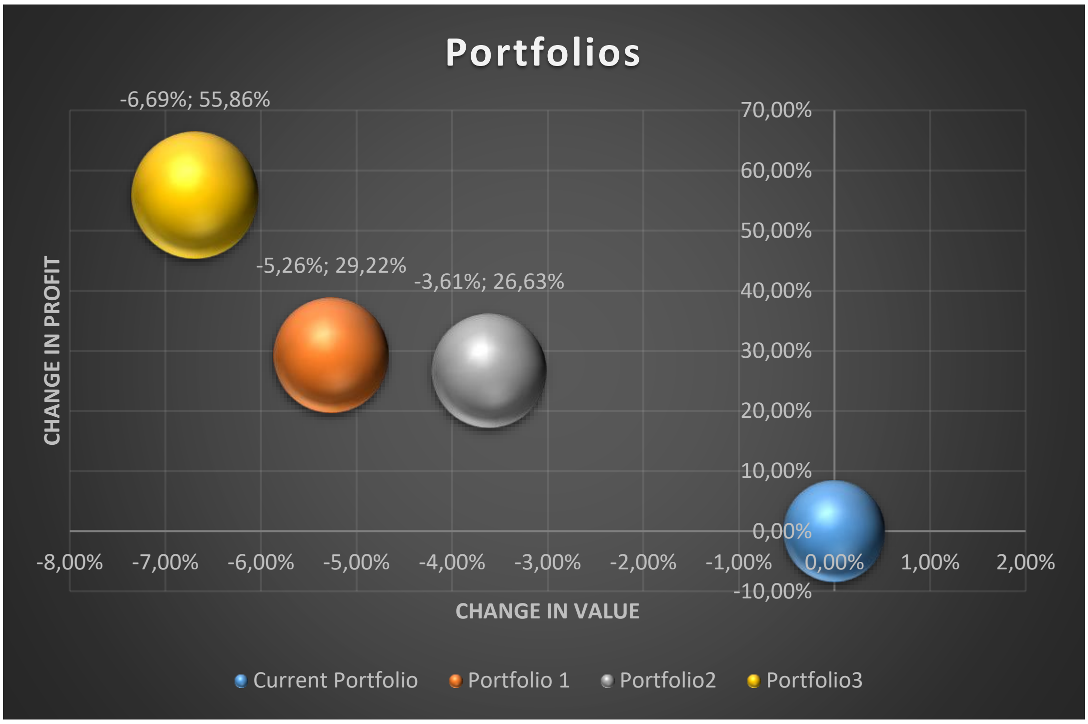


Figure 4.19: Portfolio Change Bubble Graph

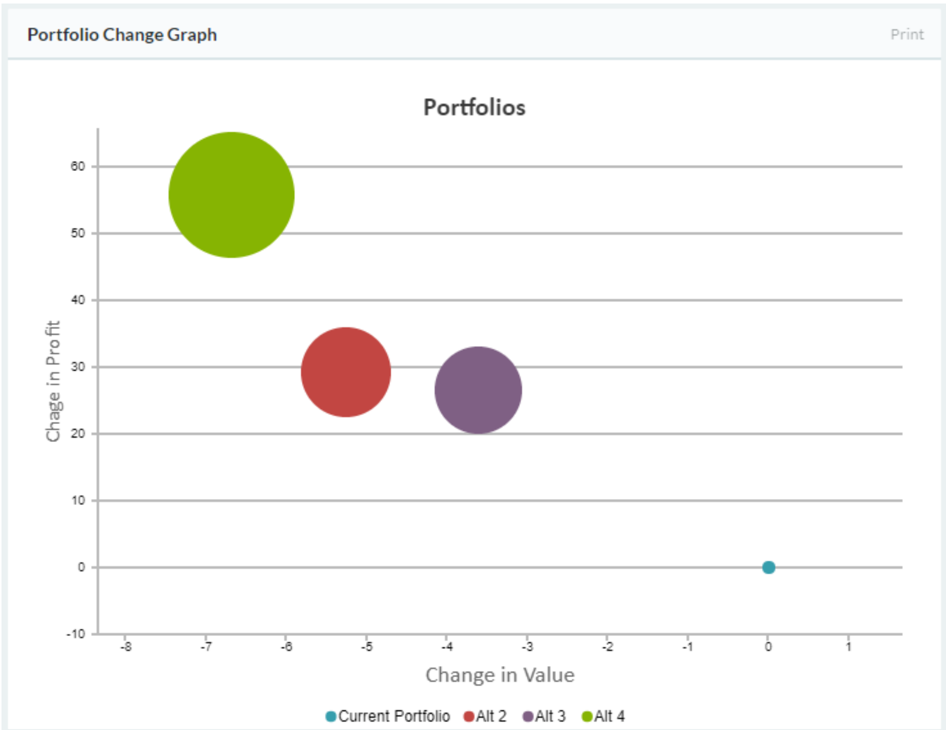


Figure 4.20: Portfolio Change Bubble Graph

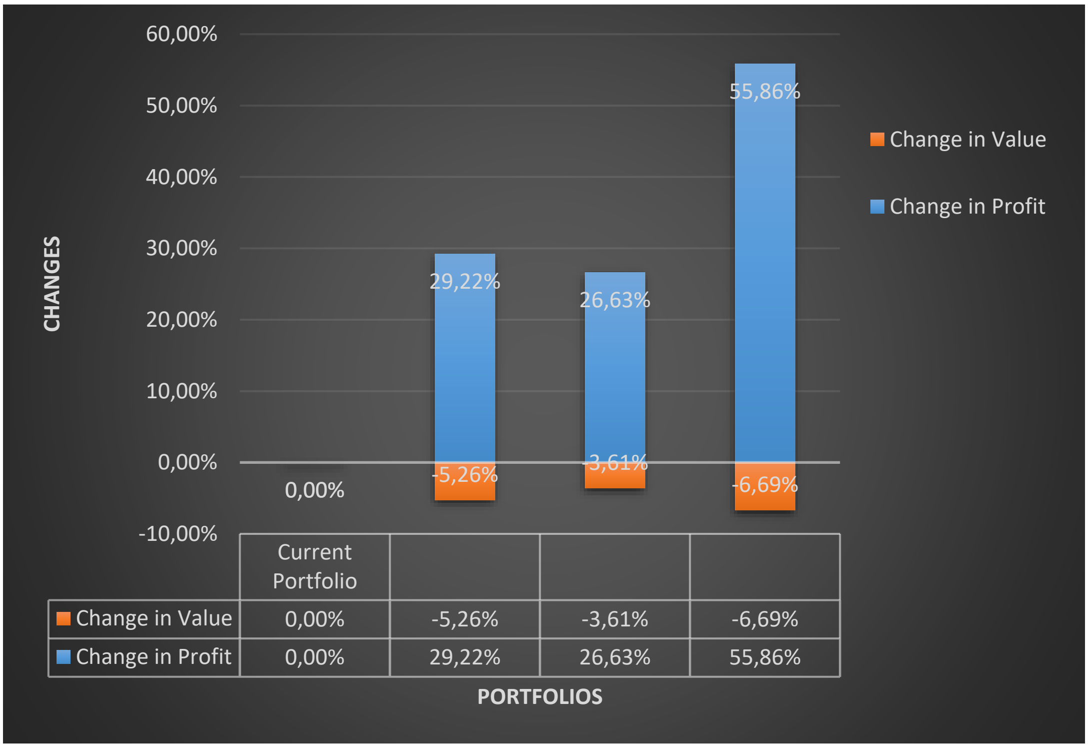


Figure 4.21: Portfolio Change Bar Chart

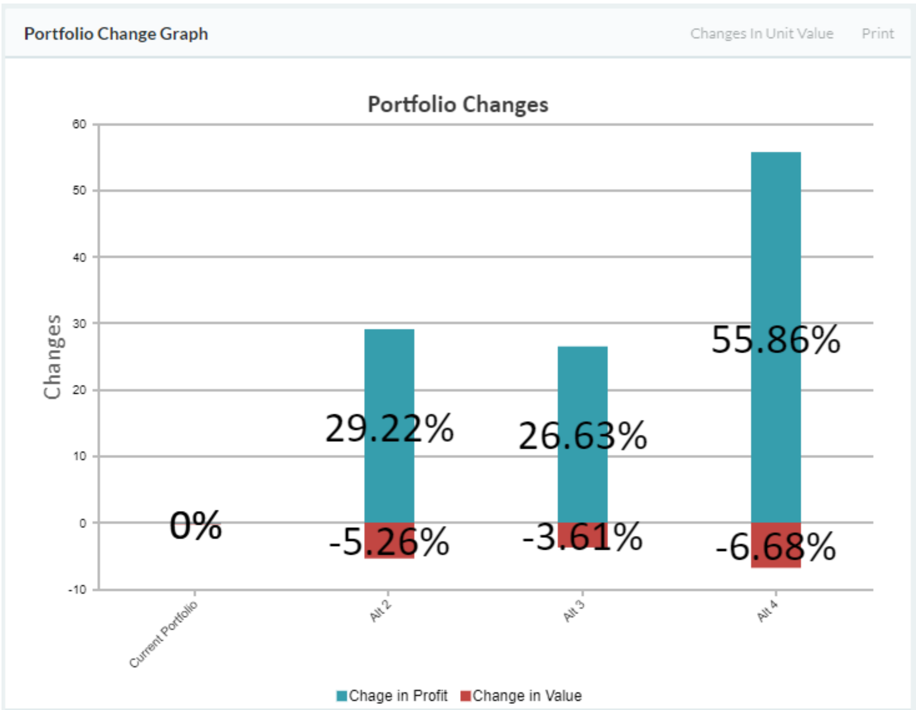


Figure 4.22: Portfolio Change Bar Chart

Summary of Portfolio Assessment: At the end of the portfolio evaluation, portfolio and project values were calculated (Table 4.62) and the results were obtained in the same way with the developed tool.

Table 4.62: Summary of Portfolio Assessment

	Current Portfolio	Portfolio 1	Portfolio 2	Portfolio 3
Network Density	6.73%	21.05%	8.78%	16.89%
Centrality - Project 21	100.00%	26.00%	38.32%	19.45%
Centrality - Project 22	62.69%	72.92%	43.49%	60.62%
Centrality - Project 23	37.31%	17.06%	56.51%	25.93%
Centrality - Project 24		84.02%		68.80%
Centrality - Project 25			61.68%	25.20%
Average Risk Score	41.03	44.22	43.97	45.93
Portfolio Risk	21.90	26.76	23.92	26.84
Portfolio Success	78.10	73.24	76.08	73.16
Average Strategic Fit Score	57.92	55.63	55.03	53.77
Portfolio Value	136.03	128.87	131.11	126.93
Portfolio Profit	67,836,600.00	87,661,000.00	85,903,266.67	105,727,666.67
Change in Profit	0.00%	21.87%	57.81%	79.68%
Change in Value	0.00%	-5.26%	-3.61%	-6.69%

Portfolio Selection: The following considerations were made for portfolio selection according to results obtained.

- The “current portfolio” between the portfolio alternatives has the highest portfolio value with "136.03" since it contains less relevant projects compared to other portfolios. When a new portfolio selection is considered, “Portfolio 2” has the highest value among the others with the value “131.11” values.
- “Portfolio 1” and “Portfolio 2” can be selected when a strategic fit-based choice is required, whereas “Portfolio 2” can be selected when a choice of risk reduction is required.
- It is expected to examine the change diagrams presented above for an analysis process in which portfolio selection is based on taking into consideration the expected profit values of the projects (Figure 4.19 - Figure 4.22). The portfolio expected to be selected in the light of the submitted figures is “Portfolio 3” (Alt4) since it is the most appropriate portfolio option when the portfolio values are examined with respect to change in profits. Similarly, if

a profit-based choice is in consideration, the tool will highlight “Alt4” (Portfolio 3) and warn the user for its selection.

- In portfolio selection, the centrality of the projects can help determine the critical projects in the portfolio. In this direction, the following projects can be designated as critical projects to be considered for the related portfolios:
  - “Project 21” for “Current Portfolio”,
  - “Project 24” for “Portfolio 1”,
  - “Project 23” and “Project 25” for “Portfolio 2”, and
  - “Project 24” for “Portfolio 3”.

4.3.5. Validation of Corporate Memory (LinCTool)

The validation studies held for LinCTool also acted as a parallel validation of its “corporate memory” to the evaluations of overall process of COPPMAN. The as a part of the joint study held by Eken (2017). As a result of the evaluation held within the joint study of Eken (2017), the generated corporate memory was evaluated in detail considering the lessons learned management system and the content of the provided lesson codification and the tag tree taxonomy through its presentation to four different company professionals from leading Turkish construction companies and evaluations were obtained through interviews on the capabilities of LinCTool. LinCTool was presented including the “39 lessons learned” generated within the context of “11 different projects” identified within the verification studies of LinCTool. The study resulted appreciation of the established system for its expected benefits as a response to common problems that may be encountered in lesson management. Professionals also delivered some issues as minor considerations mostly as the effect of company culture and individuals, which were not deemed to be critical considerations when the major aim of COPPMAN was considered. Only the detailed considerations stated by different professionals for its improvement through “provision of free-text search on lessons”, “inclusion of ‘quality effect’ in lesson codification”, “integration of reporting ability for the retrieved lessons” and “provision of some level of flexibility for similarity calculation” can be notable for further improvement of the capabilities of COPPMAN as well. However, these considerations were decided to be not critical for a current update and to be evaluated within further testing of COPPMAN through “pilot testing” and “real application”. Details of the validation study for LinCTool as the stand-alone tool version of “corporate memory” of COPPMAN is provided in complete detail in study of Eken (2017).

4.3.6. Evaluation of the Updated Alpha Version: Pilot Testing (Survey 6)

Before validation of the tool through direct utilization by its potential users in the evaluation studies of “usability testing” and “real application”, “pilot studies” were held to confirm the suitability of the “updated alpha version” of the tool for further testing. The “pilot testing” acted as a transition between the current evaluations held upon presentation of the details of the tool and the evaluations that will be made by its direct utilization. The company professionals were guided in utilization of the case studies by the research team as the director of the evaluation process. Within this context, overall tool process was validated by two case studies held by two different company professionals. As a result, the “pilot study” was a successful trial of the “usability testing” and “actual information” together with the positive evaluations made.

For overall utilization of the tool, two professionals, one from a large-scale and the other from a medium-scale construction companies were organized to use the tool with real case study and to evaluate the tool through questionnaires based on the experience with the structured case studies within the tool. Questionnaire was designed to be the improved version of the one held for “Expert Panel” through extending mainly the “usability” centered metrics for gaining some insight through its utilization by company professionals while also conducting the trial of the questionnaire to be held in "usability testing" (Appendix F). The case studies and the results obtained are presented in the following sections.

4.3.6.1. Case Study 1

Company and Expert Information: The first case study was held by a professional from procurement department of one of the Turkey's leading construction companies, which has been operating in the domestic and international market over the years.

Data: The company professional (user) entered the projects into the tool by partially replacing and encoding their current dam and transportation projects, in a way that would hinder the recognition of the projects. Within this scope, fourteen projects were entered as eight completed, three on-going and three potential projects. The project information can be summarized by the following figures obtained from the tool (Figure 4.23 - Figure 4.25).

Following entry of project information, company professional entered the lessons learned and tested the suitability of this function. Lessons learned information entered within this context can be summarized as follows (Figure 4.26).

The following lesson information is presented in more detail to illustrate one of the lessons learned (Figure 4.27).

Projects All ▾

Short Code	Project Name	Project Type	Country	Date	Project Status	Scores	Operations
P1	Project 1	Road	Iraq	**Start Date:** 04/05/2009 **End Date:** 14/10/2011	Completed	**Risk Score:** 0 **Strategic Fit Score:** 0	Display
P2	Project 2	Road	United Arab Emirates	**Start Date:** 05/01/2009 **End Date:** 26/01/2012	Completed	**Risk Score:** 0 **Strategic Fit Score:** 0	Display
P3	Project 3	Railway	Republic Of Turkiye	**Start Date:** 02/04/2007 **End Date:** 05/07/2010	Completed	**Risk Score:** 0 **Strategic Fit Score:** 0	Display
P4	Project 4	Railway	Republic Of Turkiye	**Start Date:** 08/04/2006 **End Date:** 08/04/2008	Completed	**Risk Score:** 0 **Strategic Fit Score:** 0	Display
P5	Project 5	Road	Republic Of Turkiye	**Start Date:** 01/02/2011 **End Date:** 17/03/2014	Completed	**Risk Score:** 0 **Strategic Fit Score:** 0	Display
P6	Project 6	Dam	Republic Of Turkiye	**Start Date:** 03/06/2005 **End Date:** 21/09/2008	Completed	**Risk Score:** 0 **Strategic Fit Score:** 0	Display
P7	Project 7	Irrigation	Republic Of Turkiye	**Start Date:** 25/10/2005 **End Date:** 25/07/2008	Completed	**Risk Score:** 0 **Strategic Fit Score:** 0	Display
P8	Project 8	Dam	Republic Of Turkiye	**Start Date:** 03/11/2003 **End Date:** 03/10/2008	Completed	**Risk Score:** 0 **Strategic Fit Score:** 0	Display

Figure 4.23: Completed Projects Identified in Case Study 1

Projects

All

Short Code	Project Name	Project Type	Country	Date	Project Status	Scores	Operations
P9	Project 9	Railway	Republic Of Turkiye	**Start Date:** 25/10/2016 **End Date:** 11/12/2020	On-going	**Risk Score:** 38.82 **Strategic Fit Score:** 51.74	Display
P10	Project 10	Road	Republic Of Turkiye	**Start Date:** 12/05/2016 **End Date:** 12/09/2019	On-going	**Risk Score:** 25.76 **Strategic Fit Score:** 40.18	Display
P11	Project 11	Road	Oman	**Start Date:** 08/01/2016 **End Date:** 08/01/2019	On-going	**Risk Score:** 40.55 **Strategic Fit Score:** 66.74	Display

Figure 4.24: On-going Projects Identified in Case Study 1

Projects

All

Short Code	Project Name	Project Type	Country	Date	Project Status	Scores	Operations
P12	Project 12	Road	Republic Of Turkiye	**Start Date:** 06/01/2017 **End Date:** 06/02/2020	Potential	**Risk Score:** 28.68 **Strategic Fit Score:** 41.73	Display
P13	Project 13	Road	Republic Of Turkiye	**Start Date:** 19/02/2017 **End Date:** 19/04/2019	Potential	**Risk Score:** 26.01 **Strategic Fit Score:** 36.64	Display
P14	Project 14	Dam	India	**Start Date:** 19/10/2015 **End Date:** 19/10/2020	Potential	**Risk Score:** 48.51 **Strategic Fit Score:** 61.11	Display

Figure 4.25: Potential Projects Identified in Case Study 1

Project		Lesson Learned	Operations
Project 1	✔ Detail	Change in scope by owner	✔ Detail Edit ✖ Approve
Project 2	✔ Detail	Problem in expropriation and claim	✔ Detail Edit ✖ Approve
Project 3	✔ Detail	Increase in cost estimates and project cost	✔ Detail Edit ✖ Approve
Project 4	✔ Detail	Delay due to landslide	✔ Detail Edit ✖ Approve
		Quality problem in ballast material	✔ Detail Edit ✖ Approve
Project 5	✔ Detail	Supply of pre-cast elements	✔ Detail Edit ✖ Approve
		Slow asphalting due to weather conditions	✔ Detail Edit ✖ Approve
Project 11	✔ Detail	Low productivity of local manpower	✔ Detail Edit ✖ Approve

Figure 4.26: Lessons Learned Identified in Case Study 1

Lesson Learned Information

Project Name: Project 2

Lesson Learned Name: Problem in expropriation and claim

User Name Of Saved Lesson: Coppman Admin

Best Practice:

Create Date: 08/09/2016 13:54:25

Event Description: The expropriation process was delayed due to the longer waiting period than expected. Mobilization duration was long in the work program submitted to the employer, so the success of the expropriation-based delays could not be achieved. The employer claimed that the delays in expropriation did not affect the work program. The cost of acceleration for finishing the job on time, together with the noncompliance to the work program and expropriation problem caused costs to exceed expectations. Additionally, the expected delivery date of the project was the reason for the late termination penalty.

Recommendation: Making realistic work items and time planning while making a business plan can prevent problems in future conflicts. On the other hand, this could have a positive effect under other circumstances. For this reason, business programs should be prepared considering possible risks in the project. Items such as expropriation should be monitored closely and the business plan should be updated according to the situation and the employer should be informed in time. This can help to share responsibility and make the employer behave more quickly in such work items. Regarding the employer, late termination penalties should be added to contingency calculations in future jobs.

Added Actors: UAE-based Public 1,

Effect on Project Duration: High

Effect Amount (if it is known): 55

Approve

Effect on Project Cost: Very High

Effect Amount (if it is known): 650000

Assigned Tags

Process | Management | Time Management | Planning / Schedules | Schedule Development | Delay | Causes of Delay | Owner Causes | Impacts of Delay | Cost Overrun | Financial Management | Cost Management | Cost Categories | Contractor's Direct Costs | Acceleration Costs | Claim Management | Claim | Kinds of Claim | Quantum Meurit Claims | Total cost claim

Figure 4.27: An Example for Lessons Learned

The user extracted the predictions from the entered PPA information entered for all of the projects without choosing any specific attribute and obtaining the averages for all of the projects since the projects already form a representative and meaningful set of projects (Figure 4.28).

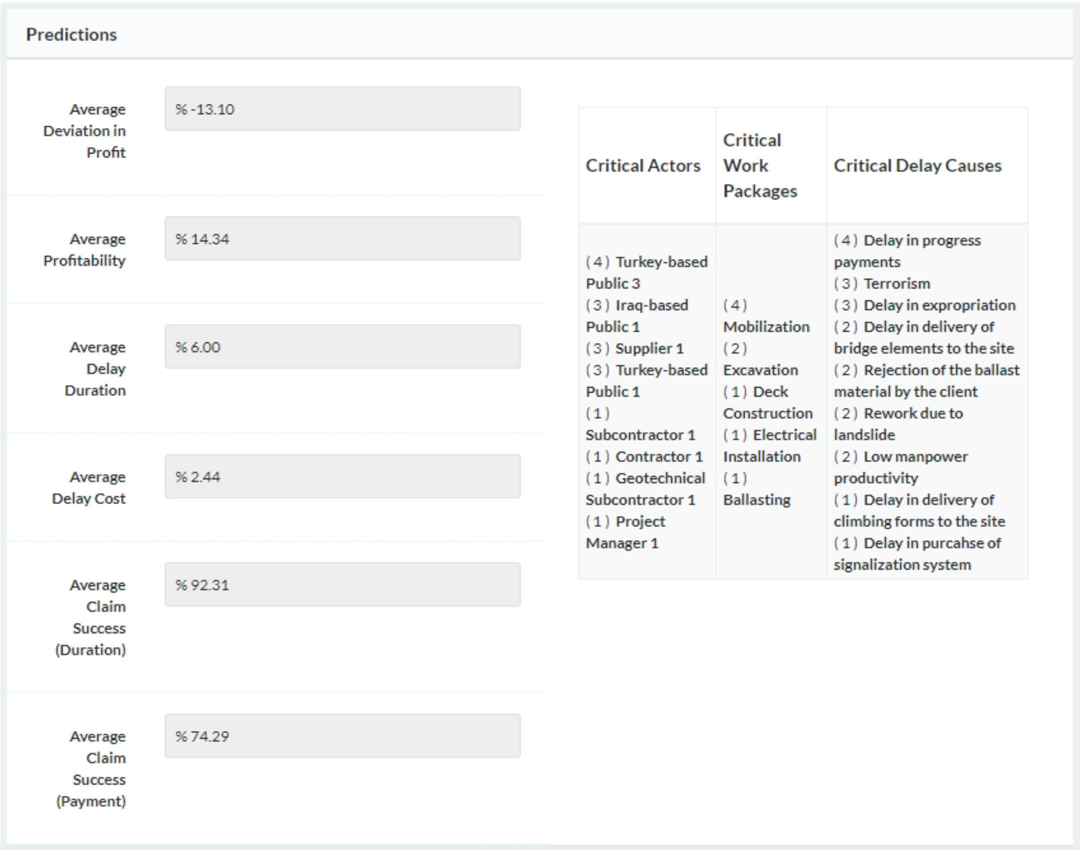


Figure 4.28: Predictions Obtained without Selection of any Attribute

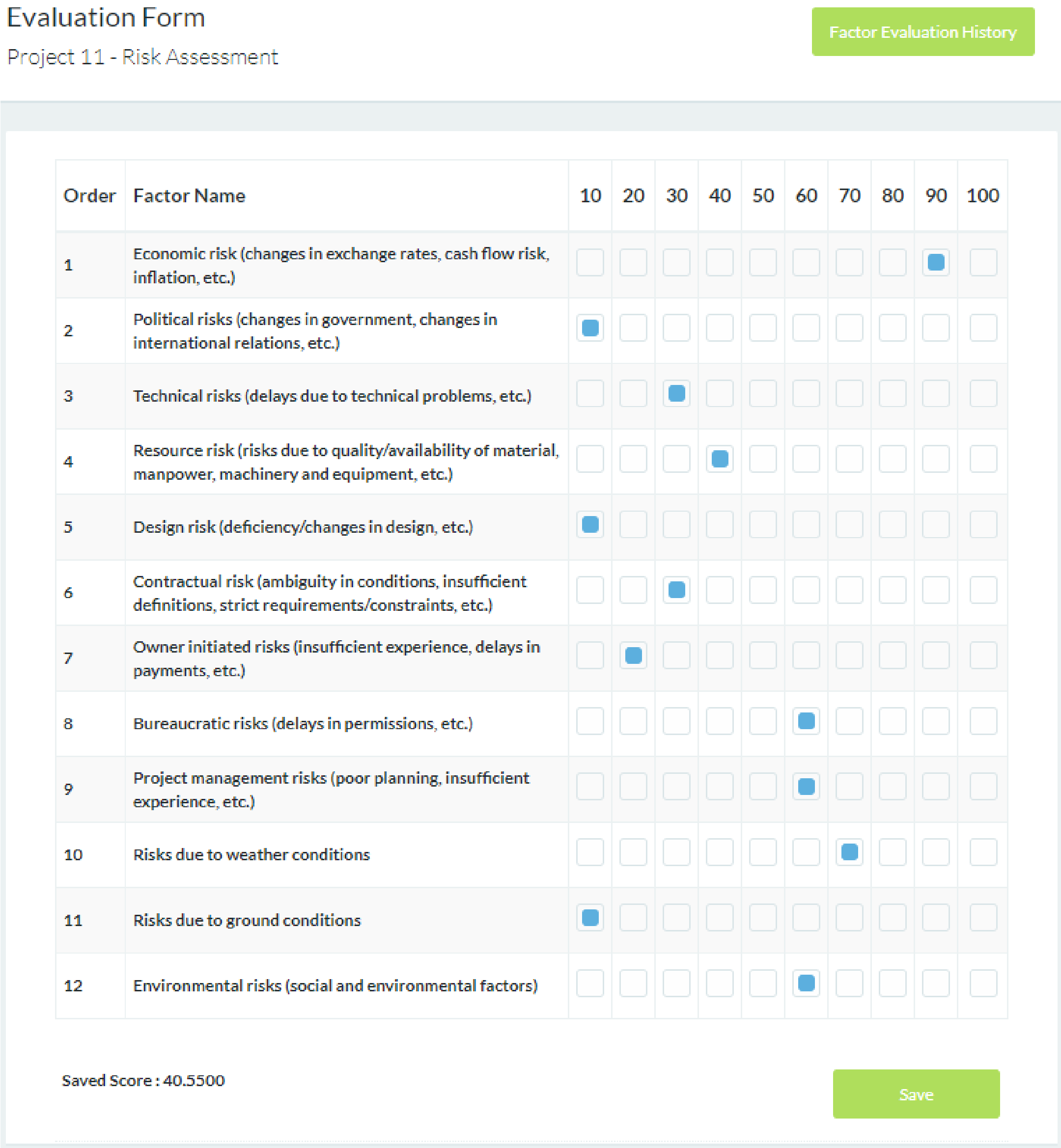
The user reviewed projects that were similar to on-going and potential projects. As an example of this process, the similarity search results for “Project 12” are as follows (Figure 4.29).

Projects

No	Name	Similarity Score	Country Similarity	Project Type Similarity	Client Similarity	Technology Similarity	Contract Type Similarity		
2241	Project 5	80.5	21	22.1	19.5	0	17.9	Project Detail	Project Card
2238	Project 2	41.6	0	22.1	0	19.5	0	Project Detail	Project Card
2239	Project 3	38.9	21	0	0	0	17.9	Project Detail	Project Card
2240	Project 4	38.9	21	0	0	0	17.9	Project Detail	Project Card
2242	Project 6	38.9	21	0	0	0	17.9	Project Detail	Project Card
2243	Project 7	38.9	21	0	0	0	17.9	Project Detail	Project Card
2244	Project 8	38.9	21	0	0	0	17.9	Project Detail	Project Card
2237	Project 1	22.1	0	22.1	0	0	0	Project Detail	Project Card

Figure 4.29: Similar Projects Obtained for P12

The user then viewed learning potentials for on-going and potential projects. In the light of the examinations made, the user made risk and strategic fit evaluations for on-going and potential projects. As an example of this process, the evaluations made for Project 11 are presented in the following figures (Figure 4.30 and Figure 4.31).



Evaluation Form

Project 11 - Risk Assessment

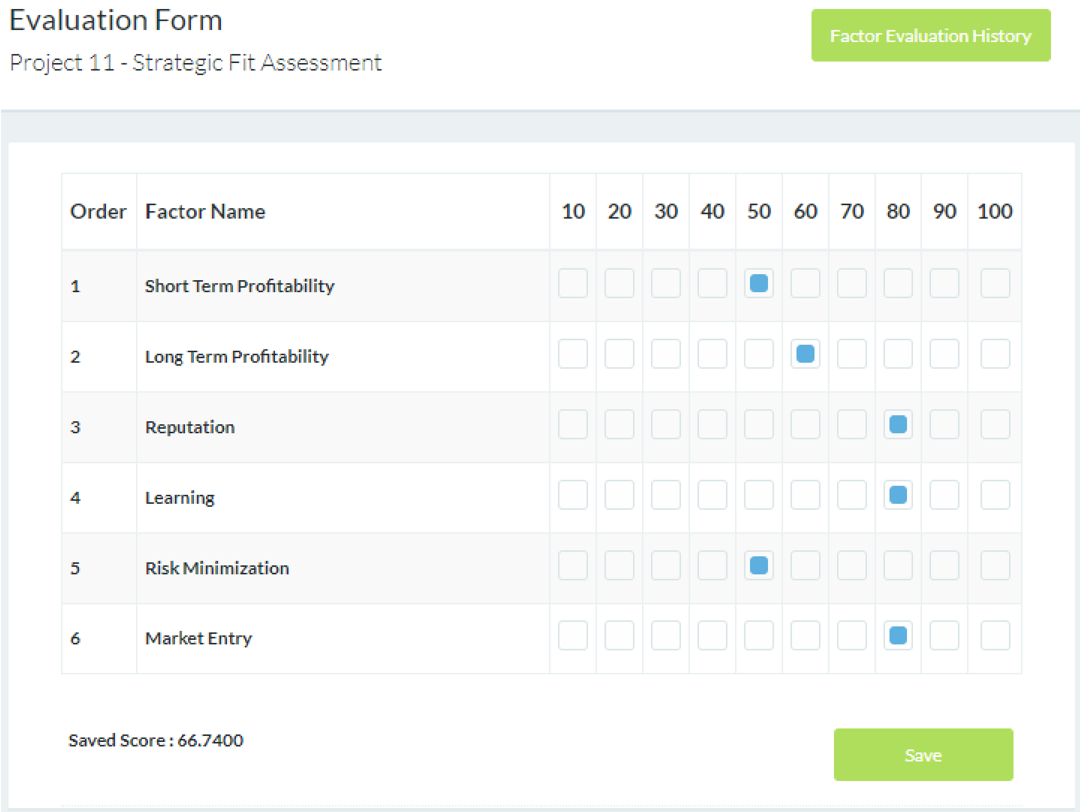
Factor Evaluation History

Order	Factor Name	10	20	30	40	50	60	70	80	90	100
1	Economic risk (changes in exchange rates, cash flow risk, inflation, etc.)	□	□	□	□	□	□	□	□	■	□
2	Political risks (changes in government, changes in international relations, etc.)	■	□	□	□	□	□	□	□	□	□
3	Technical risks (delays due to technical problems, etc.)	□	□	■	□	□	□	□	□	□	□
4	Resource risk (risks due to quality/availability of material, manpower, machinery and equipment, etc.)	□	□	□	■	□	□	□	□	□	□
5	Design risk (deficiency/changes in design, etc.)	■	□	□	□	□	□	□	□	□	□
6	Contractual risk (ambiguity in conditions, insufficient definitions, strict requirements/constraints, etc.)	□	□	■	□	□	□	□	□	□	□
7	Owner initiated risks (insufficient experience, delays in payments, etc.)	□	■	□	□	□	□	□	□	□	□
8	Bureaucratic risks (delays in permissions, etc.)	□	□	□	□	□	■	□	□	□	□
9	Project management risks (poor planning, insufficient experience, etc.)	□	□	□	□	□	■	□	□	□	□
10	Risks due to weather conditions	□	□	□	□	□	□	■	□	□	□
11	Risks due to ground conditions	■	□	□	□	□	□	□	□	□	□
12	Environmental risks (social and environmental factors)	□	□	□	□	□	■	□	□	□	□

Saved Score : 40.5500

Save

Figure 4.30: Risk Assessment for P11


Evaluation Form

Project 11 - Strategic Fit Assessment

Factor Evaluation History

Order	Factor Name	10	20	30	40	50	60	70	80	90	100
1	Short Term Profitability	☐	☐	☐	☐	■	☐	☐	☐	☐	☐
2	Long Term Profitability	☐	☐	☐	☐	☐	■	☐	☐	☐	☐
3	Reputation	☐	☐	☐	☐	☐	☐	☐	■	☐	☐
4	Learning	☐	☐	☐	☐	☐	☐	☐	■	☐	☐
5	Risk Minimization	☐	☐	☐	☐	■	☐	☐	☐	☐	☐
6	Market Entry	☐	☐	☐	☐	☐	☐	☐	■	☐	☐

Saved Score : 66.7400

Save

Figure 4.31: Strategic Fit Assessment for P11

The user carried out portfolio analysis as a result of the information entered and evaluations made. Details for the analysis are presented in the following results section.

Results

First Stage Portfolio Analysis: At the first stage of the portfolio analysis, the user performed an initial analysis by analyzing all the existing potential projects and obtained the following results (Figure 4.32 - Figure 4.36).

Portfolios

Delete All Portfolio Alternatives

Portfolio Name	Potential Projects in the Alternative	Average Risk Score (%)	Average Strategic Fit Score (%)	Network Density	Portfolio Risk	Portfolio Success (%)	Portfolio Value	Portfolio Profit	Operations
Alt 1		35.0433	52.8867	0.107	19.39	80.61	133.497	424,996,843.11 ₺	Operations ▾ Display Portfolio
Alt 2	P12,	33.4525	50.0975	0.218	20.364	79.636	129.733	453,545,711.68 ₺	Operations ▾ Display Portfolio
Alt 3	P13,	32.785	48.825	0.218	19.958	80.042	128.867	443,491,542.63 ₺	Operations ▾ Display Portfolio
Alt 4	P14,	38.41	54.9425	0.069	20.53	79.47	134.412	835,887,645.36 ₺	Operations ▾ Display Portfolio
Alt 5	P12, P13,	31.964	47.406	0.275	20.377	79.623	127.029	472,040,411.19 ₺	Operations ▾ Display Portfolio
Alt 6	P12, P14,	36.464	52.3	0.143	20.84	79.16	131.46	864,436,513.93 ₺	Operations ▾ Display Portfolio
Alt 7	P13, P14,	35.93	51.282	0.149	20.642	79.358	130.64	854,382,344.88 ₺	Operations ▾ Display Portfolio
Alt 8	P12, P13, P14,	34.7217	49.69	0.198	20.794	79.206	128.896	882,931,213.44 ₺	Operations ▾ Display Portfolio

Total 8, Displayed 1-8 Range

‹ 1 ›

Figure 4.32: First Stage Portfolio Analysis Summary Table

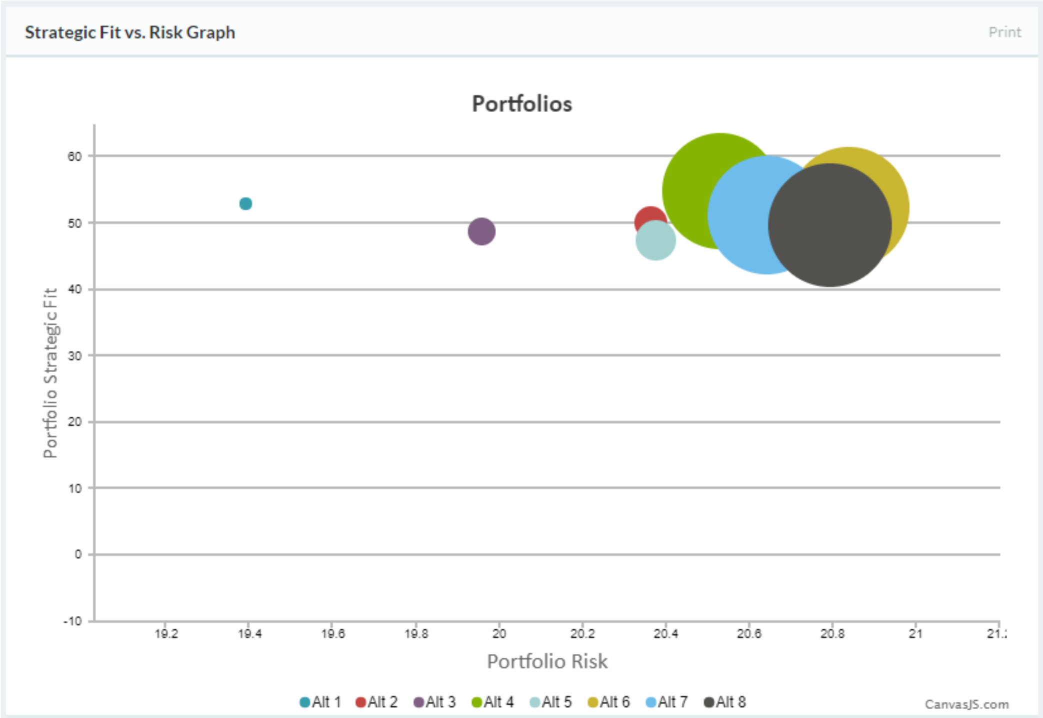


Figure 4.33: First Stage Portfolio Analysis Bubble Diagram

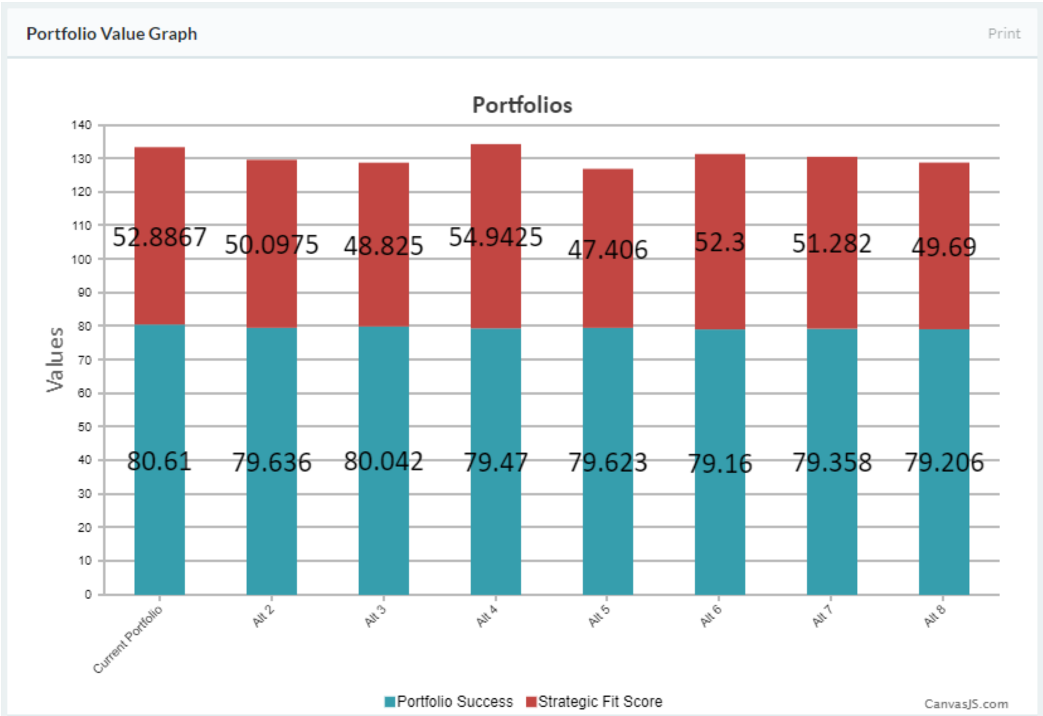


Figure 4.34: First Stage Portfolio Analysis Portfolio Value Bar Chart

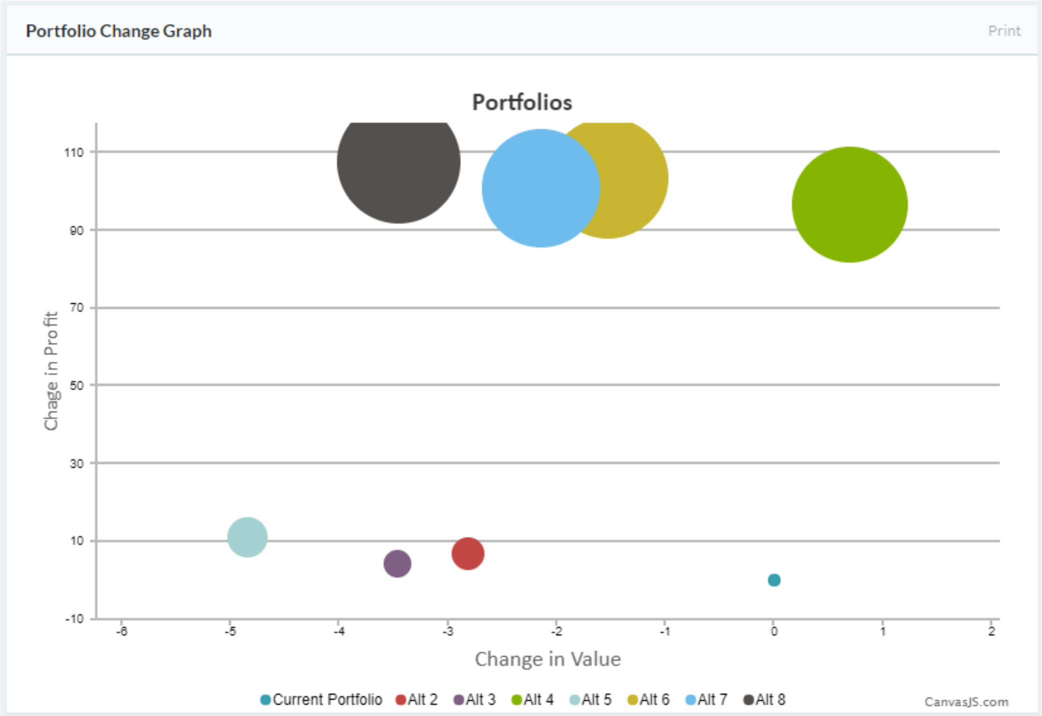


Figure 4.35: First Stage Portfolio Analysis Portfolio Change Bubble Diagram

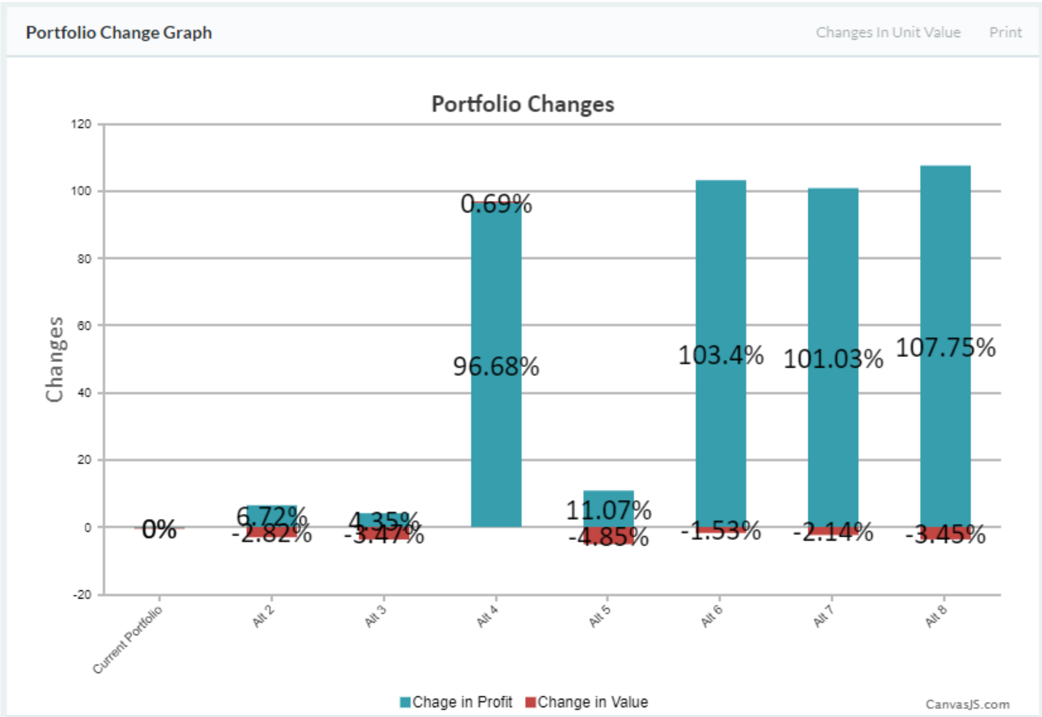


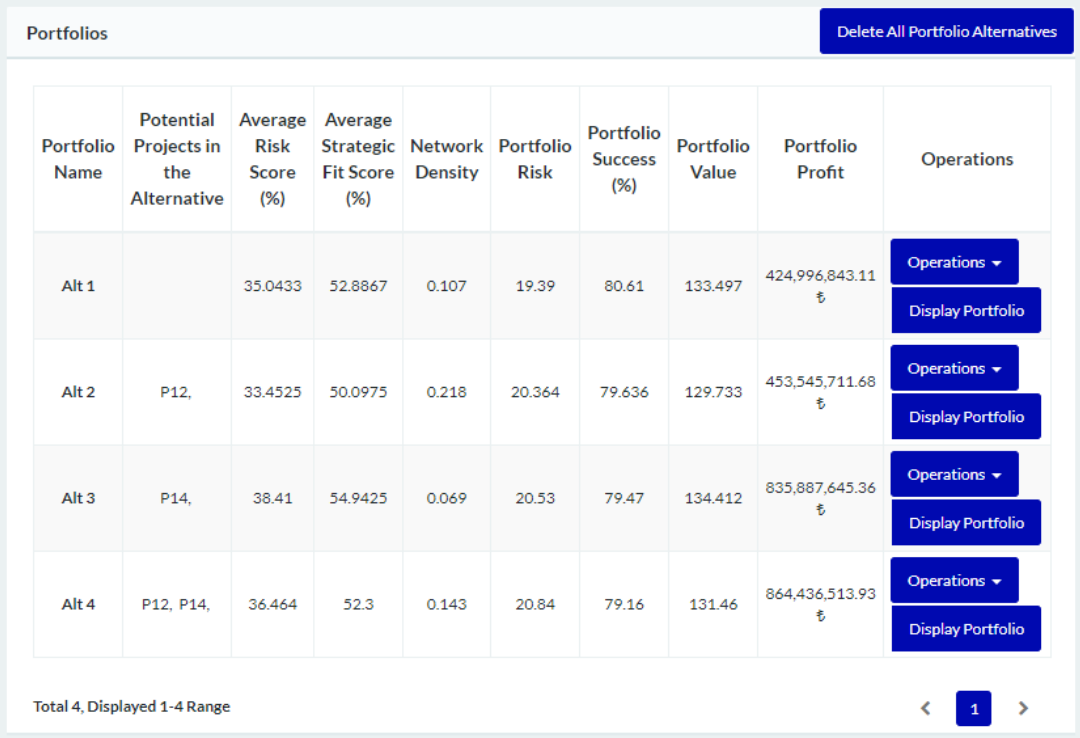
Figure 4.36: First Stage Portfolio Analysis Portfolio Change Bar Chart

Evaluation of the Analysis: The user reviewed the results presented and drew the following comments:

- When alternatives are examined, it can be clearly observed that the profitability of "Alternative 2" and "Alternative 3" and therefore "Project 12" and "Project 13" are lower than others.
- Although "Project 14" is a long-term investment and therefore profitable, funding challenge and necessity must be considered. If financing can be achieved, "Alternative 4" including "Project 14" is the most suitable alternative.
- "Alternative 6", "Alternative 7" and "Alternative 8" can be selected depending on the resource situation.
- In addition, if there is no thinking of undertaking a long-term investment in build-operate-transfer project delivery system, "Alternative 2", which includes "Project 12", appears to be the most appropriate choice.
- It is seen that both the "portfolio value" and the "profitability" changes created by "Project 13" in the portfolio indicates that "Project 13" is not preferable when it is compared to "Project 12" from the change graphs.

As a result of the first stage analysis, the "Alternative 3" including "Project 13" was decided to be eliminated from the current analysis. A second analysis was performed by deleting the current analysis and adding only "Project 12" and "Project 14", while excluding "Project 13".

Second Stage Portfolio Analysis: As a result of the second analysis, the following results were obtained (Figure 4.37 - Figure 4.41).



Portfolios

Delete All Portfolio Alternatives

Portfolio Name	Potential Projects in the Alternative	Average Risk Score (%)	Average Strategic Fit Score (%)	Network Density	Portfolio Risk	Portfolio Success (%)	Portfolio Value	Portfolio Profit	Operations
Alt 1		35.0433	52.8867	0.107	19.39	80.61	133.497	424,996,843.11 ₺	Operations ▾ Display Portfolio
Alt 2	P12,	33.4525	50.0975	0.218	20.364	79.636	129.733	453,545,711.68 ₺	Operations ▾ Display Portfolio
Alt 3	P14,	38.41	54.9425	0.069	20.53	79.47	134.412	835,887,645.36 ₺	Operations ▾ Display Portfolio
Alt 4	P12, P14,	36.464	52.3	0.143	20.84	79.16	131.46	864,436,513.93 ₺	Operations ▾ Display Portfolio

Total 4, Displayed 1-4 Range

1

Figure 4.37: Second Stage Portfolio Analysis Summary Table

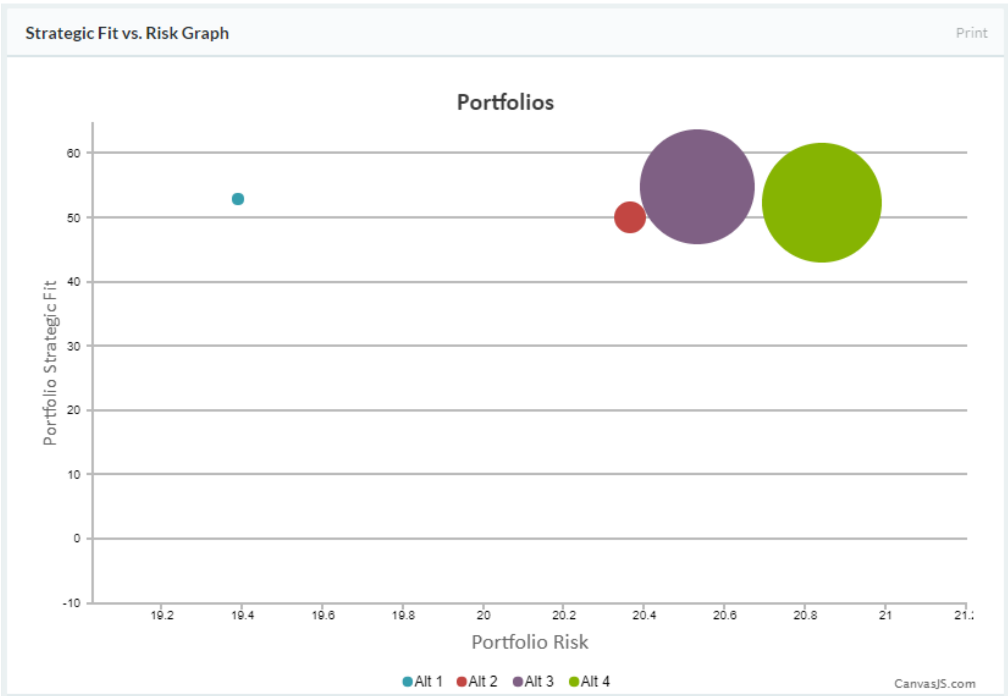


Figure 4.38: Second Stage Portfolio Analysis Bubble Diagram

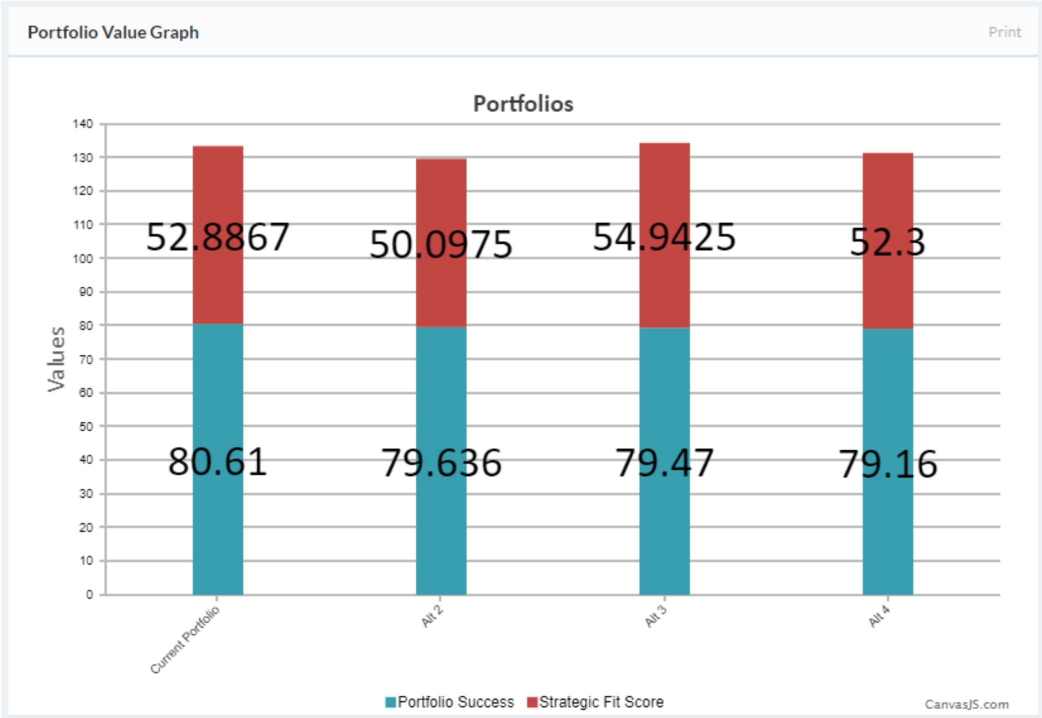


Figure 4.39: Second Stage Portfolio Analysis Portfolio Value Bar Chart

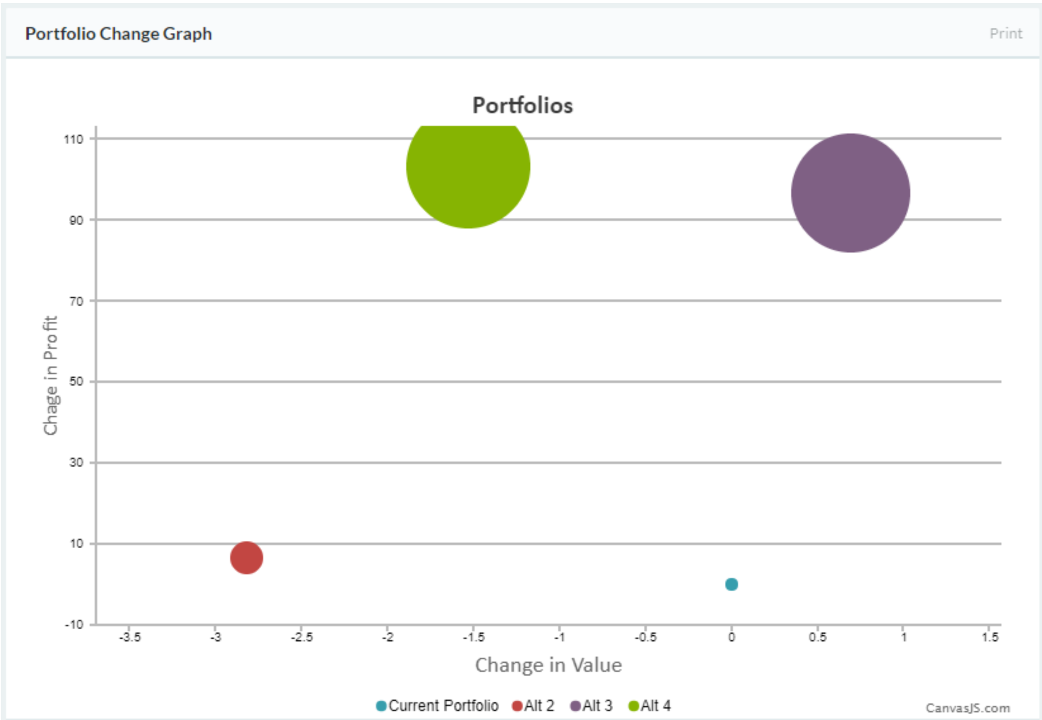


Figure 4.40: Second Stage Portfolio Analysis Portfolio Change Bubble Diagram

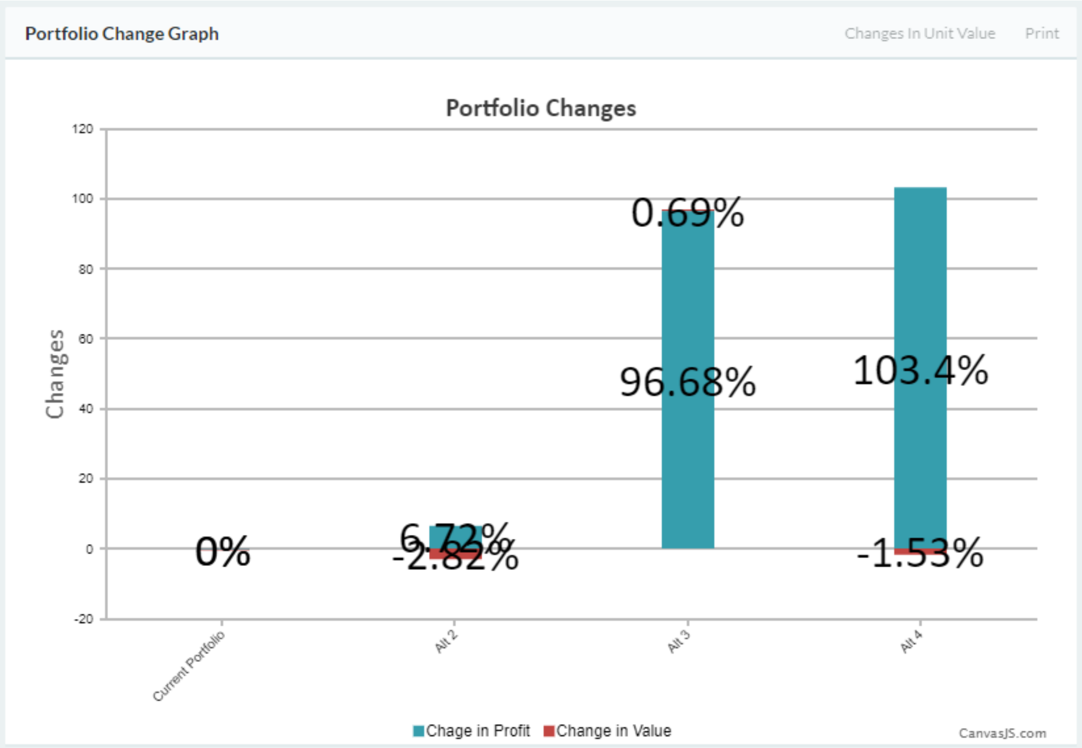
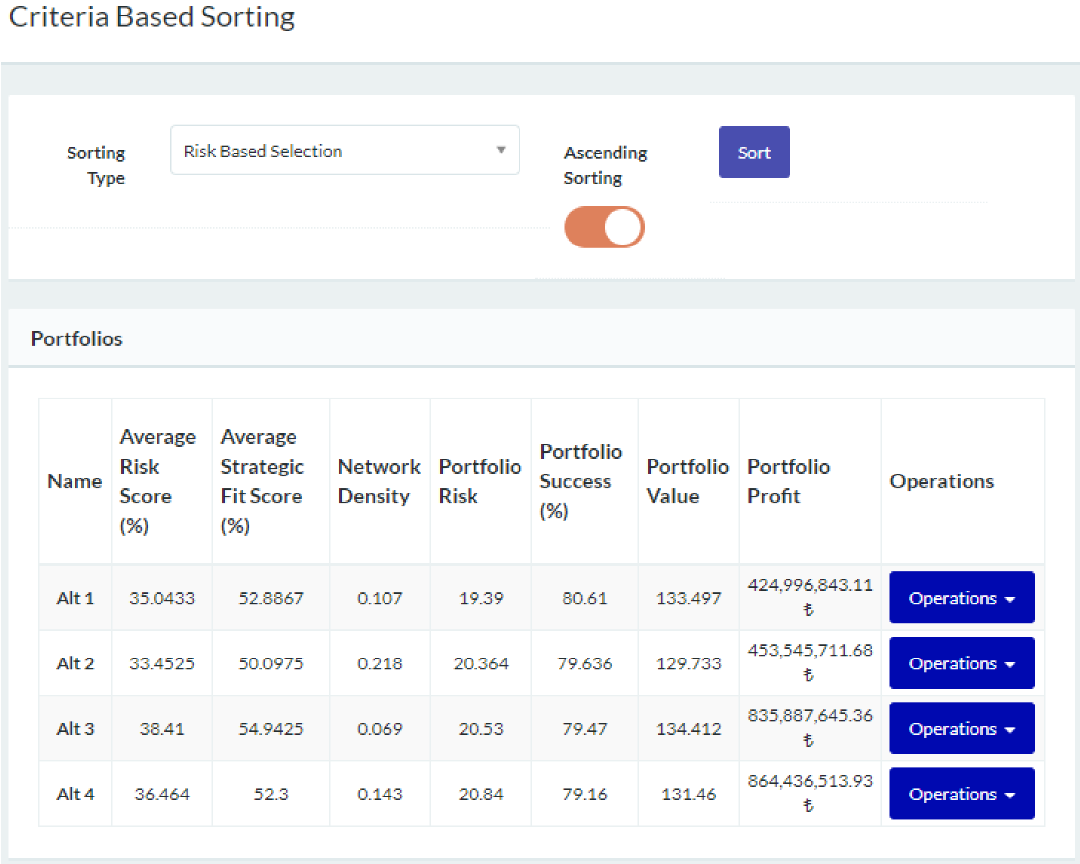


Figure 4.41: Second Stage Portfolio Analysis Portfolio Change Bar Chart

Evaluation of the Analysis: The user reviewed the results presented and made the following comments:

- When the alternatives are examined, "Project 14" is considered to be profitable in the long run, since it is a project in build-operate-transfer model. Therefore, this investment option is a separate decision and that the selection of "Project 14" is to be deferred at the first stage.
- "Project 12" seems to be selectable in the current analysis as well as it was in the first analysis.

In addition, when a risk-focused choice is considered as a result of the analysis made in the portfolio selection section of the tool, it was again seen that "Alternative 2" is a selectable portfolio following "Alternative 1", which is the "current portfolio" (Figure 4.42).



Name	Average Risk Score (%)	Average Strategic Fit Score (%)	Network Density	Portfolio Risk	Portfolio Success (%)	Portfolio Value	Portfolio Profit	Operations
Alt 1	35.0433	52.8867	0.107	19.39	80.61	133.497	424,996,843.11 ₺	Operations
Alt 2	33.4525	50.0975	0.218	20.364	79.636	129.733	453,545,711.68 ₺	Operations
Alt 3	38.41	54.9425	0.069	20.53	79.47	134.412	835,887,645.36 ₺	Operations
Alt 4	36.464	52.3	0.143	20.84	79.16	131.46	864,436,513.93 ₺	Operations

Figure 4.42: Risk Based Selection

Portfolio Selection: As a result, it was decided to select “Project 12”. When this portfolio was examined in more detail, the following information was obtained (Figure 4.43 - Figure 4.46).

Portfolio Alternative Projects

Alt 2 Projects

Name	Average Risk Score (%)	Average Strategic Fit Score (%)	Network Density	Portfolio Risk	Portfolio Success (%)	Portfolio Value	Portfolio Profit
Alt 2	33.4525	50.0975	0.218	20.364	79.636	129.733	453,545,711.68 ₺

No	Project	Date	Project Status	Scores	Operations
2245	Project 9	**Start Date:** 25/10/2016 **End Date:** 11/12/2020	On-going	**Risk Score:** 38.82 **Strategic Fit Score:** 51.74 **Centrality Value:** 0.364	Detail
2246	Project 10	**Start Date:** 12/05/2016 **End Date:** 12/09/2019	On-going	**Risk Score:** 25.76 **Strategic Fit Score:** 40.18 **Centrality Value:** 0.755	Detail
2247	Project 11	**Start Date:** 08/01/2016 **End Date:** 08/01/2019	On-going	**Risk Score:** 40.55 **Strategic Fit Score:** 66.74 **Centrality Value:** 0.126	Detail
2248	Project 12	**Start Date:** 06/01/2017 **End Date:** 06/02/2020	Potential	**Risk Score:** 28.68 **Strategic Fit Score:** 41.73 **Centrality Value:** 0.755	Detail

Figure 4.43: Summary Table for the Portfolio Projects

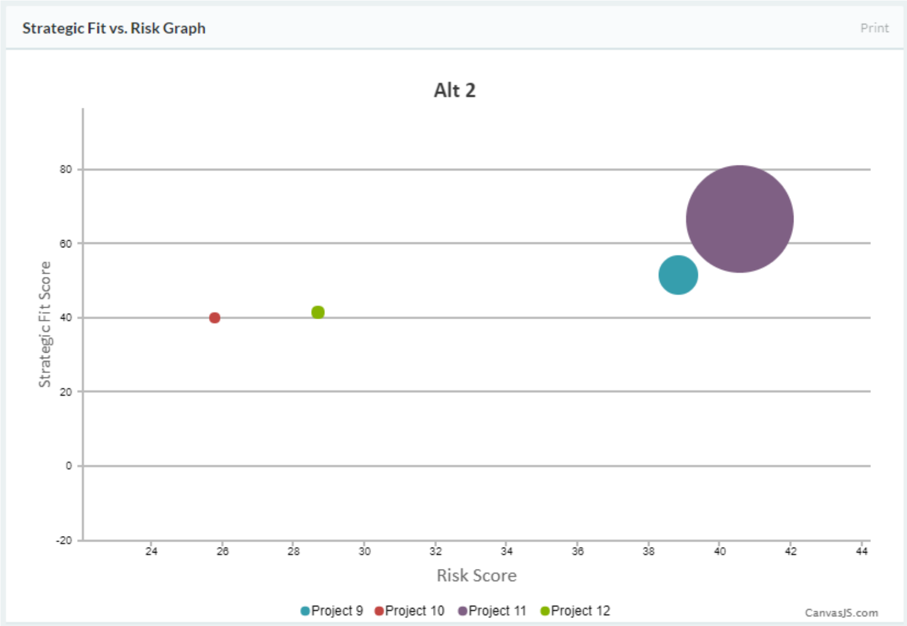


Figure 4.44: Bubble Diagram for the Portfolio Projects

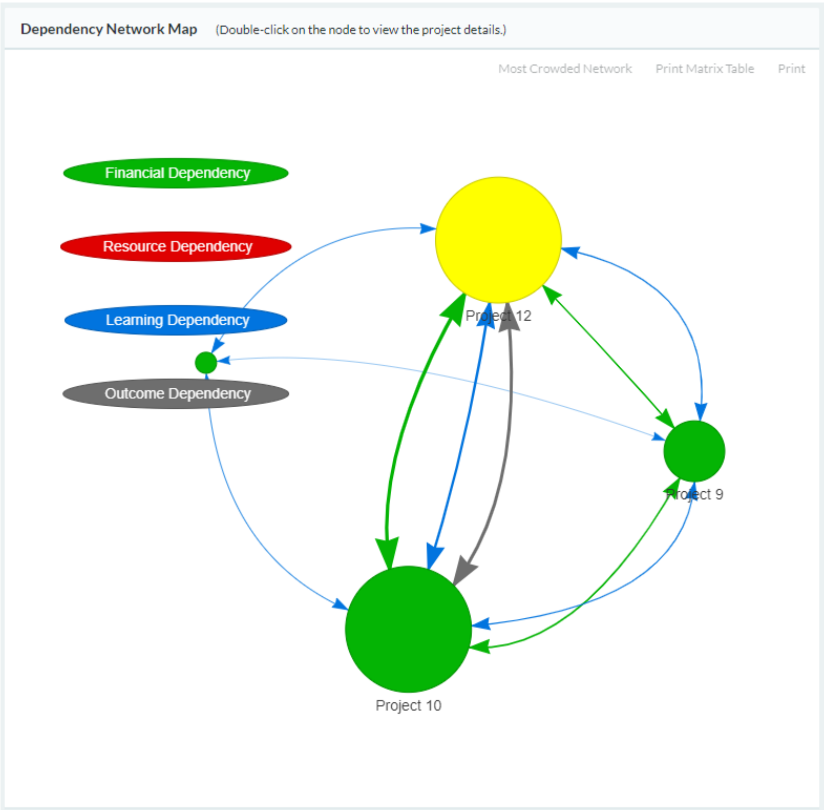


Figure 4.45: Dependency Map for the Portfolio Projects

Warnings

- Dependency network of the projects in the portfolio is at critical level, therefore investigation of the dependencies between projects and attention to these dependencies during management of the projects are suggested.
- Due to centrality of the Project 10, Project 12 in the portfolio, the situation of the projects is at the level of affecting the portfolio situation.
- The Turkey-based Public 1 assigned to the Project 10 has been defined as critical actor 3 times, evaluation of issues generated by this actor in the previous projects is suggested.
  The Turkey-based Public 1 assigned to the Project 12 has been defined as critical actor 3 times, evaluation of issues generated by this actor in the previous projects is suggested.
- Portfolio profit is dependent on ر.ع. (Omani Rial) at 73.91 percentage. Fluctuations in this currency would effect the portfolio seriously. Taking into consideration of this situation and making expenses in the same currency as far as possible to reduce the financial risk are suggested.
- Portfolio profit is 73.91 percentage financed by the Client: Oman-based Public 1. High dependency of the portfolio profit to this client entails financial risk.
- There is high learning dependency between the projects Project 9, Project 10 in the portfolio, establishment of the information transfer between these projects is suggested.
  There is high learning dependency between the projects Project 9, Project 12 in the portfolio, establishment of the information transfer between these projects is suggested.
  There is high learning dependency between the projects Project 10, Project 12 in the portfolio, establishment of the information transfer between these projects is suggested.
- Successes of the Project 10, Project 12 in the portfolio are dependent to each other since they include a result required for each other, consideration of this situation in management is suggested.

Figure 4.46: Warnings for the Portfolio

Portfolio Oriented Evaluation: When portfolio projects are examined, it is seen that “Project 12” will be at the same criticality as “Project 10” in the current portfolio. The “outcome dependency” between these two projects plays an important role in assessing inter-project dependencies. The evaluation of the current situation would change according to the type of the relation. The warning on dependency of the portfolio to the client and the currency is also very important and notable. It is also observed that “Project 12” is the least risky project of the portfolio.

Overall Evaluation: The tool was appreciated for being “web-based” and for its suitable design for handling project portfolios. It was emphasized that the “algorithm” of the tool was appropriate and that the obtained “visual outputs” have a great potential to support decision-making. In particular, it was evaluated to be very beneficial for the user to automatically create “portfolio alternatives” and can gradually add potential projects to be included in the analysis. The possibility of comparing different portfolio alternatives through the provided “measures” and “graphics” was also found suitable and successful. The user indicated that the visual features of the tool are particularly useful especially the “network map” and “project symbol” are very informative for decision-making. The user emphasized that in case of several project alternatives, the tool could lead the user in choosing the right project for the company by utilizing the expectations, which are obtained through “predictions” as a result of its own performance. In addition, it was stated that with the “flexibility” of the tool, the user can meet the changing conditions of the company as well as the developments in the construction sector to considerable extent. The scores obtained from the user’s evaluation of the survey on the 7-point Likert scale (1: “Strongly Disagree” - 7: “Strongly Agree”) are presented in the following table (Table 4.63).

Table 4.63: Survey Results following Case Study 1

	Completeness / Coverage	**Suitability / Accuracy**	**Usefulness**	**Usability**	**Receptiveness**	**Overall**
Ratings	5.93	5.83	5.80	5.79	6.00	6.00
Average	5.892 / 7					

4.3.6.2. Case Study 2

Company and Expert Information: Case study was held by a construction company professional working in the business development department at one of the medium-sized companies specialized in “ground works” in Turkey working in the domestic and international market.

Summary of the Case Study 2: The expert followed a similar process with the Case Study 1. Ten projects were entered as five completed, two on-going and three potential projects by partially modifying and encoding the selected projects in the portfolio to prevent the recognition of the projects. Eight lessons learned was entered for six different projects. At the end of the detailed analysis process of the portfolio, the expert delivered following evaluations.

Portfolio Oriented Evaluation: Portfolio projects are critical at the same extent due to their dependencies. Therefore, it will be important to keep continuous track of inter-project dependencies while managing this portfolio. Moreover, the fact that the projects have a learning dependency among each other makes it very important to implement parallel projects and share information. Due to the magnitude of the financial dependency between the "airport" and the "high-speed train" projects, it can be observed that they are more critical and a related warning is also presented for these projects. In addition, since the portfolio is fully dependent to the "Turkish Lira", this situation causes financial risks for the imported materials or products. Current projects are carried out for the same client, therefore, undertaking these two projects ("Project 8" and "Project 10") together will provide diversity in clients that the company is serving for and the financial risk will be reduced to a certain extent as well.

Overall Evaluation: It was stated that the portfolio selection part might be restricted for utilization by the company currently since the tool does not comply with the project selection strategy of the company due to its structure and medium size. However, it was also underlined that the tool would be helpful in management of the current portfolio and adding the projects that would be undertaken to the current portfolio would help to manage the existing projects with portfolio perspective while also paying regard to the inter-project "dependencies". It was stated that even the tool is not considered to be used for portfolio management, it still has capability to be utilized since it provides a "database", which makes it possible for management of "lessons learned" and "predictions" for a company. Especially, the existence of the "tagging system" and its editable "tag tree" provided in the lesson management section was found very practical and useful. The user also disclosed that he could set up a lesson management system by improving the tag tree in a way that it would be more appropriate for their company structure, for example by integrating the machine and equipment used with their brand and model information. The modifiability and practicality of the "risk and strategic assessment" sections were also found to be very useful. The scores obtained from the evaluation of the user's questionnaire on the 7-point Likert scale (1: "Strongly Disagree" - 7: "Strongly Agree") are presented in the following table (Table 4.64).

Table 4.64: Survey Results following Case Study 2

	Completeness / Coverage	**Suitability / Accuracy**	**Usefulness**	**Usability**	**Receptiveness**	**Overall**
Ratings	6.21	6.00	6.20	5.93	6.20	6.00
Average	6.090 / 7					

4.3.7. Update for the Beta Version

As a result of the evaluation studies, the tool was updated before further testing by its possible users through only minimal aesthetical changes as follows:

- minimization of the provided tables,
- re-sizing of some of the sections when the browser is minimized,
- relocation of some of the buttons (e.g., "save" button),
- repeat of some of the buttons in different pages (e.g., "delete" button),
- automatic updating ability of the related section when an operation is made, etc.

Since the "usability testing" based on this re-updated alpha version did not end up with any further update in the tool as it is presented in "Chapter 6: Usability Testing", the current version is also accepted to be the "beta version" as the version representing "complete product functionality", which was further tested through "real application" by direct utilization by the "focus group".

4.4. Concluding Remarks

This chapter reveals the step by step process followed in generation of the tool together with the improvements made in each step. It presents the progress starting with the points identified in the needs analysis, which extends to development of the process model, and finalizing in generation of the updated alpha version of the tool. The next chapter introduces this version of the tool (beta version), which is also the version used in usability testing and actual implementation as well.

CHAPTER 5

COPPMAN

This chapter presents the "updated alpha version" (also the latter "beta version") of the tool used in evaluation studies of "usability testing" and "real application" as presented in the following chapters.

5.1. Overview of COPPMAN

COPPMAN basically uses the past projects of the company for generating knowledge to be utilized today in line with the current situation and strategy of the company to support establishment of portfolios responding the current need. Therefore, COPPMAN handles the projects through main categorization in three types as:

- "completed projects" where the "lessons learned", "predictions", and "learning potential" can be retrieved,
- "on-going projects" as the projects currently being executed, and
- "potential projects" that the company is considering to evaluate for bidding/undertaking.

COPPMAN establishes the portfolios by grouping the current/active projects (i.e., "on-going" and "potential projects") through scenarios in terms of portfolios including different "potential project alternatives" in each as combinations of the "potential projects". Project dependencies within the portfolios are identified between the portfolio projects as "on-going" and "potential" projects and further used in the process of "portfolio risk assessment" and "warnings" specific for the portfolios. The tool helps evaluation of the different scenarios as alternative portfolios considering the “risks”, “strategic fits” and “expected profitabilities” together with some project/portfolio level measures in addition to analysis of the past project knowledge through different retrieval mechanisms as “filtering”, “similarity analysis”, and “tag-based search”. Therefore, the tool processes through the generated methods for automatically calculating the “dependencies” between projects, visualizing them through “dependency network maps”, and numerically integrating them into portfolio analysis process. COPPMAN is capable of evaluating the impact of any project candidate (“potential project”) to the existing portfolio within the context of scenario analysis. The effect of the project in question is depicted in terms of different types of dependencies with the intent of increasing the portfolio success by facilitating resource management of the projects considering the “resource dependencies”, risk assessment by considering the effect of “financial dependencies” and fostering learning opportunity between projects through “learning dependencies” and tracking the process in the light of the “outcome dependencies”. In addition to the support provided with the visual “portfolio dependency map”, the calculated “dependencies” between the projects and “warnings” on how this specific portfolio could be managed are provided. Through the presented capabilities the tool can direct its users to proceed the planning process of dependent projects together, to concentrate on learning opportunities between similar projects, and to assess level of risk considering dependencies between projects. The magnitudes/intensity of dependencies can be used in identification of “critical dependencies” as well as “critical projects” and “critical portfolios” in comparison to others by using the properties of network map. The dependency that has a magnitude over the limits within the portfolio is to be identified as the “critical dependency” between all dependencies and may indicate that this dependency needs attention. For example, based on this identification, the tool can warn the user to make the time planning/scheduling of the projects “A”, “B” and “C” together, to concentrate on the effective transfer of lessons learned between the projects “D” and “F”, to consider the projects “E” and “G” together in developing the risk management plans. In addition to identification of “critical dependencies”, “projects” and “networks/portfolios”, the accumulated/total effect of dependencies is taken into account in portfolio risk assessment. The effect is designated to the average risk scores obtained by individual risk assessments carried out by the user for each single project in the portfolio. Thus, the accumulated/total effect of the dependencies between the projects in a portfolio can be calculated and presented to the decision maker both by visual aids and quantitative measures to support decision-making process. In the light of the summarized features, COPPMAN can provide a complete support to management of portfolios by providing visual and numerical depiction of past and present, as well as selection of the project/portfolio in the light of the current situation and drawn up strategy.

5.1.1. Summary on Portfolio Management Principles of COPPMAN

COPPMAN can be deemed to adapting portfolio management principles and responding the need of construction companies in portfolio management through the following characteristics.

- **Portfolio Creation:** Following entry of project information, once the project alternatives to be included in the analysis are chosen the tool automatically creates portfolio alternatives and presents to the user. Thus, the user reaches the potential of evaluating the projects in an integrated framework according to their locations and their effects in the portfolio.
- **Handling Project Dependencies:** Project dependencies becomes an important issue when handling projects successfully in portfolios is considered. Unlike many other portfolio management tools, COPPMAN can automatically quantify dependencies between projects, present them to the user, and take them into consideration in the portfolio analysis phase.
- **Utilization of Past Project Information:** Since major focus in portfolio management is handling all of the projects of the organization as a permanent undertaking, utilization of all project data is important. At this point past projects are to be evaluated regarding the performance and strategies should be developed in the light of knowledge generated through these projects.

These projects may also serve as depiction of the strategies followed so further strategies should be built upon these projects. COPPMAN is aimed to be solve another deficiency of project portfolio management oriented work, which is identified as utilization of past project data is appreciated to be limited and difficult to integrate to project portfolio management when it is compared to financial portfolio management. In this respect, utilization of past project data in COPPMAN database is provided for extraction of knowledge for the use of its users at different stages of evaluation or upon user's request, such as retrieval of predictions, lessons learned, and other project data.

- **Prioritization of Portfolios:** Portfolio management is also serving for strategic management, therefore strategic considerations are to be embedded within portfolio management processes. The ability to prioritize projects in line with strategic objectives, which forms the basis of project portfolio management practices, is provided by COPPMAN. "Risk", "strategic fit" and "profitability" values of the projects can be depicted in different forms within the portfolio, and portfolio alternatives can be sorted by these values as well as by "portfolio values", which is a measure generated to indicate the portfolios with "minimum risk" and "maximum strategic fit".
- **Visualization of Portfolios:** Since portfolio management is mainly for depiction of the complex analysis case through informative and supportive measures to ease decision-making, visual aids are the main means for facilitating the process through highlighting different aspects of portfolios in comparative projections of the case. Therefore, COPPMAN has the ability to visualize the project and portfolio characteristics in various forms including visual representation of project dependencies and project/portfolio characteristics through different measures provided in various graphics.
- **Portfolio Warnings:** Portfolio tools would be more useful as long as they are equipped through capabilities of IT. In line with this, a warning mechanism is integrated to COPPMAN to highlight the points that needs attention and to prevent their missing out in the analysis. Thus, the tool can present a variety

of warnings to its users regarding portfolio alternatives that are mainly focused on risk and resource management as well as selection of these alternatives.

It is believed that these features offered in COPPMAN are sufficient to integrate project portfolio management understanding to construction projects and expected to help adoption of the portfolio management practices for construction projects.

5.1.2. Summary on Functions of COPPMAN

A typical process for utilization of COPPMAN consists of main stages of “data input”, “evaluation” and “analysis” (Figure 5.1). As initial consideration user should create the database by entering related information. Some of the project entries as “project inputs” are to be identified in the database to facilitate data entry and to ensure consistent data entry. Thus, once “project inputs” are identified, they are presented to the user as a drop-down list during project addition process. In addition, COPPMAN includes some user-defined fields provided for personalization of tool utilization. After defining the relevant parameters as “project inputs” and “user preferences”, the user will be able to define the “completed projects” and the information to be used in the evaluation of the projects through entry of the data for “Post Project Appraisal” and “Lessons Learned” sections. Following entry of past project data for establishing the “corporate memory”, information of the active/current projects will also be entered and the project information entry will be completed.

Following establishment of the database, the user will be able to start evaluating the projects. The proposed operation at this point will be obtaining an inference for the current projects by using the past project information at hand before making the required evaluations. Through the support provided by evaluation of the past project data by different display options, the required project evaluation processes in terms of “Risk” and “Strategic Fit” assessments will be based on sound assessments.

Once the assessments are completed, COPPMAN would be ready for portfolio analysis. The user would be able to examine the alternatives resulting from the portfolio analysis and to select a portfolio that is appropriate for the company strategy by taking into account the presented figures and warnings.

The process in terms of basic functions is summarized in the following figure (Figure 5.1).

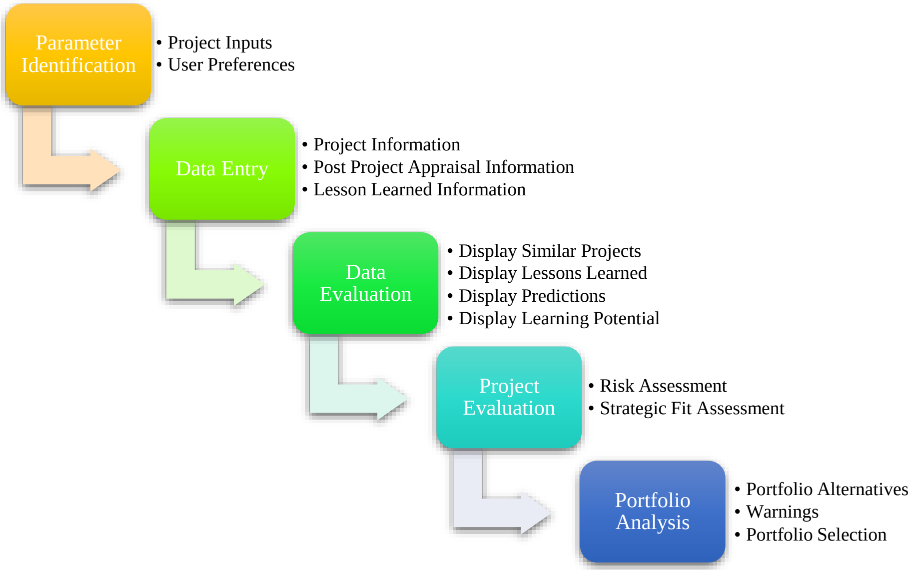


Figure 5.1: Summary of Functions

5.1.3. Summary on Capabilities of COPPMAN

In the light of the basic information presented, COPPMAN has the following capabilities:

- To keep the project and learned lesson information in the database and to present to the user by different search methods to be selected by the user,
- Supporting risk and strategic fit assessment processes by reviewing past project information,

- Automatic calculation, visualization and analysis of inter-project dependencies,
- Automatic creation and visualization of portfolio alternatives,
- Providing warnings to users regarding each portfolio alternative,
- Guidance and warnings provided to the user regarding portfolio selection,
- Warning the user about incorrect / incomplete and forthcoming operations,
- Providing flexibility in the use of the tool through user-defined fields, and
- Establishment of a company-specific information management network with different levels of authority that can be assigned to users.

As complementary to the summary provided, the details of COPPMAN are presented in the following sections.

5.2. Fundamentals of COPPMAN

This section presents COPPMAN through a more detailed way in terms of its complete details on its “framework”, “functions”, “interface” and “implementation”.

5.2.1. COPPMAN Framework

Main objective of the conceptual framework of COPPMAN is conversion of “projects” to “portfolios” through minimum input by the user (Figure 5.2). User is required only to check and evaluate projects and carry out analysis at the portfolio level. Therefore, the “project knowledge” captured in the “database” by the “project team” and “managers” constitutes the foundational components of the framework as establishment of the basis for tool utilization. “Database” serves for provision of the “supportive information” as the valuable information retrieved from the previous projects for their use in evaluation of “current projects”, and also keeps the project information for automatic calculation of “project dependencies”. Thus, “analyst” is expected to investigate the “supportive information” as retrieved information of similar projects, lessons learned, predictions and learning potentials and in the light of this support evaluate “current projects” prior to analysis in terms of their risks and strategic fits. “Project dependencies” are depicted through network maps and also automatically included in the “portfolio analysis” process as a part of the portfolio risk. Through “portfolio analysis” the user gets portfolio level measures such as portfolio risk, portfolio strategic fit, and other portfolio properties as well as the information of projects within the portfolios. Thus, at the end of the analysis, the user obtains possible “portfolios” that can be formed in line with the “current projects” in hand, and receives some useful advice about selection and management of these portfolios.

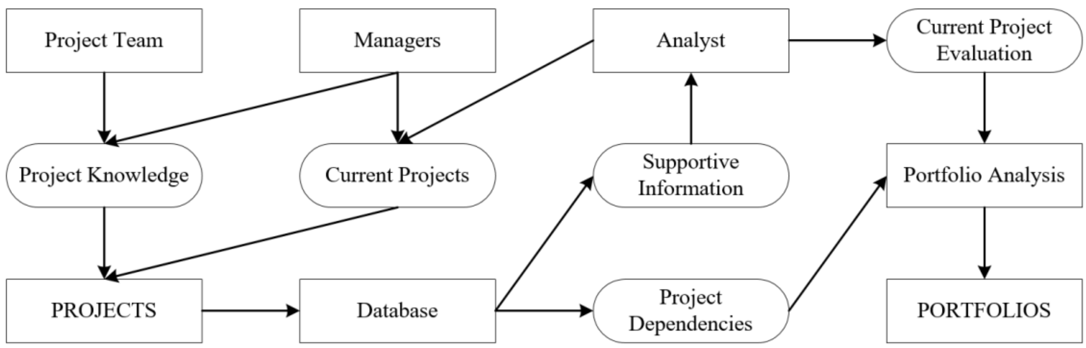


Figure 5.2: Conceptual Framework (Bilgin et al., 2018)

COPPMAN identifies projects under three categories of “completed”, “on-going”, and “potential” projects based on their statuses. “Completed” project information is to be identified within the system to successfully represent the past and establish new portfolios accordingly. COPPMAN helps user to retrieve this valuable information to evaluate the current projects as “on-going” and “potential” projects. Once evaluations on projects are completed, user can proceed with portfolio analysis and obtain summaries and warnings on the established possible portfolio alternatives. Complete process model of the tool can be summarized on three sections as “data input” for establishing the database, “data analysis” for displaying supportive information and evaluating current projects, and “data output” for portfolio analysis results as it is provided in the following figure (Figure 5.3). Further details of these section of the process model will be provided in the following section (5.2.2: COPPMAN Functions).

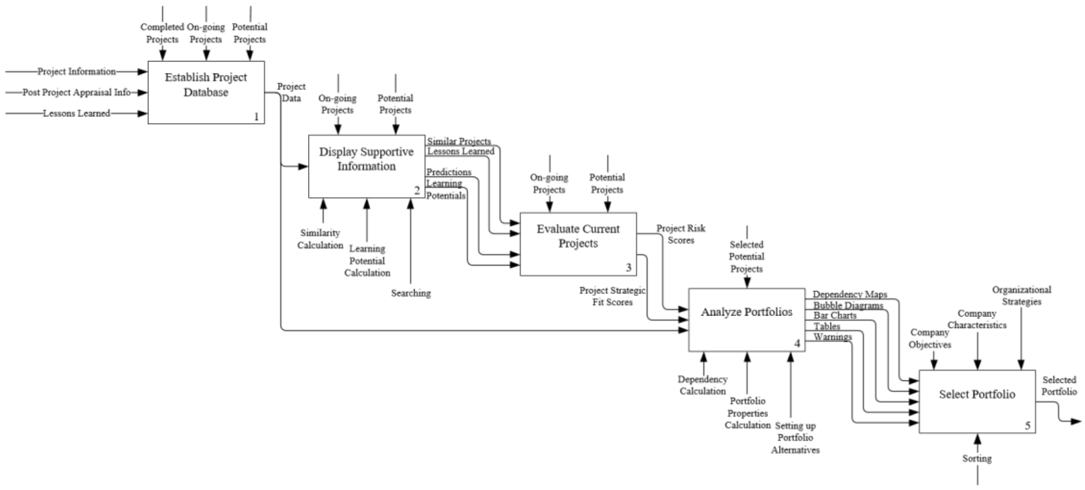


Figure 5.3: Overall Process Model (Bilgin et al., 2018)

In the light of the presented process model, COPPMAN provides exchange of data provided in its database through “inputs” and “outputs”. COPPMAN utilizes a methodology that requires input from the user in terms of “project information”, “post project appraisal”, “lessons learned”, “risk evaluation”, “strategic fit evaluation”, “project inputs” and “user preferences” (by which user can define ready-to-use inputs, change weights of attributes, change evaluation factors and the tag tree). Before risk and strategic fit assessment processes the tool can provide outputs as “learning potential”, “predictions”, “similar projects” to project under evaluation, and query of “lessons learned”. Following this investigation process, “risk” and “strategic fit” evaluations are made as inputs to the tool. To perform portfolio analysis, further inputs as the selected “potential projects” that intended to be evaluated in the portfolio together, and the “common currency” to provide evaluation of projects with different currencies are provided. Following the analysis, tool presents data on portfolio alternatives and provides outputs as “dependency map” of projects; “bubble diagrams” of different parameters as project/portfolio risk, project/portfolio strategic fit, portfolio value; "bar charts" of change in portfolio value vs. change in portfolio profit. In addition to these visual outputs, "warnings" can also be obtained according to the situation of the portfolio alternatives. The flowchart displaying main input-output data of the system is presented in the following figure (Figure 5.4).

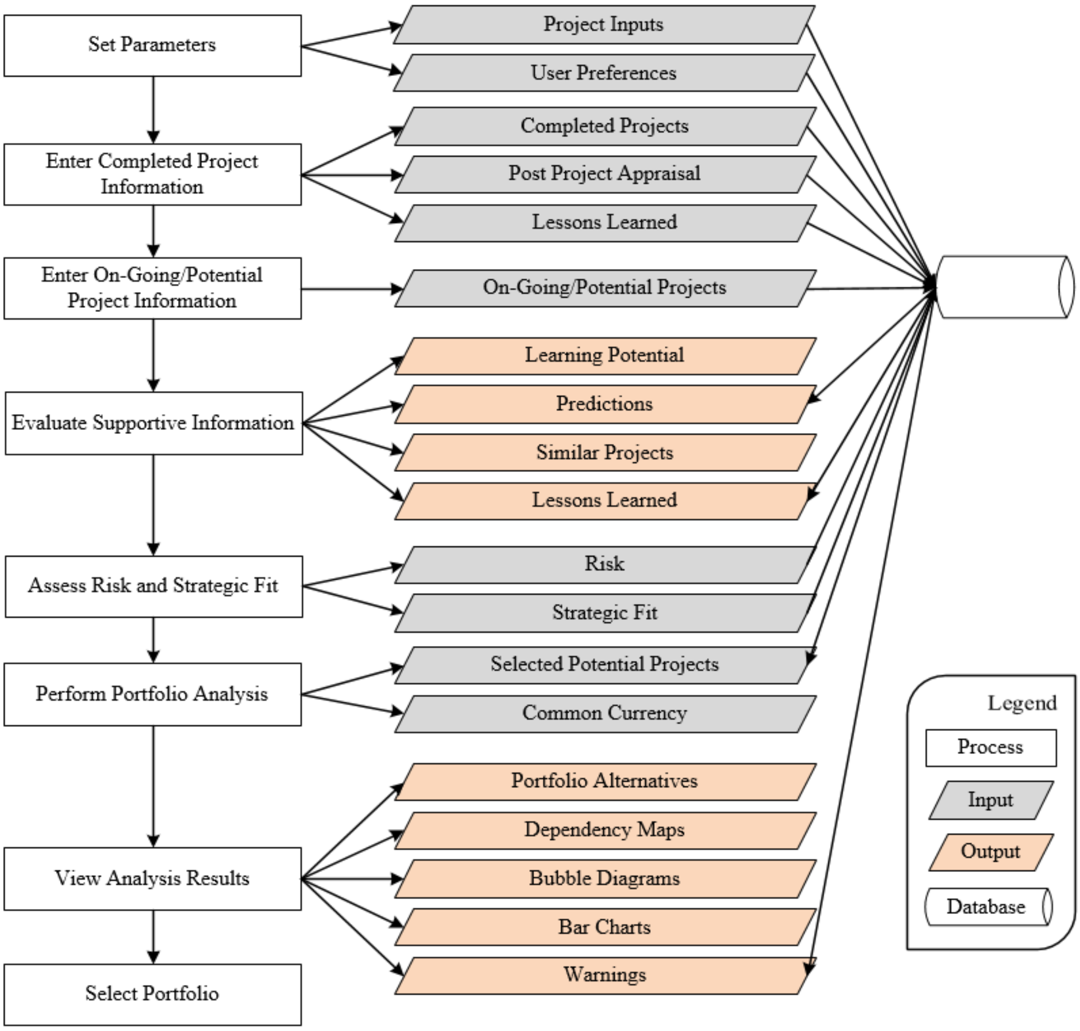


Figure 5.4: Flowchart for Main Inputs and Outputs

In accordance with the data "input" and "output" diagram, the data flow diagram of COPPMAN is generated as provided in the following figure for mapping out the flow of data within the established system (Figure 5.5).

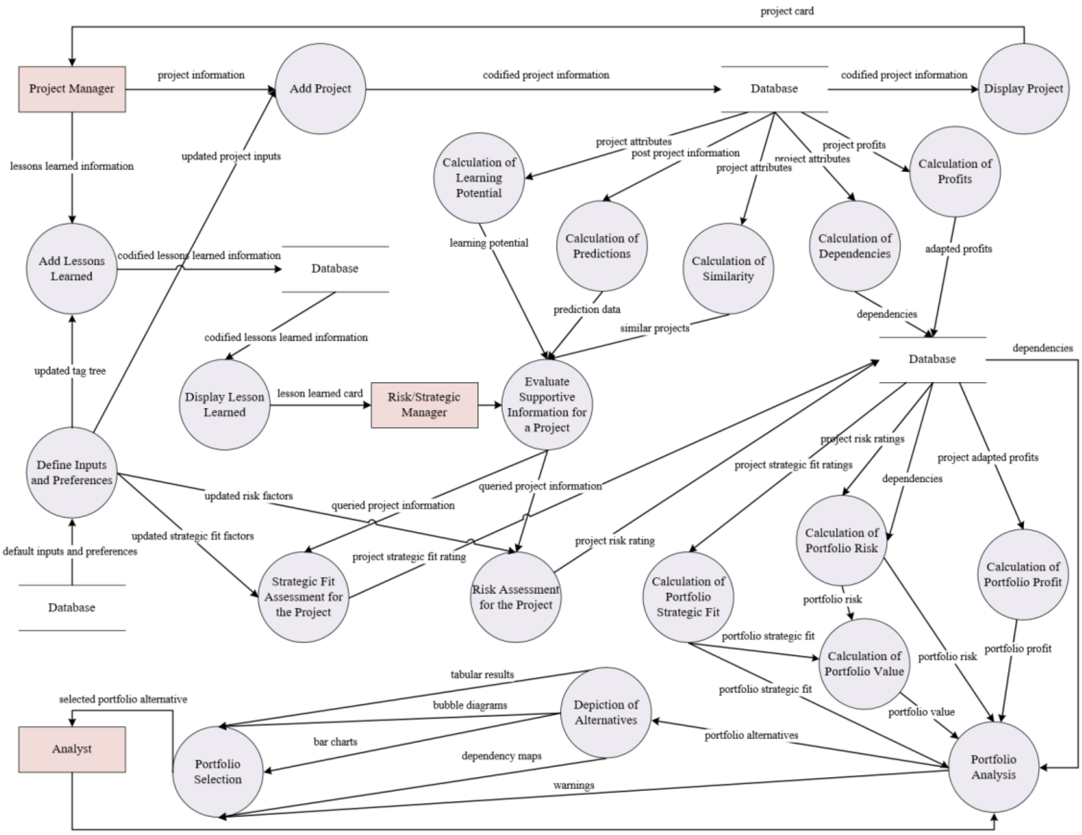


Figure 5.5: Data Flow Diagram

Regarding its codification, COPPMAN is a cross-browser compatible single page web application developed on top of "ASP.NET MVC" framework. Server-side components are programmed with "C#" and client-side components are programmed with "JavaScript". The user interface is functional for data entry and visualization where simple selections are required for analysis and review of results. Assistance in decision-making process is also provided through warnings appearing with portfolio alternatives and for portfolio selection. The provided main "menu" and "related" functions are generated as follows to serve for the intended complete system:

- "Project Inputs" and "User Preferences" to allow user to define parameters,
  - Define/Change ready-to-use inputs or parameters
  - Define password protected users with limitations in access to specific functions

- “Projects” to define projects, perform project operations and view projects,
    - Enter/Display/Edit/Remove project information for all types of projects
    - Enter post project appraisal data for completed projects
    - Display similar projects to a specific project
    - Obtain learning potential information for on-going/potential projects
    - Make risk and strategic fit evaluations for on-going/potential projects
    - Display risk and strategic fit evaluation history for all types of projects
- “Corporate Memory” to enter and retrieve lessons learned,
    - Enter/Display lessons learned data for all types of projects
- “Predictions” to query predictions through different options,
    - Obtain predictions for a specific project through filter or similarity query options
- “Portfolio Management” to perform portfolio analysis and select a portfolio,
    - Perform portfolio analysis
    - Display portfolio situation through tables and diagrams
    - Get warnings for situation of a specific portfolio and also for selection
    - Display/Remove current portfolio and portfolio alternatives
    - Investigate all portfolio alternatives considering on-going projects and at most 4 on-going project alternatives at once
    - Select portfolio through considering different selection criteria
- “Library” to use as a help.

The details COPPMAN in terms of “functions” will be provided also through its “interface” in the following sections (“Section 5.2.2: COPPMAN Functions” and “Section 5.2.3: COPPMAN Interface”).

5.2.2. COPPMAN Functions

This section presents the details on functions of COPPMAN grouped under main sections of “data input”, “data analysis”, and “data output” as follows.

5.2.2.1. Data Input

User should make the necessary adjustments according to the need to use the tool effectively and facilitate the entry of the required information. Necessary process for establishing the database that forms the basis of tool functions can be summarized in the following order:

- **Project Inputs:** COPPMAN provides identification of ready-to-use project inputs that are provided as drop-down lists structured for company specific use to ease the data entry process.
- **Preferences:** To provide some level of flexibility and adjustment for specific use, the tool lets the user change some numerical figures used in calculations and evaluation criteria used in the process which are provided in default values in the installation of COPPMAN. Setting the roles and authorization of users are also required to manage users of the tool for establishing an effective utilization where every user has a specific role in the system and accesses only to the necessary functions/operations of the tool.
- **Project Entry:** Project information is to be entered following setting of the inputs and the preferences. Project information is entered on three different statuses as "completed", "on-going" and "potential" (the completed projects in the study are referred as "past project" and the on-going and potential projects as "current/active project"). There are standard forms provided specifically for each project status to ask the minimum information required according to the status of the projects. The forms are equipped with dropdown and recall lists to minimize the effort required, whereas some free text areas are provided to leave the user free to describe the case and to provide flexibility as well. In addition to the general project information to be entered, there is a "Post-Project Appraisal" section for the completed projects, unlike the others. The data saved via this section will be presented to the user under the section "Predictions", and the user will be able to get insight about the general status of the projects. Therefore, only the completed project form includes post project appraisal section additionally to

basic project information to make the user complete the required project information to utilize the tool at full capacity.

- **Lesson Learned Entry:** By entering the “Lessons Learned” information for the completed projects, the “Corporate Memory” section of the tool will be created so that the user can contribute to the learning of the company in the light of this information and will be able to identify points to be considered, to be careful and to take precautions regarding the projects. COPPMAN directs the user for entering the lesson learned for completed projects; however, user may enter lessons learned for current projects in case of an intent of timely capture of the lessons in the established knowledge management system. Therefore, it is optional that lessons learned can be entered for on-going and potential projects to ensure that the lesson learned to be recorded at the time of their occurrence; however, the user is enforced to enter this information at least for the completed projects in the tool. A single form is designed for lesson entry to ensure simplicity and consistency in data entry while a tagging system is provided to make lesson entries applicable to all types of projects and experiences through the categorization possibility provided. A hierarchical tag tree of around 2000 concepts in construction is provided in an editable format to enable the user freely classify the lessons in the intended level of detail and effectively retrieve the lessons according to the categorization established. Lesson entry form itself already provides some level of classification in terms of “type” (best practice or not), “effect” (on duration and cost), and “responsible party” (actor) of a lesson as supportive inputs to “description” and “recommendation”. Then user is further asked to assign related tags where they are highlighted in the tag tree with their location in the hierarchy through free-text search on the tag tree taxonomy. Thus, user can enter a particular lesson according to the intended level of detail and categorization by the assigned tags (Eken et al., 2017, Eken, 2017).

5.2.2.2. Data Analysis

Prior to the evaluation of the “Risk” and “Strategic Fit” required for on-going and potential projects, the user is guided to review the past project information. COPPMAN directs user to investigate available past project information in terms of different aspects obtained through several retrieval mechanisms. COPPMAN provides user to display the following as “supportive information” to the evaluation process:

- **Similar Projects:** are investigated through automatic sorting of completed projects according to calculated similarities to the current project at hand. This ability attracts user to investigate the projects that need particular attention. Therefore, user can review the project card including the summarized project information or directly reach to the entered information. This will make it easier for the user to access similar projects while allowing a more detailed examination of a project and incorporating it into the evaluation of the obtained information.
- **Lessons Learned:** that may be the most beneficial and useful for the project in hand are retrieved by several mechanisms as filtering-based, similarity-based, and tag-based search. In order to be able to create the database, it is required to enter lesson learned information for completed projects; but it is aimed to increase the data accuracy by allowing the user to simultaneously enter these information into the application and evaluation stages of the current projects. This information will enable the user to assess or evaluate the likelihood of such problems or successes, and to manage or reinforce their project planning decisions. Thus, user is reminded with the considerations of past actions and their results for possibility of improving their current actions (Eken, 2017).
- **Predictions:** are presented to the user based on the information entered in the post project appraisal section in terms of “mode” or “average” of the entered data calculated based on selection of either similarity-based or filtering-based retrieval. Predictions provides generation of some level of insight according to the scope of the project in the light of the past projects. This will allow the user

to use this impression from past projects in risk and profitability evaluations for the current projects.

- **Learning Potential:** is the score presented to attract the user as indication of the project that may be more beneficial for achievement of strategic goals in terms of learning centered objectives since it requires a comparatively new execution process for the company. The score may also indicate the project that require special attention in risk assessment for its criticality since it includes further risk due to learning period of the execution.

Following investigation of available information, user can proceed with risk and strategic fit evaluations for the current projects through a more sound analysis of the case. Both these sections have a list of factors for evaluation and scoring criteria in its default of installation of COPPMAN; however, user can set the specific evaluation factors and criteria within the tool. In accordance with every evaluation criteria, COPPMAN calculates the risk/strategic fit scores over 100 and utilizes this value in calculation of risk/strategic fit scores for the portfolios. Average of the scores are directly taken as the value for portfolio strategic fit, whereas COPPMAN integrates dependencies to average risk score to obtain portfolio risk considering the effect of dependencies between projects of the portfolio. Additionally COPPMAN keeps and presents histories of these evaluations and warns user to update his/her risk evaluation prior to portfolio analysis. The evaluations to be completed for all current projects before performing the portfolio analysis are as follows:

- **Risk Assessment:** Risk scores are obtained for all current projects resulting from the completion of risk assessment forms in the tool. These scores represent the risk of the project directly and are further used to calculate the risk of the generated portfolio.
- **Strategic Fit Assessment:** Strategic fit assessment forms work as in the same form of risk assessment system and assess the suitability of each current project to the company strategy. The scores obtained for the evaluation of each factor are used to calculate strategic fits on project and portfolio basis.

5.2.2.3. Data Output

After completion risk and strategic fit assessments for all current projects, the system would be ready to perform portfolio analysis. COPPMAN establishes all the portfolio alternatives in the form of potential project combinations added to the current set of on-going projects. Once the user selects the potential projects to be included in the analysis, all the portfolio options are obtained and presented to the user for investigation of the portfolios for their management and selection as well through visualization of project and portfolio properties and warnings obtained. Thus, the user is guided to a selection in line with the company strategy and in accordance with the available resources while also establishing the measures for successful management of portfolios. Details of the outputs are as provided below:

- **Portfolio Alternatives:** are depicted through "portfolio level" measures, firstly through "table" summarizing the portfolio properties including:
    - listed short codes of potential projects in the portfolio,
    - average risk and strategic fit scores of the projects,
    - network density of dependency map of the projects,
    - portfolio risk score,
    - portfolio strategic fit score,
    - portfolio success (as the value that indicates minimum portfolio risk),
    - portfolio value (integrated value of portfolio strategic fit and portfolio success to indicate the portfolio with lowest risk and highest strategic fit), and
    - portfolio profit (average adjusted profit of the projects where expected profit is adjusted according to past project financial data).

  "Bubble diagram" of alternatives is provided to represent the risks against strategic fits where each bubble also indicates the adjusted profits of the portfolio alternatives and also opens the details of the selected portfolio when double clicked. Portfolio values are displayed in a subdivided "bar chart" representing the portfolio strategic fit and success through its portions. Corresponding change in the portfolio profit according to change in the portfolio value is demonstrated through “bubble diagram” and also “bar chart”, where unit change bar chart graph is also distinguishable to ease the comparison of alternatives. Finally, a “warning” on this profit-value change equilibrium is provided to the user to support portfolio selection. Following investigation of the portfolio alternatives through “portfolio level” measures at once, user can further investigate a portfolio in detail through the measures at “project level” specific to that portfolio.

- **Portfolio Details:** depicted through a “table” that reminds the properties of the selected portfolio and additionally summarizes the project properties through:
    - project name,
    - start and end dates,
    - status (on-going or potential),
    - risk score,
    - strategic fit score,
    - centrality value, and
    - details button that directs user to the project card.

As in “bubble diagram” of portfolio alternatives, risks and strategic fits of the projects are displayed on a bubble diagram where each bubble indicated the adjusted profits of the projects and also opens the related project card when it is double clicked. The most supportive element of the tool regarding dependencies of the multi-projects within the portfolio is presented in this section through the “dependency map”. The nodes on the map represents different projects in the portfolio while arrows between the project nodes represents the calculated dependencies between the projects in different colors each indicating a different dependency type. Thicknesses of the arrows indicates the comparative magnitudes of the dependencies while project nodes are drawn to be sized comparatively according to the level of their centralities, which further represents criticality of a project in the portfolio. Magnitudes of dependencies and centralities are also numerically provided by “pop-up information boxes” that appears when the related arrow/node is selected. Additionally “matrix table” of the dependencies also opens up on the graph for numerical depiction of the magnitudes of dependencies. As a final consideration, “warnings” on the portfolio at hand are provided based on (Bilgin et al., 2017):

  - network density of dependency map (for critical attention to complex dependencies of portfolio alternatives),
  - centrality of projects (for most critical projects within the portfolio),
  - completion percentage of projects (for consideration of projects that are close to completion),
  - profitability of projects (for projects with low profit),
  - risk score of projects (for projects with high risk),
  - clients/partner companies as critical actors (for clients/companies that caused problem previously),
  - financial dependency of projects on same currency/client (for identification of major financial dependency),
  - resource dependencies of projects (for consideration in work/procurement planning),
  - learning dependency of projects (for establishment of information transfer) and
  - outcome dependency of projects (for consideration of the dependent result of the projects).

- **Portfolio Selection:** is section is used for prioritization of the projects by sorting the alternatives according to the priority criterion selected by the user. User can sort the alternatives according to risks, strategic fits, values or adjusted profits of the portfolios to provide a direct focus on a smaller set of portfolio alternatives for detailed comparison of the alternatives.

5.2.3. COPPMAN Interface

Further details of COPPMAN interface such as the menu properties and different pages provided through these menu links are provided in detail in Appendix G through “COPPMAN User Instructions”. This section further includes a link to the “Glossary” of COPPMAN with Appendix H.

5.2.4. COPPMAN Implementation

COPPMAN provides evaluation of project alternatives by performing scenario analysis together with on-going projects and past project information can be used for forecasting purposes. For this purpose, it is expected that the database of the completed projects will be created by entering the information of the “completed projects”. Following entry of the information for “on-going” and “potential” projects, user can continue with the analysis phase. As a result of the analysis, user will be informed about the portfolio alternatives to be formed with “potential projects” and directed for portfolio selection. Therefore, flowchart for the roadmap for possible utilization of the tool is as provided in the following figure (Figure 5.6). To utilize COPPMAN at full capacity of its expected benefits, user should at least:

- define all projects in hand,
- define inputs specific to the cases in hand,
- enter lessons learned for at least completed projects,
- make risk and strategic fit evaluation by investigating supportive information,
- make sure that all evaluations are made according to the active set of factors and evaluations for risk are not made before at least 3 months,
- select set of on-going projects to be added to the analysis, and
- review results to either select portfolio or select new set of on-going projects for another analysis.

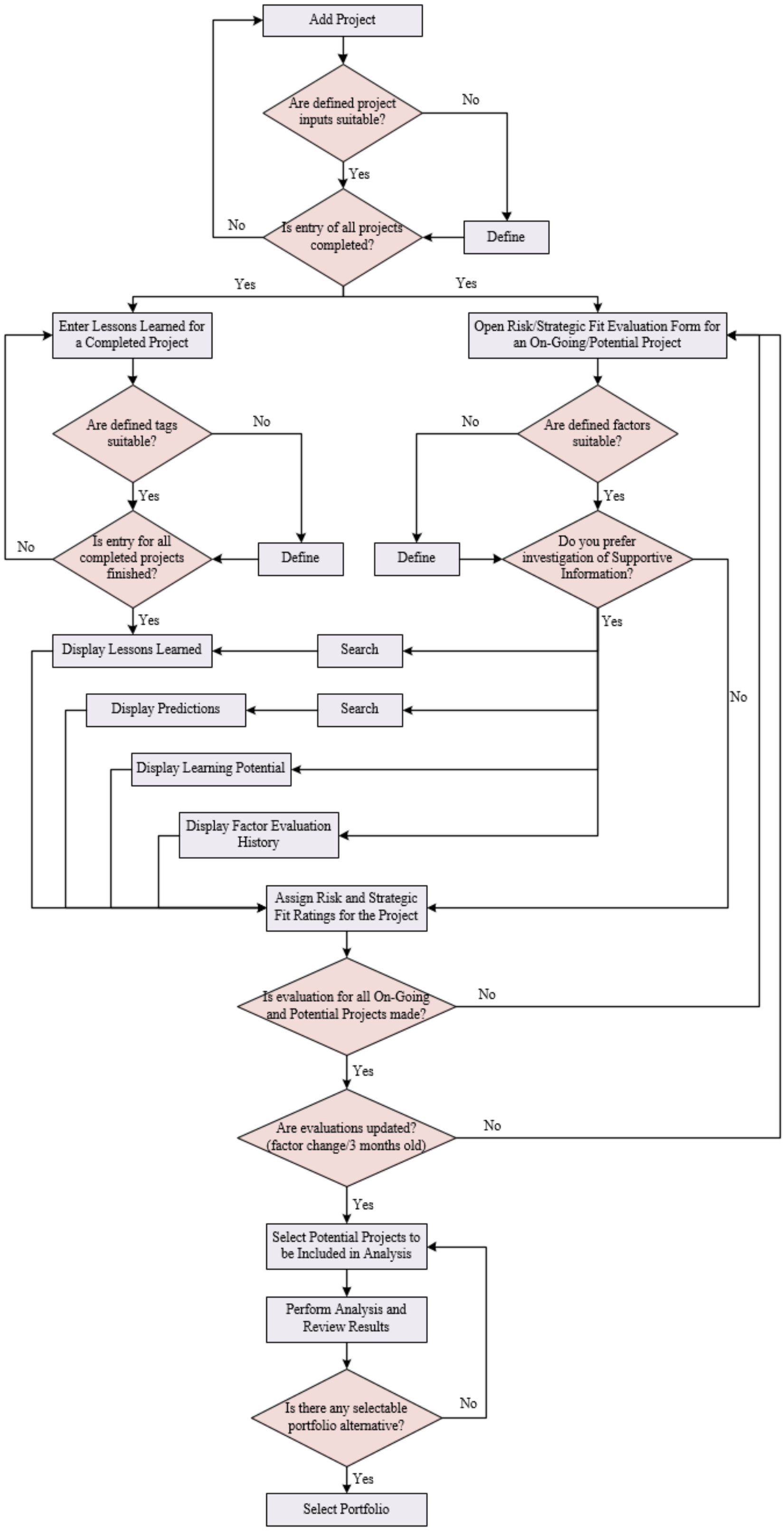


Figure 5.6: Roadmap Flowchart

In light of the required basic operations, the use case diagram of COPPMAN is as provided in the following use case diagram for further structuring the utilization process of the tool with the user management system to be established (Figure 5.7).

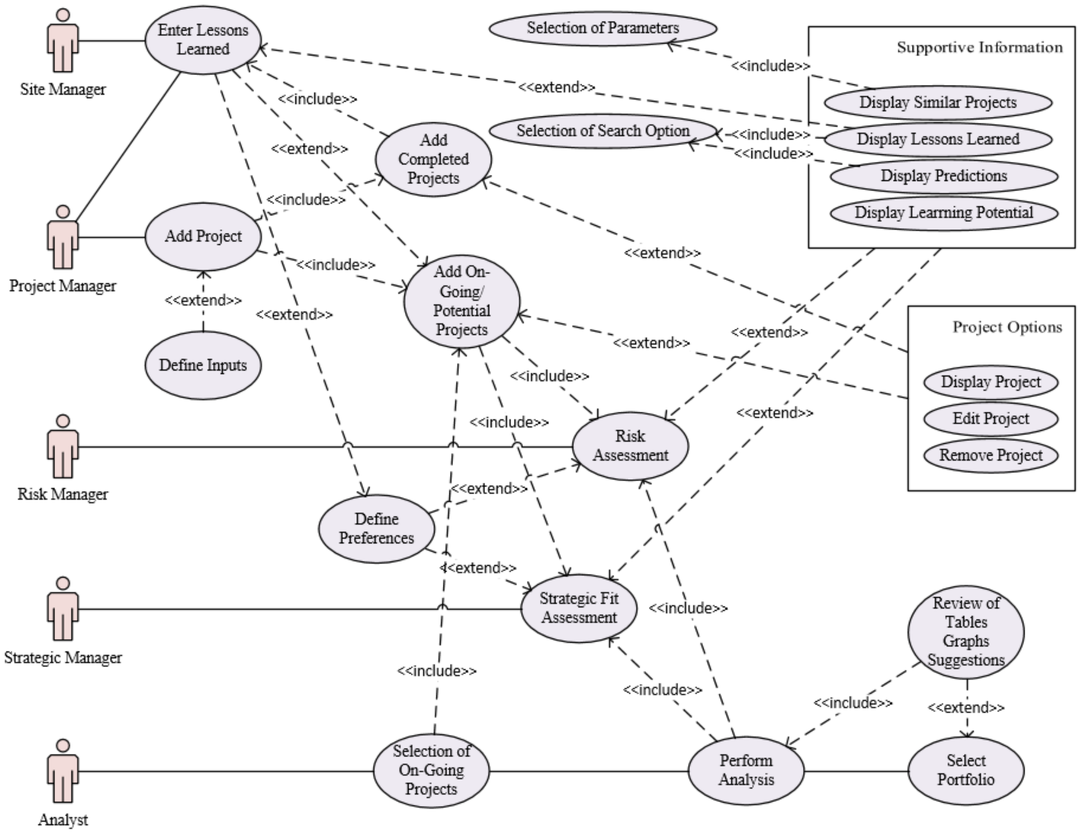


Figure 5.7: Use Case Diagram

COPPMAN is to be best operated in an environment where knowledge management system exists. It provides sections for codification of “explicit knowledge” in terms of project information and post project appraisal form to provide some statistical information for generating estimates (predictions) for the specific project in hand. Besides this, live capture of “implicit/tacit knowledge” in terms of lessons learned during project life-cycle is also provided through a web-based system where different users can enter information from anywhere (Figure 5.8).

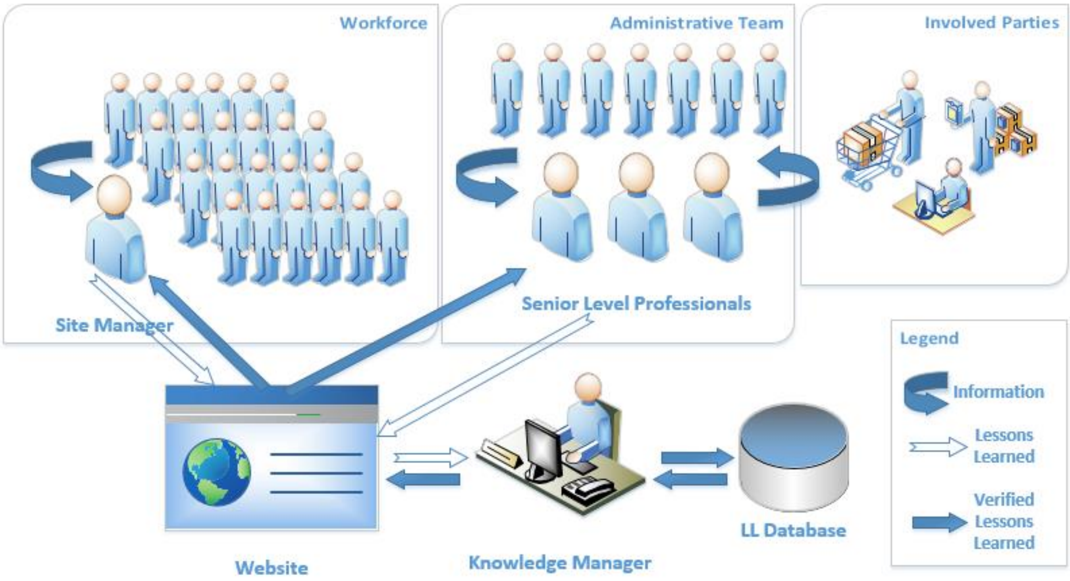


Figure 5.8: Knowledge Management System (Eken et al., 2015)

Different levels of users can be identified within the tool with their own usernames and passwords. This feature fosters the benefits of internet as a communication system, thus provides timely documentation and retrieval of knowledge at anytime from anywhere. Authorization of these users can be identified and limits to their access can be set by the main-user, so this property enables the main-user to structure a knowledge management system according to the current need as the intended level of privacy and security, since knowledge creates the value for the company (Ferrada et al., 2014; Tidd and Bessant, 2013). These properties of COPPMAN enable usability and reachability of the live entry of cases, which may overcome the disadvantages encountered with use of post-project meetings for codification of lessons learned. “Edit” and “Delete” options are provided for the main-user to change the description or classification of the lessons entered, where an “Approve” option is also provided for further classification of the lessons to ensure the quality and currency of the entries to overcome the knowledge overload problem. Before dissemination of the knowledge acquired, it needs to be organized (Tserng and Chang, 2008), therefore COPPMAN already provides an editable classification system through the provided tagging system which also serves for their retrieval.

Retrieval of the entries can be made by the users directly through the mechanisms provided or by the main-user in order to push the related lessons to the responsible parties. Thus, a system where active codification of knowledge is possible through participation of different users is required to overcome the barriers with knowledge management in construction companies. Users can set to be senior level professionals or site managers that provide the link with the workforce, and overall system may be under control of a “Knowledge Manager (KM)” as the main-user. KM can act as an admin with access to all functions, whereas “Field Personnel” may be provided accounts with limited access to functions as only entry or display of lessons learned for facilitating data collection. Similarly, “Risk/Strategic Manager” can have an account limited with review of supportive information and evaluation of factors only. Therefore, KM can establish a knowledge management system according to availability of personnel and intended level of privacy by using the authorization and user management capabilities of COPPMAN. Successful utilization of this knowledge-based portfolio management system may overcome the current barriers and help construction companies to enhance their organizational learning abilities and the quality of their decisions during selection and management of projects/portfolios.

Identification of roles that require different responsibilities using the access and authorization section of the tool will enable the users to access only the related parts of the tool. This will ensure that the information is entered in an effective manner while protecting the confidentiality of the company's information. It may be possible for the tool to work effectively with the roles identified below as well as the employees to be authorized on the basis of these roles:

- Role 1 Project Inputs (Excluding Actor)
- Role 2 Project Inputs (Actors Only)
- Role 3 User Preferences (Tag Tree)
- Role 4 User Preferences (Evaluation Factors and Coefficient Constants)
- Role 5.1 User Preferences (Exchange Rate Constants - Add)
- Role 5.2 User Preferences (Exchange Rate Constants - Edit)
- Role 6 User Preferences (User Management and Access Authorization)

- Role 7 User Preferences (Edit Library)
- Role 8 Projects (Add Project) Authority (Edit-Delete)
- Role 9 Projects (Project Operations)
- Role 10 Projects (Display Projects)
- Role 11 Corporate Memory (Lessons Learned Entry) (Add Only)
- Role 12 Corporate Memory (Lessons Learned Display)
- Role 13 Corporate Memory (Lessons Learned Management - Approval) (Edit-Delete)
- Role 14 Predictions
- Role 15 Portfolio Management (Analysis - Selection)
- Role 16 Portfolio Management (Current Portfolio)
- Role 17 Library
- Role 18 Risk and Strategic Fit Assessment

The role assignment section created in COPPMAN is flexible and the companies that will use the system will be able to change the roles according to their own structure. The pre-defined roles can be assigned to the users added to the system, so that the authorities of the users can be easily identified. For example, field staff with the authority to enter learned lessons and view the entered lessons can be authorized with "Role 11" and "Role 12". Whereas the central office staff responsible for corporate memory management would be authorized with "Role 11" and "Role 12", as well as "Role 13" to have the authority to manage the corporate memory, such as providing the approval and deletion of the entered lessons learned.

CHAPTER 6

USABILITY TESTING

"Usability" is defined as "*when a product or service is truly usable, the user can do what he or she wants to do the way he or she expects to be able to do it, without hindrance, hesitation, or questions*" (Rubin and Chisnell, 2008). Any product is designed to be efficiently used in the long term by presenting features that are not only responsive to accomplish intended tasks but also easily and fully comprehensible. Design quality should be ensured in every aspects of a product considering its appearance, feature set and the interaction scheme (i.e., interface of a software product as the elements that people will be interacting). All of these elements should be in the context and fit with the purpose. A trial process is needed in a systematic way where actual users are observed within the process of trial and data is obtained for evaluation as potential improvement (Liu and Zhu, 2012). Therefore, usability testing is required to improve the design of a tool through the data gathered from its representative users (Rubin and Chisnell, 2008). Validation studies held for COPPMAN are all held to serve for this purpose; however, usability testing handled in this chapter is required mainly to focus on evaluation of COPPMAN regarding usability metrics such as "ease of use", "effectiveness", "satisfaction", etc. for revealing potential problems in "navigation", "presentation", etc. Within this context, representative users experienced COPPMAN directly in a lab environment through utilizing different scenarios in COPPMAN. The performance and feedback of the users were gathered as an attempt for further evaluation to improve COPPMAN. Thus, the chapter includes introductory information on “Usability Testing” and details of usability testing procedure of COPPMAN through testing methodology, process and results.

6.1. What is Usability Testing?

Usability testing is generally referred to any process that indicates evaluation of any product/system. The major objective in usability testing is identification of usability related problems and obtaining recommendations addressing these problems. A usability problem/defect can be defined as “*a product characteristic that makes it difficult or unpleasant for users to accomplish tasks supported by the product*” (Nielsen and Mack, 1994). Definition of the objective, usability problem and expectations from a usability testing of a specific product should be identified at the beginning for possible measurement at the end of the testing (Nielsen and Mack, 1994). Considering the extent of usability testing processes, usability testing referred in this chapter is rather the “*process that employs people as testing participants who are representative of the target audience to evaluate the degree to which a product meets specific usability criteria*” (Rubin and Chisnell, 2008). Thus, usability testing basically requires establishment of the attributes and metrics (for measuring the attributes) required for the testing process (Seffah et al., 2006; Bertoa and Vallecillo, 2004). A more attribute oriented definition is provided by International Organization for Standardization/International Electrotechnical Commission (ISO/IEC) (1998) as follows “*the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use*” (Liu and Zhu, 2012). Usability of a product or service can be measured mainly by the following attributes (Rubin and Chisnell, 2008; Kunert, 2009; Liu and Zhu, 2012; Seffah et al., 2006; Lin et al., 1997; Davis, 1989; Chin et al., 1988):

- **Usefulness:** can be summarized as willingness of the user to use the product since the product has the potential to enable the user to achieve his/her goals (i.e., the product enhances the job performance of the user),

- **Efficiency:** is mainly the ease of use as the measure of time that is spent to accurately and completely achieve the intended goal (e.g., task completion rates), it is the mental workload required to complete the task (resources expended to complete the task – e.g., time spent, number of steps to completion, followed paths, etc.),
- **Effectiveness:** is the extent of meeting the expectations of the user and easiness of the required process, accuracy and completeness of the tasks (e.g., successful completion of tasks),
- **Learnability:** is measured with competence level or ability of the user in operation of the system following the related training process (i.e., the effort needed to learn the system),
- **Satisfaction:** is the measure regarding perceptions, feelings, and opinions of the users as the statement of discomfort/positive attitudes (e.g., rankings and ratings obtained through written and oral questioning).

Usability testing is an important step in interface design as a complementary way to two others as following the "style" and the "design guidelines" provided (Acartürk and Çağıltay, 2006). Usability has becoming a vital criterion in software design and needs to be taken into consideration in the overall design life-cycle (Lin et al., 1997). Usability testing can be conducted at different stages of development process with different focus of analysis and also before and after development. Therefore, by establishing different objectives and attributes/metrics to testing, different usability testing processes can be structured for different purposes such as "exploratory test" (for more conceptual analysis), "assessment test", "validation test", or "comparison test" (for more behavioral analyses) (Rubin and Chisnell, 2008; Seffah et al., 2006). However, specifically software should be tested early in the design process to prevent costly changes that would be difficult to enforce once the coding has been completed (Goldberg and Wichansky, 2003). Considering a software design, the "alpha code" as representing the feature functionality and the "beta code" as for the complete product functionality can be tested within design development of the product (Goldberg and Wichansky, 2003). Early integration of the end-users to provide feedback on design is a valuable factor in the software design development, so users are asked to evaluate the design on the prototypes of the software to establish a user-centered design (Bandi and Heeler, 2013; Ruthford and Ramey, 2000). Users can be left with open-ended and more general instructions while evaluating a product or they can be guided with task scenarios to deal with particular aspects of a complex product in a certain flow of goals or actions (Nielsen and Mack, 1994). Users may either provide comments on the product or may provide ratings on questionnaires. Data for evaluation can be supported with advances of usability engineering such as additional data of eye-tracking and annotation of multimodal behavior (Vervenne et al., 2006).

As it is underlined with the definitions, "*usability is a quality characteristic that is intrinsically dependent upon the kind of 'use' that is expected, and the kind of 'user' that will use the product*" (Bertoa and Vallecillo, 2004). Thus, many different considerations structure the usability testing approach. Usability testing approaches range according to the objective set and resources arranged for utilization in testing. Main approaches in usability testing can be listed as follows (Lin et al., 1997):

- **Laboratory Testing:** testing the prototype with actual performance data by using advances of specially equipped laboratories,
- **Protocol Analysis (Thinking Aloud):** user is asked to think aloud while directly using the system,
- **Formal Modelling:** developing theories with the aim of structuring more objective techniques for evaluation based on design specifications rather than the prototype/product,
- **Guidelines/Checklists:** provided for guiding the design process considering usability goals, and
- **Heuristic Methods:** provided for judgement of adequacy of a design prototype/product.

All of the methods serve for different purpose of evaluation and have their own advantages and disadvantages (Lin et al., 1997). Therefore, the usability testing process requires an essential planning and design of the overall process.

6.2. Usability Testing of COPPMAN

Laboratory testing was selected for evaluation of COPPMAN, since the advances of laboratory as evaluations of direct user interaction would be complementary to the other evaluation studies held in design of COPPMAN, which were more focused on content and the system. Laboratory testing with eye-tracking abilities provides analysis of micro-level behaviors as indicator of problems that may not be possible to detect otherwise (e.g., success of a specific element on the interface, overall navigational success of the interface, etc.) (Goldberg and Wichansky, 2003). According to Bastien (2010), development of usability testing in a laboratory setting generally requires following steps (Yıldız, 2012):

- defining test objectives,
- selecting test participants,
- creating test scenarios and tasks,
- identifying the measures and the way data will be captured,
- preparing test materials and usability laboratory,
- designing user satisfaction questionnaires,
- presenting and discussing the test results.

Desired participant number is stated to be “10-12”, being from different age ranges, gender profiles and different likeliness of using the product/service (Rubin and Chisnell, 2008). In their study, Rubin and Chisnell (2008) reinforce that use of “4-5” participants reveal 80% of the problems that may be obtained through use of “10-12” participants. Thus, they underline that “4-5” participants would be enough to complete a usability testing; however, more participants may uncover more problems as well. Similarly, Nielsen (1993) also states that study with “5” participants can reveal 75% percent of usability problems with a product (Acartürk and Çağıltay, 2006).

“Thinking aloud” technique is a successful technique for gathering thoughts of the participants, so it can also be combined with a testing process in laboratory setting.

However, further probing is not much recommended in usability testing processes for validation, which are generally held at the later stages of development cycle, to keep the participant and test moderator interaction as minimum as possible (Rubin and Chisnell, 2008).

6.2.1. Testing Methodology

Consideration of usability includes several aspects such as how easily the users learn the system, how efficiently they use the system once they learn how to use it, and how much they are pleasant to use it. The errors during the testing process with the frequency and criticality information are also supportive data for consideration of overall usability and possible areas of further improvement (Nielsen and Mack, 1994). To establish a sound usability testing process and obtain a level of validity at the end, care should be provided on the following issues (Lin et al., 1997):

- subjects (participants) should be representative for the intended user group,
- the testing should be conducted properly (according to the plan), and
- obtained usability data should be carefully analyzed (sound results).

For conducting usability test, testing plan is required for designing the overall process considering the metrics that will be measured for evaluation and also the materials that will be used to support the overall process. Within the context of planning one should consider main elements of testing process such as, what will be the major aim, how the test will be conducted, what metrics will be captured during testing, how many participants will perform the testing, and what scenarios will be used (HHS, 2016a). Supporting the testing process both with qualitative and quantitative data through traditional methods of empirical research (e.g., questionnaires, further probing interviews at the end of the test) and advances of usability engineering (e.g., eye-tracking, record of behavior) would be a more sound approach to evaluate and improve the usability of COPPMAN. Therefore, the obtained objective data is to be supported with the subjective data and this may enable identification of the main underlying reasons and their consequences behind the performance of the user during the test (Vervenne et al., 2006; Liu and Zhu, 2012).

Details of the methodology is provided in the following sections of "6.2.1.1: Testing Plan" indicating how the testing is structured, "6.2.1.2: Testing Metrics" for details of measurement of the attributes, and "6.2.1.3: Testing Materials" as the resources used to guide the overall testing process.

6.2.1.1. Testing Plan

According to the test plan outline provided by Rubin and Chisnell (2008) the following matters were considered in developing the testing plan:

- **Purpose, goals, and objectives of the test:** to evaluate the overall performance and effectiveness of the tool operations and tool interface through its direct use by the users on common tasks
- **Research questions:** How easily do users use the buttons/options and find the related information/section on the interface? How closely does the flow of the tool operations are parallel with what the user expects for the workflow? How easily and successfully do users perform the common operations/tasks? How easily can users correct their mistakes in the operation? How much the tool directs the users through messages on operations? Is the response time of the tool is a cause of user frustration/errors? Can users use the tool without assistance or training or using help/library? How much training is effective in learnability of the tool?
- **Participant characteristics:** Main consideration with participants should be that they should have some level of domain knowledge and IT background (Bandi and Heeler, 2013). Since validation of the tool was made with integrating experts and company professionals at different ages for the content of the tool, usability testing at this step was decided to be held between rather young participants that are actively using computers instead of establishing a

participant set from different ages and likeliness of computer usage. The participants were selected from research assistants of Civil Engineering Department, Middle East Technical University, Ankara as an akin set of possible users of the tool. The assistants were selected randomly from different divisions in the department, so no knowledge or direct studies in Construction Management was the prerequisite for the participants, but they were familiar with construction terms and also with interface designs due to considerable use of computer programs. This selection was thought to provide more valuable information regarding the tool operations and interface and enable efficiency of the testing process. Three participants from the research team were determined for the pilot testing process, whose performance would also be used for benchmarks in the analysis of test results. Three "internal participants" were to be used as both for pilot testing and obtaining the best case results for the participant performance benchmarking. Six participants were considered for the testing process, an addition to participants was left to re-consideration in the course of the testing process. The participants with rather low performance rates were decided to be re-tested to measure the improvement in the performance results and so the learning in the process.

- **Method (test design):** All of the participants were planned to be tested with the same testing material in the same order of the testing materials and no grouping of the participants are required. Different scenarios were to be selected from different processes so there was no requirement of changing the order of scenarios to eliminate the learning effect. Participants were provided several scenarios that would serve as a summary of the common tasks of the overall tool process. Participants were asked to review and sign nondisclosures with recording permissions and information and related background of the participants were collected through a pre-test questionnaire. Participants were informed with their role in the testing and a brief summary of the overall process was summarized at the beginning. Room configuration, recording systems, observers were explained and participants were encouraged to "think aloud" without interrupting the testing process.

There were post task questionnaires to collect more detailed feedback regarding each task. An overall evaluation including an open questions section was provided to participants to obtain more comprehensive evaluation of the tool by opinions of the participants regarding the details over the task-level. Details of the questionnaires are provided in the following sections (6.2.1.3: Testing Materials). Overall process was planned to be last approximately “30” minutes and “15” minutes interval between the participants was decided to be enough for re-starting the test process.

- **Task list:** Since the major aim was evaluating the overall tool, major concern in selection of the tasks was that they should constitute a minimum set of tasks regarding all operations within the tool. Tasks were designed to be representative for the overall process required to utilize the tool and care was taken to select different tasks that would be complementing each other under different scenarios. Thus, learning through the testing process was minimized for the participants taking the test for the first time since there were no common tasks under the scenarios. Tasks were grouped under 14 scenarios and were ordered in a typical order of the required tool process as in its active usage. No change in the order of the tasks was required to minimize the learning effect of the participants. Details of the tasks and the scenarios are provided in the following sections (6.2.2.4: Scenarios and Tasks).
- **Test environment and the equipment:** The test was to be conducted in lab setting since the gaze data and other recordings were identified within testing metrics. The laboratory environment should include two rooms for testing and observation, where moderator is sitting next to participant in the testing room and an observer is managing the technical requirements in the separate room. The testing software was consisting of a desktop computer to perform the scenarios and a recording software to capture and analyze the testing process. A video image of the computer screen was to be captured by the software during each testing process. The laboratory also includes cameras for video/audio taping the test sessions and an equipment for collecting the eye-

tracking data of the participants to create the visual diagrams of gaze data of the participants.

- **Test moderator and observer roles:** The “test moderator” (also the note-taker) was planned to sit next to participant during testing process and take notes for the session audits. The moderator was to provide the testing material as questionnaires and read the information required for information entry processes of the tasks. There was no planned roles for the test moderator like probing or intervening during the testing as long as the process was going successfully to its completion as it was expected. The moderator can encourage “thinking aloud” during testing process and can perform “retrospective probing” at the end of each task or overall testing. The “observer” (as a second test moderator) was decided to be in the observation room to guide the technical process, start and finish the testing process by running the software and take action in case of any technical inconvenience during the testing process.
- **Data to be collected and evaluation measures:** Performance (quantitative) and preference (qualitative) data of the participants were to be collected through overall testing process. The software outputs, the questionnaires and the session audits conducted by the test moderator would enable the thorough evaluation of the tool. Successful completion rates, time-on-tasks, error-rates, number of clicks, use of library during tasks, ratings through questionnaires were identified as the basic criteria that the tool would be tested against. Additionally, visual outputs of the gaze data would provide information on success of the tool interface in terms of users’ parallel success in noticing/reading the related sections and processing related information how easily on the screen through the focused areas on the gaze data. Details of the testing criteria are provided as the related metrics in the following section (6.2.1.2: Testing Metrics).
- **Report contents and presentation:** Testing results would be reported as the summary of the overall process, details of observations in the session audits, performance data obtained through session audits and software outputs, and

preference data obtained as ratings and comments through questionnaires. Testing results will be provided in the following sections (6.2.3: Testing Results).

6.2.1.2. Testing Metrics

In usability testing, metrics are required to measure how much the identified attributes are existing in the tested system/product (Bertoa and Vallecillo, 2004). Therefore, a typical usability testing process requires collection of data to evaluate the process in detail through considerations such as (Rubin and Chisnell, 2008):

- Whether each task was completed successfully
- Whether prompting/assistance was required in tasks
- Major problems/obstacles associated with each task
- Time required to perform each task
- Observations/comments concerning actions of each participant

The test metrics identify the data that will be collected during testing process such as counts, rates, time durations and comments/opinions through questionnaires and as testing software outputs. Metrics are generally identified under two major groups as “qualitative” and “quantitative” metrics. Qualitative/Subjective metrics can be evaluated through questions put prior to testing, after completion of each scenario, and following completion of the overall testing by focusing on the criteria such as, ease, satisfaction, likeliness of use, etc. Quantitative metrics can be obtained through the testing process as the performance data of achieving the tasks under the scenarios such as successful completion rates, error rates, time on task, etc. (HHS, 2016a).

Evaluation of COPPMAN was structured through establishing the overall process based on different measurable metrics that were questioned at different processes of testing and serving for main usability attributes that can be listed as:

- Ease of Use / Efficiency

- Effectiveness
- Usefulness
- Satisfaction
- Consistency
- Learnability
- User Guidance

Some other usability attributes were also considered either under these main attributes or through sections that provide overall evaluation without grouping under usability attributes. In the light of the selected attributes, main metrics in usability testing of COPPMAN were identified as follows (Rubin and Chisnell, 2008; HHS, 2016a; HHS, 2016b; Seffah et al., 2006):

- **Task Completion Rates:** indicates performance of each participant on tasks with/without critical/non-critical errors (number and percentage of task completion). Task accuracy is measured as percentage of participants performing successfully within benchmark without major errors (task completion success rates). Error-rates (counts of errors) as the number of problems/reworks encountered in conducting each task will also be indicative of the possible areas of improvement according to the types provided below:
  - **Critical Errors:** are major errors that result in deviation from the targets of the scenario (e.g., reporting the wrong data value, not being able to complete the task, etc.).
  - **Non-Critical Errors:** are minor errors that are recovered by the participant within the process so they are not preventing the successful completion but they may result in less efficient task completion (e.g., exploratory behaviors such as using a button/icon/menu-item incorrectly, extra clicks in the process, incorrect selections, errors of omission, etc.).
  - **Error-Free Rate:** is the percentage of test participants who successfully complete the task without any critical/non-critical errors.
- **Time On Task:** is the amount of time it takes each participant to complete the task. Task timings are simply measured with how much time that the

participants require to complete each scenario. Statistics that represent task timings can be mean time and the standard deviation which indicate the average and its distribution range/variation (Rubin and Chisnell, 2008).

- **Subjective Measures:** are quantitative evaluations as ratings (on a Likert scale) or qualitative evaluations as comments/opinions provided by the participants (e.g., evaluations in terms of satisfaction, ease of use, ease of finding information, etc. or comments/opinions on likes, dislikes, recommendations, improvement areas, etc.) and diagrams of performance obtained within software outputs (e.g., gaze-plots, heat maps, etc.).

Session auditing is a complementary process in testing that will be helpful in reporting the collected data. Supportive considerations to be obtained through session audits were identified as follows (HHS, 2016a; Rubin and Chisnell, 2008; Yıldız, 2012; Seffah et al., 2006):

- Quantitative measures during session audit:
  - Was the participant able to complete the task? Completion Rate – count
  - Did the participant encounter any problem during tool use? If problems were encountered, what were these problems? Number of Errors – count, Criticality of Problems - count
  - Did the participant use the library/help option of the tool? Use of Library – count
    - Could the participant find a solution through the library? Effectiveness of Library – count
- Qualitative measures during session audit:
  - Did the participant state any comments?
  - Did the auditor detect any use of body language or observation of facial expressions/hesitations? How long did it last?
  - Did the participant asked any hints/prompts?

Summary of the quantitative usability measures with the related data source, usability attribute and usability goal (research question) information can be provided as follows (Table 6.1):

Table 6.1: Summary of Quantitative Usability Measures

Usability Measure	Data Source	Usability Attribute	Usability Goal
number of participants who successfully completed a task	Laboratory Testing & Session Audit	Effectiveness	Is it easy to use the tool? How well the participant complete the task?
amount of task completion time of each inexperienced participant	Laboratory Testing	Ease of Use / Efficiency	How the inexperienced participant is efficient in using the tool? How much the participant performing quickly?
amount of task completion time of experienced/re-tested participant	Laboratory Testing	Learnability	How the experienced participant is efficient in using the tool? At what extent, the participant learns to use the tool?
amount of mouse clicks of each participant in conducting each task	Laboratory Testing	Ease of Use / Efficiency	How much the participants are efficient in using the tool?
number of help use during conducting each task	Session Audit	Ease of Use / Efficiency	Is it easy to use the tool without help?
number of successful guidance by use of help	Session Audit	Effectiveness, User Guidance	How much the help option is useful?
number of problems/reworks encountered in conducting each task	Session Audit	Ease of Use / Efficiency	What type of and how many problems did the participants encounter?
average rating obtained at the end of each task	Post-Task Questionnaire	Ease of Use / Efficiency, Satisfaction, Consistency, Learnability, User Guidance	How the users evaluate usability of the tool specific to each task?
average rating obtained at the end of the test	Post-Test Questionnaire	Satisfaction	What is the overall satisfaction obtained?

Qualitative usability measures that would be investigated through session audits, questionnaires and visual outputs can be summarized with the following usability attributes some of which were also questioned in quantitative usability measures as follows (Table 6.2):

Table 6.2: Summary of Qualitative Usability Measures

Usability Measure	Data Source	Usability Attribute	Usability Goal
visual outputs: clusters, gazeplots, and heatmaps	Laboratory Testing	Ease of Use / Efficiency, Effectiveness, Learnability	How the users perform with the tool interface?
use of body language or observation of facial expressions/hesitations or ask of hints/prompts	Session Audit	Ease of Use / Efficiency, Effectiveness, Usefulness, Learnability, Satisfaction	Is there a problem specific to a task?
comments/opinions provided by each participant	Post-Test Questionnaire	Usefulness, Satisfaction	How the users evaluate overall usability of the tool?

Overall summary of the testing metrics considering both quantitative and qualitative usability measures can be provided as in the following table (Table 6.3):

Table 6.3: Summary of Testing Metrics

Test Objective	Usability Attributes	Measurement Technique	Description
Quantitative Objectives	Ease of Use / Efficiency, Effectiveness, Learnability	Laboratory Testing	Tobii Eye Tracker records the performance of participants and Tobii Studio provides numerical outputs for the usability measures.
	Ease of Use / Efficiency	Laboratory Testing & Session Audit	Tobii Eye Tracker records the performance of participants through screen record with replay possibility and session audit supports the background of the recorded performance.
	Ease of Use / Efficiency, Effectiveness, User Guidance	Session Audit	Test facilitator records number of help use of each participant and its result.
	Ease of Use / Efficiency	Session Audit	Test facilitator records user problems in tool use during laboratory testing sessions.
	Ease of Use / Efficiency, Satisfaction, Consistency, Learnability, User Guidance	Post-Task Questionnaire	Participants fill out questionnaire after they completed the given tasks.
	Satisfaction	Post-Test Questionnaire	Participants fill out questionnaire (rating questions) after they completed all tasks.
Qualitative Objectives	Ease of Use / Efficiency, Effectiveness, Learnability	Laboratory Testing	Tobii Eye Tracker records eye tracks of participants and Tobii Studio provides visual outputs.
	Ease of Use / Efficiency, Effectiveness, Usefulness, Learnability, Satisfaction	Session Audit	Test facilitator records user reactions in tool use during laboratory testing sessions.
	Usefulness, Satisfaction	Post-Test Questionnaire	Participants fill out questionnaire (open-ended questions) after they completed all tasks.

The testing materials, namely questionnaires, are equipped with some other usability attributes such as “Productivity”, “Safety”, “Trustfulness”, “Accessibility”, and “Universality”, which are embedded or implied within the statements grouped under presented main usability attributes.

6.2.1.3. Testing Materials

Testing materials are required to communicate with the participants and collect their data, while satisfying legal requirements. They also help to structure and organize the testing process (Rubin and Chisnell, 2008). Main testing materials are listed as follows (Rubin and Chisnell, 2008):

- **Orientation script:** is used to inform the participant about the overall testing process including what they will be doing and how they can end the testing process. It is also important to underline in an orientation script the fact that the product is being tested rather than the participant himself/herself.

- **Background questionnaire:** is required for basic screening of the participant profile (summary of participant characteristics).
- **Data collection instruments:** are any supportive tools ranging from note-taking by using basic word document prints to sophisticated tracking software.
- **Nondisclosure agreement and recording consent form:** is required to establish an agreement on both prevention of unauthorized disclosure of the product information and getting permissions from the participants for recording them during the testing process (recording waiver).
- **Pre-test questionnaire:** is the questionnaire held at the beginning of the testing for obtaining the background information from the participants considering their qualifications or level of expertise.
- **Task scenarios:** are the group of typical tasks created as representations of the actual work that the participants would be performing while using the product. The scenario is provided within a context and the participant is motivated with accomplishment of the task as in the real case so the performance of the user can be dealt as the exemplified result of real usage of the product.
- **Post-task questionnaire:** provides more valid and diagnostic evaluation of usability since they are provided immediately after completion of the task based on direct experience of the participant (Sauro and Dumas, 2009)
- **Post-test questionnaire:** provides overall evaluation on the product in terms of opinions/feelings of the participants to clarify strengths and weaknesses of the product (Sauro and Dumas, 2009)
- **Debriefing topics guide:** is the list of certain topics that you may use for further discussion by structuring them according to the specific test session.

Within the testing planning of COPPMAN the following materials were prepared to be used in the overall testing process:

- **Scenarios and Tasks:** Since COPPMAN is including various functions and modules, tasks grouped under different scenarios were prepared to guide the evaluation process of the participants. Scenarios and Tasks were structured to be representative of a complete process of COPPMAN utilization. Details of the Scenarios and included Tasks are provided in the following sections (6.2.2.4: Scenarios and Tasks).

- **Voluntary Participation Form:** Voluntary Participation Form was prepared as technical requirement of the testing process to inform the participant about the testing process and to get the required permission of the participants as signed declaration of participation. The form includes details on the object and content of the study, expectations from the participant, collection and evaluation of the collected data, and matters regarding application of the test. Each participant read and signed the form at the beginning of the testing. The Voluntary Participation Form is provided in full text in Appendix I (Survey 7).
- **Orientation Script:** Orientation Script was written in a more friendly voice to provide more practical knowledge about the process. It was read by the moderator to each participant at the beginning of testing to reinforce the details and cover any discrepancies that may arise due to participants not reading the Voluntary Participation Form. The Orientation Script is provided in full text in Appendix I (Survey 7).
- **Session Audit Form:** Session Audit Form was structured with the blanks provided for taking notes on the related participant, scenario and observations regarding that participant and scenario. It was filled during each testing process to record observations that may support evaluation of the performance and opinions of participants. The Session Audit Form is provided in Appendix J (Session Audit Form).
- **Pre-Test Questionnaire:** User profile needs to be listed as at least in the information of “label”, “education”, and “experience” to ensure the right person is invited to evaluation in a usability testing. Specific user profile is needed to make sure that evaluation provided will help identification of the perspective of the user and the knowledge brought to the tasks (Nielsen and Mack, 1994). Therefore, to reinforce the decision with selection of the

participants a quick review questions were provided in the survey to obtain some level information regarding computer usage and knowledge in the area. Differentiation in the results would be desired to obtain representative set of participants. Main information required in the pre-test questionnaire is title, education, gender, age, computer usage (hours per week), knowledge (high/medium/low) in construction management, in portfolio management, and in information technology. Details of the Pre-Test Questionnaires is provided in Appendix I (Survey 7).

- **Post-Task and Post-Test Questionnaires:** Six post-task questionnaires were prepared for different groups of task scenarios providing evaluation of the performance through ratings on statements specific to included tasks. The statements were provided under main sections of "ease of use", "satisfaction", "consistency", "learnability", and "user guidance". A post-test questionnaire was also provided for overall evaluation in terms of ratings and open-ended questions for further probing. For structuring of the statements and questions the main focus was on the areas that may not be observed directly through performance of the participant. In addition, the research questions stated in the testing plan formed overall direction and content of the questionnaires. Statements and questions mainly investigate the organization and navigation of the interface, accessibility, clarity and quality of the information and graphics provided, technical accuracy, etc. (Rubin and Chisnell, 2008). The extent of the questionnaires also improved by considering a more extensive approach on usability issues, which is provided by Nielsen (1994), as the list of "heuristics" that can constitute the general principles that may be taken into consideration in product design. Evaluation on these metrics as ratings/comments provided by the users would be supportive evaluation data in addition to performance data to be obtained through tasks. These constitute the details that were taken into consideration while structuring the questionnaires for testing of COPPMAN. The stated heuristics can be summarized as follows (Nielsen, 1994):

- **Visibility of system status:** providing feedback to keep users informed about the status,
- **Match between system and the real world:** using of users' language, with words, phrases, and concepts familiar to the user, and providing information in a natural and logical order,
- **User control and freedom:** supporting undo and redo,
- **Consistency and standards:** making sure the users about actual meanings of the words, situations, or actions provided,
- **Error prevention:** providing error messages,
- **Recognition rather than recall:** providing easily retrievable information and instructions for use,
- **Flexibility and efficiency of use:** enabling customizable frequent actions and successfully serving for both inexperienced and experienced users,
- **Aesthetic and minimalist design:** providing information visibility and eliminating excess information,
- **Help users to recognize, diagnose, and recover from errors:** providing error messages in plain language while addressing the problem and its solution,
- **Help and documentation:** providing easily retrievable and sound help and documentation.

Similarly, Seffah et al. (2006) present the relation between an extended list of usability attributes (factors) with the usability criteria as in the following figure (Figure 6.1). These factors and the criteria provided were also taken into consideration in drawing up the questionnaires. Therefore, questionnaires include statements on identification of how much COPPMAN has these capabilities and meets these criteria. In addition, studies by other authors on usability testing (Lund, 2001; Rubin and Chisnell, 2008; Seffah et al., 2006; Yıldız, 2012; Sauro and Dumas, 2009; Chin et al., 1988) and some other evaluation studies (Shen and Marks, 2016; Lee and Rojas, 2013; Chong et al., 2013) also supported the structure of questionnaires and the statements in questionnaires were reformed according to examples provided in these studies. The questionnaires were constructed with seven-point Likert scale, since it has been the appreciated scale for usability-centered studies (Finstad, 2010; Sauro and Dumas, 2009). Participants were asked to evaluate (rate their level of agreement with) the provided statements, ranging from "strongly disagree (1)" to "strongly agree (7)". The final version of the questionnaires are provided in Appendix I (Survey 7).

	Factors									
Criteria	Efficiency	Effectiveness	Satisfaction	Productivity	Learnability	Safety	Trustfulness	Accessibility	Universality	Usefulness
Time behavior	+			+						
Resource utilization	+			+						+
Attractiveness			+						+	
Likeability			+							
Flexibility		+	+					+	+	+
Minimal action	+		+		+			+		
Minimal memory load	+		+		+			+	+	+
Operability	+		+				+	+		+
User guidance			+		+			+	+	
Consistency		+			+	+		+	+	
Self-descriptiveness					+		+	+	+	
Feedback	+	+							+	+
Accuracy		+				+				+
Completeness		+				+				
Fault-tolerance						+	+			+
Resource safety						+				
Readability								+	+	
Controllability							+	+	+	+
Navigability	+	+					+	+	+	
Simplicity					+			+	+	
Privacy							+		+	+
Security						+	+			+
Insurance						+	+			
Familiarity					+		+			
Loading time	+			+					+	+

Figure 6.1: Relations between Usability Attributes and Criteria (Seffah et al., 2006)

6.2.2. Testing Process

Following structuring of the testing methodology, the content of the survey study was submitted for ethical investigation. Ethics committee approval was provided for usability testing of COPPMAN by Middle East Technical University, Applied Ethics Research Center with protocol number “2016-FEN-059”. Further details of testing process is presented in the following sections in terms of technical information of the testing tool and environment, information on participants, scenarios and tasks, and also details of application.

6.2.2.1. Testing Tool

The eye tracker provided in the selected laboratory setting is “Tobii T120”, which collects data on how the participant processes screen. All the eye movements of the user during the experiment are also monitored and recorded with the help of testing tool. The participant proceeds the test on the computer attached to the eye tracker, which is also coupled to another computer in the control (or observation) room, and the on screen view of the participant is recorded. The information received from the reflectors and the infrared detector cameras are transformed into visual and digital data, and also recorded and provided as data for analysis by the software “Tobii Studio” developed by the manufacturers of the eye tracker. The software also provides tools for analysis of the recorded data (“Equipments and Softwares”, n.d.).

The main visual outputs are obtained as gaze-plots (indicating scan path, gaze time and fixations), heat-maps (representation of fixations according to their time and number) and “area of interests” (clusters according to density of fixations) in addition to tables or charts of some quantitative data (including fixation time, time to first fixation, first fixation duration, number of fixation, observation length, observation count, number of mouse click, time to first mouse click) (“Eye Tracking”, n.d.). Eye-tracking technology records eye movements of users as an indicator of how the users interact with a text, online document, or interface (Liu and Zhu, 2012). Eye-tracking data obtained through usability testing are utilized as objective measures of information recognition and processing. These evaluations are mainly based on the connection between visual reception behavior and correspondence of cognitive processes. Eye-tracking parameters such as fixation spot, fixation time and frequencies and the gaze path are used to evaluate cognitive processes like attention, stimulus complexity or data processing. These are based on the assumptions that the visual attention focus of the user stays on the object of cognitive processing (eye-mind assumption) and the fixation time is the measure of duration of cognitive processing (immediacy assumption) (Vervenne et al., 2006; Goldberg and Wichansky, 2003). They are also indicators that are used to assess efficiency of screen navigation and task flow (Nielsen and Mack, 1994). "Gaze-paths" provide possible evaluation on areas of main focus of attention, initial and latter fixation spots, saccadic movements (jumps) between single fixation spots (as an indicator of "searching"), sizes of fixation spots (fixation time as an indicator of "attention"), certainness of the path taken by the user (as an indicator of "extent/complexity of visual search"), deviations from the intended reception, etc. Additionally, "heat-maps" as aggregation of fixation frequencies (time spent) of a user or different users serve for identification of nature of the problem/success as individual or common (Vervenne et al., 2006; Liu and Zhu, 2012; Goldberg and Wichansky, 2003). The visual data can also be presented through clusters of fixation density indicating the certain "areas of interest" ("Eye Tracking", n.d.).

Tobii Studio allows investigation of many formats of materials such as, images (in Joint Photographic Experts Group (JPEG) format), movies (in Audio Video Interleaved (AVI) format), web (Uniform Resource Locator (URL) opened by web browsers), external videos (records from other sources), and screen recording (for use of any other software). Following the selection of the format to be analyzed, scenarios and the participants are created within the software. Each participant is made sure to sit at a "70 cm" distance to the eye-tracker by adjusting the seat and table. The "start recording" option runs the system for the participant being tested and the first step is the “calibration” where the tool identifies the movements of the participant by linking the record with the movements of a dot followed on the screen. Once the calibration is completed, the participant continues with undertaking the tasks in their order. Each record becomes ready for checking or analyzing once the participant accomplishes all of the tasks (Liu and Zhu, 2012; Goldberg and Wichansky, 2003).

6.2.2.2. Testing Environment

The testing process was held in Human-Computer Interaction Research and Application Laboratory, METU. The room has the classic testing laboratory setup as it is provided in the following figure (Figure 6.2). In this setup, communication with the observation/control room is established through an intercom and speaker arrangement. The room is separated with one-way mirror and the visibility is adjusted with dimmer control units for lighting. The testing process is monitored with video cameras (one is focused on the face of the participant and the other is on the keyboard) and audio tape recorders to provide a complete set of data of the testing process.

Since COPPMAN is a web-based tool, there was no requirement for setup on this desktop computer for testing process, instead its web address (URL) was used for direct access through testing. Related testing materials such as forms and questionnaires were ready in the testing room and applied when they were required. Questionnaires were filled out by the participants within the testing room before/after the accomplishment of tasks by each participant. The main interaction with the observer was the comments sent by the moderator for starting/finishing the testing process for each participant.

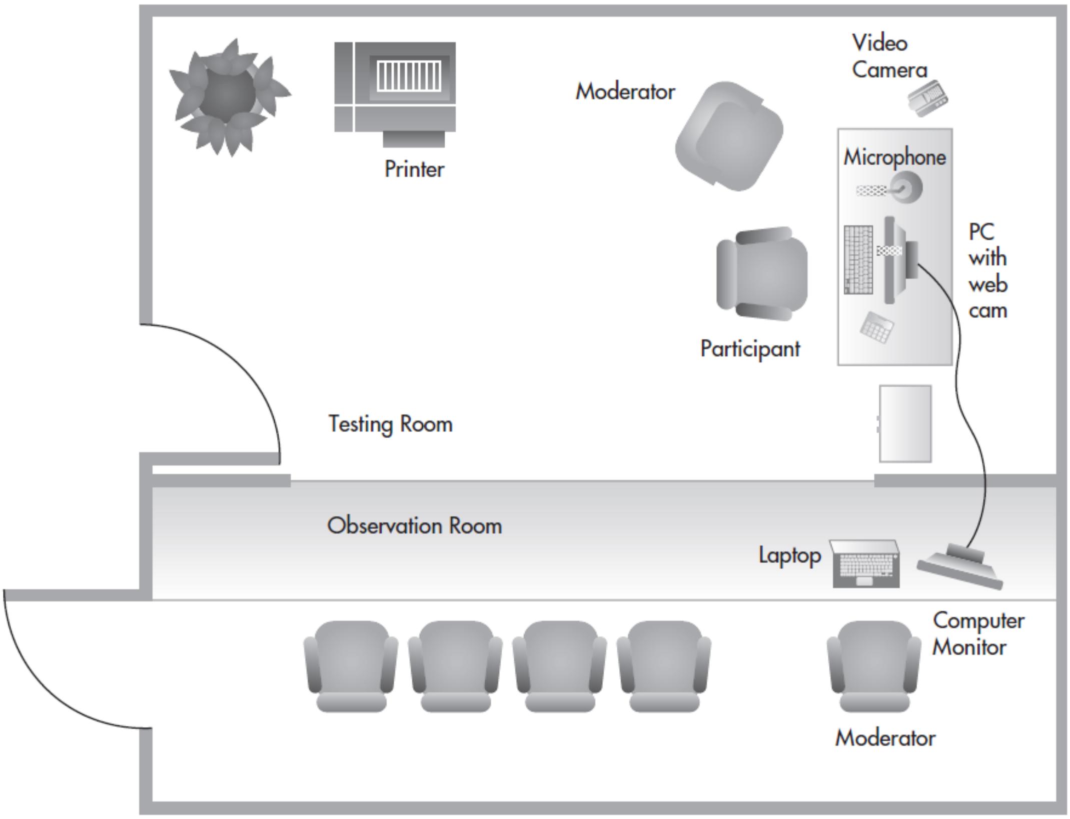


Figure 6.2: Testing Laboratory Setup (adapted from Rubin and Chisnell, 2008)

6.2.2.3. Participants

Information of participants was obtained as presented below. Research assistants were selected randomly according their availability and their information shows acceptable level of difference in characteristics. Research assistants were selected from Civil Engineering department for some level of familiarity with the object of the tool and computer usage to prevent failing of a participant in accomplishment of testing, which may result with failure in feedback. Research assistants were also selected since they may be deemed as candidates of future users of COPPMAN; however, sound experience in construction/portfolio management was not a major concern in selection to also measure the comprehensibility of the tool. Therefore, the obtained participant profile depicts a representative set of participants for the intended user profile for testing of COPPMAN.

- Title: All Participants are “Research Assistants”
- Education: All Participants has MS Degree, and are PhD Candidates
- Gender:
    - Male: 4 Participants
    - Female: 2 Participants
- Age:
    - 18-24: 1 Participant
    - 25-28: 3 Participants
    - 29-32: 2 Participants
- Computer Usage:
    - 0-10 hours per week: None
    - 11-25 hours per week: None
    - +26 hours per week: All Participants
- Knowledge in Construction Management:
    - High: 3 Participants
    - Medium: 1 Participant
    - Low: 2 Participants
- Knowledge in Portfolio Management:
    - High: 1 Participant
    - Medium: 1 Participant
    - Low: 4 Participants
- Knowledge in Information Technology:
    - High: None
    - Medium: 5 Participants
    - Low: 1 Participants

6.2.2.4. Scenarios and Tasks

Scenarios and tasks represent “pieces of real work” as the summary of possible tasks that the real users will be dealing in the future (Nielsen and Mack, 1994). They direct the user to provide evaluation on the focused areas so increase the effectiveness of testing process. Following tasks were delivered to the participants under groups of “14 scenarios” as a summary set of tasks for a representative application with COPPMAN. Evaluations through questionnaires were requested only for groups of related scenarios under the same tool menu. Within the context of testing, the generated Post-Task Questionnaires were applied as:

- Questionnaire 1 for “Project Inputs Menu” (Scenarios 1&2),
- Questionnaire 2 for “User Preferences Menu” (Scenarios 3&4),
- Questionnaire 3 for “Projects Menu” (Scenarios 5-8),
- Questionnaire 4 for “Corporate Memory Menu” (Scenarios 9&10),
- Questionnaire 5 for “Predictions Menu” (Scenario 11), and
- Questionnaire 6 for “Portfolio Management Menu” (Scenarios 12&14).

Tasks were structured based on the data generated with the “Numerical Example” and participants were asked to use the tool through manipulations on this data. Details of the scenarios and the included tasks are as follows:

- **Scenario 1:** Defining User Inputs - Adding an Actor
- **Scenario 2:** Defining User Inputs - Searching and Editing an Actor
- **Scenario 3:** Editing User Preferences - Editing Risk Evaluation Factor Set
- **Scenario 4:** Editing User Preferences - Displaying and Editing a Factor
- **Scenario 5:** Adding a Project - Potential Project
- **Scenario 6:** Performing Project Operations - On-going Project - Displaying Learning Potential
- **Scenario 7:** Performing Project Operations - Potential Project - Making Risk Assessment

- **Scenario 8:** Performing Project Operations - Potential Project - Removing Project
- **Scenario 9:** Corporate Memory Operations - Adding Lesson Learned
- **Scenario 10:** Corporate Memory Operations - Searching and Viewing Lesson Learned
- **Scenario 11:** Predictions Operations - Viewing Predictions
- **Scenario 12:** Portfolio Management Operations - Viewing Portfolio Projects
- **Scenario13:** Portfolio Management Operations - Making Portfolio Analysis and Reviewing Results
- **Scenario 14:** Portfolio Management Operations - Selecting Portfolio

6.2.2.5. Application

As the initial consideration of testing application, all of the participants were scheduled according to their available time for the testing process. The test was programmed within two consecutive days (for the first run of testing) according to availability of each participant. At the beginning of each testing process, the Voluntary Participation Form was read and signed by the participant. Pre-Test Questionnaire was filled and returned to the moderator before testing process. Following that, Orientation Script was read by the test moderator to reinforce the details with testing process. The moderator underlined that the performance of the participant actually demonstrates the performance of COPPMAN, so they were reminded to feel comfortable during overall testing process and to feel free to interrupt the testing by clicking "Escape" when required. They were also asked to use the library in case of a need of assistance. The moderator in the observation room started the testing process for each participant and the tasks were presented to the participants on the software interface directly to minimize contact with the participant. The time to read scripts of the scenarios were automatically excluded from task completion performances of the participants. Only the data required for information entry, which are included within the tasks, were read silently by the moderator next to participant without violating the participant's performance. The participant was asked to "Think Aloud" without interrupting the testing process. After completion of the task or set of tasks, the related Post-Task Questionnaire was applied immediately before proceeding with the remaining tasks. The moderator was not recording some of the testing performance results, since the software automatically records performance details such as task start and end times, number of clicks, record of screen, etc. The moderator was caring on recording on the Session Audit Form typically the considerable points with participant's behavior, reactions need to be taken into consideration, reasons of faulty actions, needs of help, short evaluations captured while participant was thinking aloud, requests for assistance, etc. The participant was filling-out the Post-Test Questionnaire once all of the tasks were completed. The moderator further held "debriefing" on the areas that needs retrospective probing and noted the additional details on the Session Audit Form. Three of the participants successfully completed on the first day and the others are taken on the second day. The second day also served for re-testing of two participants with rather low performance results. Another participant with one critical and considerable non-critical errors was tested on the third day as the final testing process. Following section presents the results of testing.

6.2.3. Testing Results

The following "usability benchmarks" were identified as the accepted limits for the identified usability attributes and their corresponding techniques and measures as control point for analysis of the records. "Best estimates" were decided to be values obtained by the means obtained by performance of the internal participants where the "acceptable level" was defined as "doubled best estimate". Identified limits for the rest of attributes and related measurement techniques are as provided in the following table (Table 6.4).

Table 6.4: Usability Benchmarks

Usability Attribute	Measurement Technique	Usability Measure	Usability Benchmarks	
			Best Estimate	Acceptable Level
Effectiveness	Laboratory Testing & Session Audit	Completion Rate	-	100%
Efficiency	Laboratory Testing	Total Fixation Duration	x seconds	2x seconds
Efficiency	Laboratory Testing	Mouse Click Count	y	2y
Ease of Use / Efficiency	Session Audit	Library Use	-	30%
Effectiveness, User Guidance	Session Audit	Library Success	-	50%
Ease of Use / Efficiency	Session Audit	Error Rate	-	0%
Ease of Use/ Efficiency	Post-Task Questionnaire	1-7 Likert Scale	-	4
Satisfaction	Post-Task Questionnaire	1-7 Likert Scale	-	4
Consistency	Post-Task Questionnaire	1-7 Likert Scale	-	4
Learnability	Post-Task Questionnaire	1-7 Likert Scale	-	4
User Guidance	Post-Task Questionnaire	1-7 Likert Scale	-	4
Satisfaction	Post-Test Questionnaire	1-7 Likert Scale	-	4

First of all, two internal participants were tested as an initial reference point for the best results. Following that, external participants were tested within consecutive days, where the third internal participant was also tested in between. All of the scenarios were completed without intervention of the test moderator or observer in the room during the testing process with participants. The participant who made a fault or performed with the longest duration or together with high number of non-critical errors identified during session audits were re-tested to evaluate the "learnability" of COPPMAN. The details of "12 records" including "3 internal participants (researchers)", "6 external participants", and "re-testing of 3 external participants" are as provided in the following table (Table 6.5).

In the light of the provided overview in terms of the benchmarks and obtained records, following sections present details of the analysis results obtained step-by-step within the overall evaluation process.

Table 6.5: Researchers, Participant and Recording Overview

		Record Numbers	
	Participants	**Main Record**	**Second Run**
Internal Participants	GB	REC01	-
	GE	REC02	-
	BO	REC07	-
External Participants	P1 (AT)	REC03	-
	P2 (SA)	REC04	REC10
	P3 (MA)	REC05	REC09
	P4 (MT)	REC06	REC12
	P5 (HE)	REC08	-
	P6 (MI)	REC11	-

6.2.3.1. Session Audit Reporting

Session auditing provided direct observation of participant where any type of notification was to be noted down as it happened. This enabled pre-assessment of the performance and preference data which served as complementary to the recorded data as the reasons behind actions/evaluations of the participants or the problems in the records at hand. During session auditing particular observation was also made to note down problems or rework encountered in each task together with any attempt to use of help or library. Therefore, this section presents results on background of the task performances by observations made and live feedback obtained throughout note-taking process.

As a result of analysis of session audits, actions and feedbacks were evaluated. There was no need for use of library by none of the participants in none of the scenarios. The following tables (Table 6.6 and Table 6.7) depict the results.

There was only one completion error (Participant 4) in the test and it was due to a mistaken selection of the exit button (Escape Key (ESC)). There were minor errors in the process some of them were grouped under several sections of the tool. This grouping indicates an attention on these areas; however, all of the problems were recorded mainly due to first use of the tool. Considerable improvement of the second run of the two participants and the verbal confirmation of the participants on the "real cause as the first use" support that it would be easily learned otherwise.

Table 6.6: Critical Errors and Non-Critical Errors

	P1		**P2**		**P3**		**P4**		**P5**		**P6**		**P2(2nd)**		**P3(2nd)**		**P4(2nd)**	
	C	**N**	**C**	**N**	**C**	**NC**	**C**	**N**	**C**	**N**	**C**	**N**	**C**	**N**	**C**	**N**	**C**	**N**
S1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S2	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
S3	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-
S4	-	-	-	-	-	1	-	3	-	1	-	1	-	-	-	-	-	1
S5	-	-	-	-	-	-	-	2	-	1	-	-	-	-	-	-	-	-
S6	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
S7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S9	-	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
S10	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-
S11	-	1	-	1	-	1	-	2	-	-	-	-	-	-	-	1	-	-
S12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	-	2	-	2	-	4	1	10	-	2	-	1	-	-	-	1	-	1

Table 6.7: Task Completion Rates

	S1	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**	**S11**	**S12**	**S13**	**S14**
P1	√	√	√	√	√	√	√	√	√	√	√	√	√	√
P2	√	√	√	√	√	√	√	√	√	√	√	√	√	√
P3	√	√	√	√	√	√	√	√	√	√	√	√	√	√
P4	√	√	√	√	√	√	√	√	√	X	√	√	√	√
P5	√	√	√	√	√	√	√	√	√	√	√	√	√	√
P6	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Success	6	6	6	6	6	6	6	6	6	5	6	6	6	6
Completion Rate	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %	83 %	100 %	100 %	100 %	100 %

6.2.3.2. Performance Data: Testing Software Outputs

Performance data includes results of measures of participant behavior during testing process that are simply the observation of either the live testing process through session audits or review of the recordings of the software following completion of the testing process (Rubin and Chisnell, 2008). In this section, performance data obtained from software (Tobii Studio - 3.4.5), which is also supported by the session audits, will be presented.

Eye movement tracking technology is based on measurement of main two events as “fixations” and “mouse clicks” of the user. TOBII Studio provides calculation of eye movement metrics through “descriptive statistics” based on “eye and mouse tracking metrics” (“Tobii AB”, 2016). To analyze the obtained recordings, firstly the data was grouped according to participants as the recordings of “All Participants”, “External Participants” and “Internal Participants” where the recordings belonging to external participants were further categorized as “External Participants – First Run” and “External Participants – Second Run” to distinguish the “Learnability” within tasks through the results of participants that were tested two times. Outputs obtained for “Internal Participants” were used as the “best case” for each of the tasks to compare with the outputs of “External Participants – First Run” as the first reaction of the user with the tasks and COPPMAN interface. Outputs for “External Participants – Second Run” served mainly for distinguishing how much the results were evolved to the ones obtained as the “best case” as indicating the success of COPPMAN with learnability. Outputs for “External Participants” and “All Participants” were used to oversee the trend with the obtained results where effects of groups of the participants supported the analysis process. For separating the overall recordings into manageable outputs, since COPPMAN is web based tool, results were mainly analyzed based on “URL and Size” as one of the default options provided for dividing recordings to tasks through “Web Groups”. However, fine-tuning was made through “Manual” grouping to certainly distinguish the recordings according to tasks and finalize the “unique media element” as the main focus (“Tobii AB”, 2016). As a result of the analysis made, obtained outputs are presented in the following sections in two main sections in terms of the “Numerical Outputs” and “Visual Outputs”.

6.2.3.2.1. Numerical Outputs

TOBII Studio enables analysis through representing data for each metric by using "descriptive statistics" based on identified Areas of Interest (AOI), which were identified as overall screen in testing analysis of COPPMAN. Between the provided results the following metrics were selected according to nature of the test and directly obtained as performance measures from TOBII Studio ("Tobii AB", 2016):

- **Time to First Fixation:** "measures how long it takes before a test participant fixates on an active AOI or AOI group for the first time",
- **Total Fixation Duration:** "measures the sum of the duration for all fixations within an AOI",
- **Mouse Click Count:** "measures the number of times the participant left-clicks with the mouse on an AOI or an AOI group",
- **Time to First Mouse Click:** "measures how long it takes before a test participant left-clicks with the mouse on an active AOI or AOI group for the first time", and
- **Time from First Fixation to Next Mouse Click:** "measures the time from the first fixation within an active AOI or AOI group until the participant left-clicks within the same active AOI or AOI group".

Among the presented outputs, "total fixation duration" indicates the total time of the participant as contact time with the screen while performing the overall task. Therefore, "total fixation duration" was accepted as the "time on task" metric as indicating the time that the participant spent for performing each task. Additionally, "mouse click count" is the direct indicator of the effort expended with the tasks. "Time to first fixation" was obtained for all tasks as almost "0 seconds" since the AOIs were identified as overall screen obtained throughout the task. Times to "mouse clicks" were investigated and the results were obtained parallel to the success with other measures. Since this metric provides detailed results in terms of each screen encountered within tasks and cannot be summarized for the overall scenario, they will not be presented in this section in detail. Therefore, details of "total fixation duration" and “mouse click count” results for each scenario with regard to each participant group are as provided in the following tables (Table 6.8 and Table 6.9).

Table 6.8: Total Fixation Duration (Time on Task)

	External Participants First Run		External Participants Second Run		Internal Participants	
	Average (seconds)	Standard Deviation (seconds)	Average (seconds)	Standard Deviation (seconds)	Average (seconds)	Standard Deviation (seconds)
S1	29.97	5.35	16.05	3.71	19.96	9.48
S2	28.19	3.88	18.49	5.66	17.47	3.10
S3	32.81	6.37	17.17	1.33	18.19	2.54
S4	57.06	16.67	26.70	3.34	29.67	2.77
S5	105.76	20.72	64.90	6.61	61.39	9.28
S6	24.63	3.76	17.26	1.64	16.56	6.87
S7	46.60	7.82	33.70	1.63	36.25	9.33
S8	14.16	1.87	10.57	1.05	13.22	3.74
S9	70.50	6.85	41.37	2.49	45.47	2.52
S10	56.57	10.26	35.10	5.57	37.14	7.54
S11	52.00	5.83	28.73	2.61	30.09	4.10
S12	86.62	20.67	49.13	4.54	45.48	7.51
S13	80.74	15.45	52.65	3.11	52.29	5.23
S14	18.23	3.55	12.35	1.08	11.57	0.56

Table 6.9: Mouse Click Count

	External Participants First Run		External Participants Second Run		Internal Participants	
	Average (clicks)	Standard Deviation (clicks)	Average (clicks)	Standard Deviation (clicks)	Average (clicks)	Standard Deviation (clicks)
S1	9.00	2.28	8.66	1.29	8.33	1.15
S2	10.34	3.28	8.67	1.15	8.67	1.15
S3	8.67	1.86	7.67	0.58	7.33	0.58
S4	16.67	6.90	10.33	1.15	10.33	1.16
S5	46.50	13.18	42.00	1.73	42.00	1.73
S6	5.83	0.75	5.33	0.58	5.00	0.00
S7	19.17	1.72	18.33	0.58	18.67	0.58
S8	6.67	0.69	6.00	0.00	6.67	1.15
S9	27.00	5.66	24.33	2.08	23.00	1.00
S10	14.50	2.35	14.00	2.00	13.67	0.58
S11	15.67	2.73	13.33	1.53	14.67	2.31
S12	3.50	0.66	3.33	0.58	3.33	0.58
S13	21.50	1.05	20.67	0.58	20.33	0.58
S14	6.33	0.52	6.00	0.00	6.00	0.00

6.2.3.2.2. Visual Outputs

TOBII Studio provides “visual qualitative inspection of results” through three main visual outputs as the “Cluster”, “GazePlot”, and “HeatMap”. These outputs provide “dynamic representation” of the obtained data through recordings as it is exemplified in the following figure where output for “Adding Project” task (Scenario 5) is provided for “All Participants” (Figure 6.3) (“Tobii AB”, 2016).

Figure 6.3: Examples for Visual Outputs by TOBII Studio

As it can be observed through Figure 6.3, the recordings can be analyzed from different point of views (“Tobii AB”, 2016):

- **Clusters:** indicate the area of interest on the background image, which is the screen viewed throughout the task, as the “areas with high concentrations of gaze data points”,
- **GazePlots:** provide the “sequence and position (dots) of fixations” as the “gaze pattern” where “size of dots” represents “fixation duration” and “number in dots” represents “order of fixations”,
- **HeatMaps:** depict “density of fixations” by different colors in terms of either “count” or “duration” of fixations where “red” indicates the “highest number” or “longest duration” in its default.

"Clusters" were used mainly to distinguish the success of areas where screen has "group boxes" to group different sections of the interface in accordance with the requirements of the intended process. "Gazeplots" were for identification of the search of the participant all over the interface (order of dots) and also stay of his/her fixation (size of dot) on the focused area that indicates the success of the design of the interface. "Heatmaps" were the outputs as indicator of the "density" of gaze data that bears traces from both "clusters" and "gazeplots" where it successfully combines underlining the area of interests together with the cumulative stay of the fixations. Therefore, "Heatmaps" constituted the main outputs for analysis where they were supported with "Clusters" and "Gazeplots" for "areas" and "order" of fixations respectively ("Tobii AB", 2016).

Through the options provided, "Clusters" can be arranged according to different "Threshold" values as it is depicted in the following figure in the order of increasing threshold values (Figure 6.4) (Scenario 5 – All Participants). "Clusters" obtained for analysis of COPPMAN were arranged according to corresponding screens and gaze data. Same number of clusters (with share of "100%" percentage from all participants for each cluster) were aimed for outputs of the same screen with different participant groups to ease comparison as long as it was applicable.

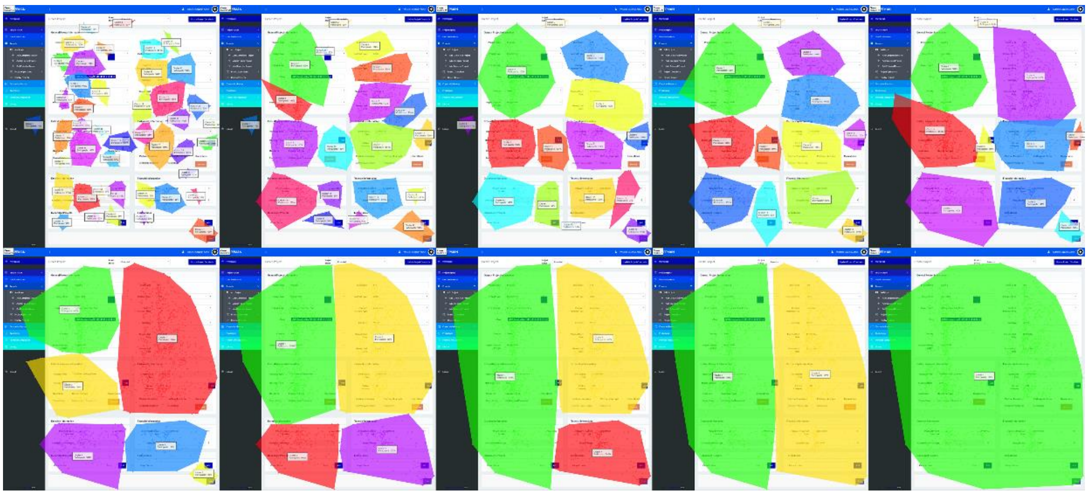


Figure 6.4: Clusters with Different "Threshold" Options

Similarly, “Heatmaps” can be arranged according to different “Radius” options as it is provided in the following figure in the order of increasing radii (Figure 6.5) (Scenario 5 – All Participants). Consideration with “Heatmaps” was arranging the “Radius” to fit with the screen without violating the visibility of the related areas (“87 pixels” was set for the radius of all of the outputs while “100%” opacity was selected for coloring).

Figure 6.5: Heatmaps with Different “Radius” Options

“Absolute duration” was used for heatmaps rather than “count” of fixations to include the “stay” of the user on the fixation point. Finally, the “gaze opacity” option was also used for heatmaps with “75%” opacity to ease identification of the focused areas as it is exemplified in the following figure (Figure 6.6) (Scenario 5 – All Participants).

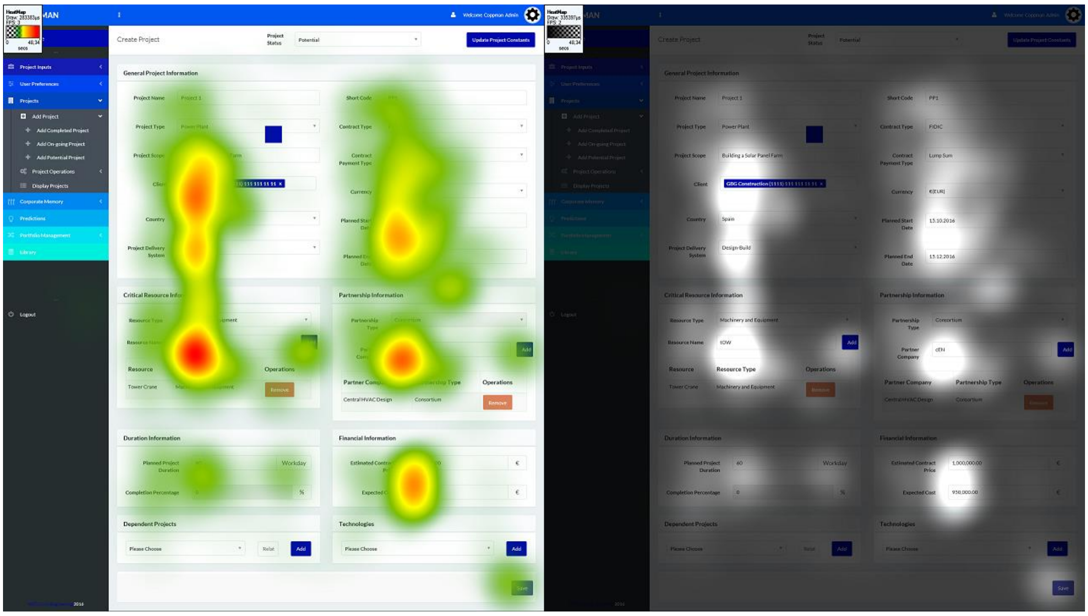


Figure 6.6: Heatmap with “Gaze Opacity” Option

Therefore, the provided four outputs as the “Clusters”, “Gazeplots”, “Heatmaps” and “Opaque Heatmaps” were obtained and analyzed for all of the tasks according to each different participant group. The following figure depicts the process where each main outputs are exemplified for each participant group rather than for only “All Participants” as in the previous examples (Scenario 5). The outputs in the figure are ordered from the left by “All Participants”, “External Participants”, “External Participants – First Run”, “External Participants – Second Run”, and “Internal Participants” respectively (Figure 6.7).

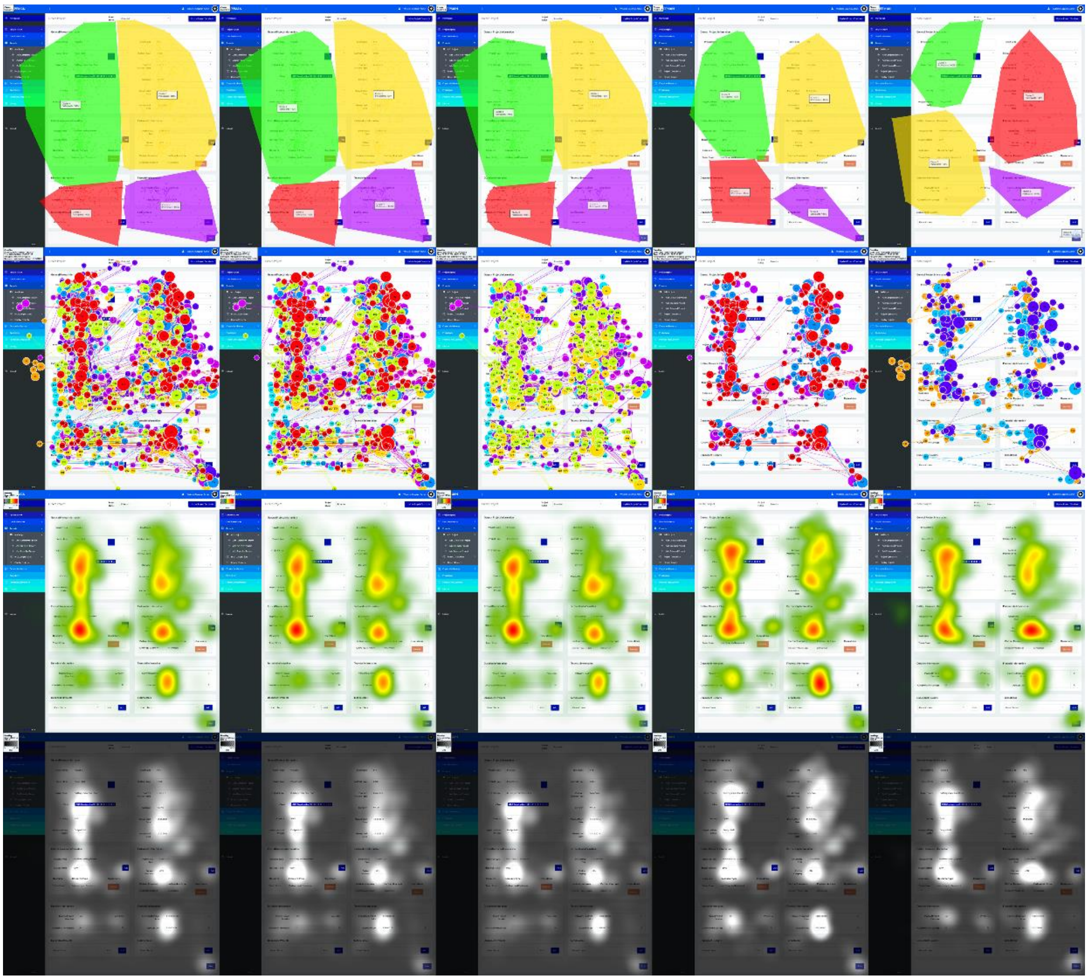


Figure 6.7: Outputs with Different Participant Groups

In total, “700” outputs were analyzed for “35” different screens visualized within the tasks of “14” scenarios used in the testing process where each screen has “4” main outputs obtained for “5” different participant groups. The visual outputs provided successful results regarding the success of the interface design and acted as complementary data for the other results obtained within the overall analysis.

6.2.3.3. Preference Data: Questionnaire Results

Preference data includes results of measures of participant opinion on the product as a subjective evaluation of the tested product through any type of questionnaires conducted following the testing process (Rubin and Chisnell, 2008). This section presents the results of evaluations of the participants upon both each task and the overall test.

6.2.3.3.1. Post-Task Results

Ratings obtained as the result of six questionnaires held upon completion of different groups of tasks/scenarios are as presented in the following table (Table 6.10).

Table 6.10: Post-Task Questionnaire Ratings

		Ease of Use	Satisfaction	Consistency	Learnability	User Guidance	Sub-Average
P1	**Q1**	7.00	7.00	7.00	7.00	7.00	**7.00**
	Q2	7.00	7.00	7.00	7.00	7.00	**7.00**
	Q3	7.00	7.00	7.00	7.00	7.00	**7.00**
	Q4	7.00	7.00	7.00	7.00	7.00	**7.00**
	Q5	7.00	7.00	7.00	7.00	7.00	**7.00**
	Q6	7.00	7.00	7.00	7.00	7.00	**7.00**
	Sub-Average	**7.00**	**7.00**	**7.00**	**7.00**	**7.00**	**7.00**

Table 6.10: Post-Task Questionnaire Ratings (continued)

		Ease of Use	Satisfaction	Consistency	Learnability	User Guidance	Sub-Average
P2	**Q1**	6.67	7.00	7.00	7.00	7.00	**6.93**
	Q2	6.80	7.00	7.00	7.00	7.00	**6.96**
	Q3	7.00	7.00	7.00	7.00	7.00	**7.00**
	Q4	7.00	7.00	7.00	7.00	7.00	**7.00**
	Q5	7.00	7.00	7.00	7.00	7.00	**7.00**
	Q6	7.00	7.00	7.00	7.00	7.00	**7.00**
	Sub-Average	**6.91**	**7.00**	**7.00**	**7.00**	**7.00**	**6.98**
P3	**Q1**	6.50	6.14	6.80	6.43	6.50	**6.47**
	Q2	6.27	6.43	6.60	6.29	6.57	**6.43**
	Q3	6.44	6.14	6.80	6.57	6.17	**6.42**
	Q4	6.53	6.71	6.40	6.57	6.50	**6.54**
	Q5	6.55	6.71	6.40	6.43	6.40	**6.50**
	Q6	6.67	6.86	6.40	6.29	6.33	**6.51**
	Sub-Average	**6.49**	**6.50**	**6.57**	**6.43**	**6.41**	**6.48**
P4	**Q1**	7.00	7.00	7.00	7.00	7.00	**7.00**
	Q2	7.00	7.00	7.00	7.00	7.00	**7.00**
	Q3	7.00	7.00	7.00	7.00	7.00	**7.00**
	Q4	6.27	6.43	6.60	6.00	6.40	**6.34**
	Q5	7.00	7.00	7.00	7.00	7.00	**7.00**
	Q6	7.00	7.00	7.00	7.00	7.00	**7.00**
	Sub-Average	**6.88**	**6.91**	**6.93**	**6.83**	**6.90**	**6.89**
P5	**Q1**	6.67	6.57	7.00	6.43	7.00	**6.73**
	Q2	6.27	6.57	7.00	6.43	7.00	**6.65**
	Q3	5.94	5.43	6.80	6.14	6.00	**6.06**
	Q4	6.87	6.43	7.00	6.43	6.60	**6.67**
	Q5	6.91	6.43	7.00	6.86	7.00	**6.84**
	Q6	6.62	6.71	7.00	6.29	7.00	**6.72**
	Sub-Average	**6.55**	**6.36**	**6.97**	**6.43**	**6.77**	**6.62**
P6	**Q1**	6.92	6.57	6.20	6.86	6.33	**6.58**
	Q2	5.80	6.29	6.00	7.00	5.00	**6.02**
	Q3	6.69	6.57	7.00	6.71	5.67	**6.53**
	Q4	6.87	6.14	7.00	6.29	6.00	**6.46**
	Q5	6.36	6.57	7.00	7.00	4.60	**6.31**
	Q6	6.62	6.57	7.00	7.00	6.00	**6.64**
	Sub-Average	6.54	6.45	6.70	6.81	5.60	**6.42**
ALL AVERAGE		**6.73**	**6.70**	**6.86**	**6.75**	**6.62**	**6.73**

According to the results, it is seen that most of the attributes are highly rated in the questionnaires, where their overall averages are at least "6.62". The statements that got lower points are parallel with the identified mistakes/problems of the participants. Lower rating averages that need attention are as recorded follows:

- Ratings of P4 over “Q4” which includes “Scenarios 9 and 10” that are for the “Corporate Memory Menu”: related with the participant’s completion error in “Scenario 10: Lesson Learned Search”.
- Ratings of P5 over “Q3” which includes “Scenarios 5 to 8” that are for the “Projects Menu”: related with the participant’s concurrent difficulties in the same menu such as adding project dates, loading times in searches, and use of some buttons.
- Ratings of P6 over “Q2” which includes “Scenarios 3 and 4” that are for the “User Preferences Menu”: related with the participant’s main difficulty in “Factor Ordering”. Also “User Guidance” is evaluated to be low due to lack of informative boxes on some buttons and guidance in information entry.

6.2.3.3.2. Post-Test Results

The results of the overall evaluation made at the end of the testing process are as presented in the following table (Table 6.11).

Table 6.11: Post-Test Questionnaire Ratings

	P1	**P2**	**P3**	**P4**	**P5**	**P6**
Overall Rating	7.00	7.00	6.39	6.96	6.61	6.70
AVERAGE	6.78					

Overall evaluation resulted with ratings for experience with COPPMAN as “6.78” on average and minimum “6.39”, which indicates the pleasure with the overall utilization process and provided capabilities of COPPMAN. Besides the ratings on overall evaluation of the tool, comments obtained through open-ended questions are as follows (hit-rates are provided in parenthesis):

- Appreciated features of the tool:
  - User-friendly interface (clean and plain appearance) (4)
  - Easy-to-follow, quick, and learnable process (1)
  - Web-based easy operation (1)
  - Informative menus (1)
  - Tolerable to user errors (1)
  - Provision of usable and familiar short-cuts (such as use of “Tab”) (1)
  - Providing appropriate information under appropriate modules (1)
- Inadequate features of the tool:
  - Use/Visibility of some buttons may be improved (5)
  - Loading time may be improved (loading of search results) (3)
  - Selection of date from the calendar may be improved (2)
- Difficult tasks:
  - Sorting strategic factors (1)
- Suggestions:
  - Integration with Excel (2)
  - Demo projects or portfolios may be provided (1)
  - Provision of pop-up informative descriptions for use of some buttons (1)

6.2.3.4. Results Summary

Analysis of the “performance” data together with the points obtained through “preference” data provided a complete support for the problems identified with “session audits”. Especially, performance measures provided as both “numerical” and “visual” outputs allowed objective analysis of screens and typical tasks of COPPMAN, which would not be identified with traditional methods.

The “numerical outputs” showed that the performance of the participants were within the limits set by “benchmarks” for the metrics. The following table shows the completion rates of the participants (“External Participants – First Run”) without minor/major errors (Table 6.12). Benchmark with the “completion without major errors” was set to be “100%” (i.e., “0%” error rate) and “Scenario 10” seems to be violating the results. However, this error can be underestimated in the overall, since it can be evaluated as a technical error and also success of the participant in the second run depicts a quick recovery of the problem. Additionally, “completion without minor errors” depict that “6” of the “14 scenarios” were completed without minor errors, which means that all participants completed the tasks without any hesitation.

Table 6.12: Task Completion Success Rates

	Task Completion Success Rates	
	Percentage Without Minor Errors	**Percentage Without Major Errors (Percentage of Participants Completing Successfully)**
S1	100%	100%
S2	83%	100%
S3	67%	100%
S4	33%	100%
S5	67%	100%
S6	83%	100%
S7	100%	100%
S8	100%	100%
S9	67%	100%
S10	83%	83%
S11	33%	100%
S12	100%	100%
S13	100%	100%
S14	100%	100%

“Time on task” data also depicts that participants successfully performed within the expected limits of time, which was set to be maximum “two times” of the best case (Table 6.13). The case is also same with the “mouse click counts”, which shows that participants put expected level of effort for the tasks (Table 6.14).

Table 6.13: Checking Task Completion Time Averages

	Time on Task		
	External Participants First Run Mean Time (seconds) (a)	**Internal Participants Mean Time (seconds) (b)**	**Benchmark Check (a)/(b)**
S1	29.97	19.96	1.50
S2	28.19	17.47	1.61
S3	32.81	18.19	1.80
S4	57.06	29.67	1.92
S5	105.76	61.39	1.72
S6	24.63	16.56	1.49
S7	46.60	36.25	1.29
S8	14.16	13.22	1.07
S9	70.50	45.47	1.55
S10	56.57	37.14	1.52
S11	52.00	30.09	1.73
S12	86.62	45.48	1.90
S13	80.74	52.29	1.54
S14	18.23	11.57	1.58
		Average	1.59

Table 6.14: Checking Mouse Click Counts

	Mouse Click		
	External Participants First Run Mean (clicks) (a)	**Internal Participants Mean (clicks) (b)**	**Benchmark Check (a)/(b)**
S1	9.00	8.33	1.08
S2	10.34	8.67	1.19
S3	8.67	7.33	1.18
S4	16.67	10.33	1.61
S5	46.50	42.00	1.11
S6	5.83	5.00	1.17
S7	19.17	18.67	1.03
S8	6.67	6.67	1.00
S9	27.00	23.00	1.17
S10	14.50	13.67	1.06
S11	15.67	14.67	1.07
S12	3.50	3.33	1.05
S13	21.50	20.33	1.06
S14	6.33	6.00	1.06
		Average	1.13

“Numerical outputs” also served for depiction of the learnability effect within the tasks of COPPMAN. As it is provided in the following table, participants provided a considerable shortage in duration in their second run, which ranges between “25-53%” and “38.36%” on average (Table 6.15). This constitutes a considerable shortage in the initial effort. Comparison of results of the second run of the external participants with the internals also provides “96.43%” score, which means that their performance is so close to each other on the average. Results also show that external participants performed better than internals in “6 scenarios”, which can be deemed as a sound indicator of “learnability” with COPPMAN.

Table 6.15: Improvement in Total Fixation Durations

	Total Fixation Duration			Improvement of External Participants (Second Run)	
	External Participants First Run (a)	External Participants Second Run (b)	Internal Participants (c)	With Respect To External Participants First Run [(a)-(b)]/(a)*100	With Respect To Internal Participants (b)/(c)*100
	Average (seconds)	Average (seconds)	Average (seconds)	Shortage in Duration (%)	Success (%)
S1	29.97	16.05	19.96	46	80
S2	28.19	18.49	17.47	34	106
S3	32.81	17.17	18.19	48	94
S4	57.06	26.70	29.67	53	90
S5	105.76	64.90	61.39	39	106
S6	24.63	17.26	16.56	30	104
S7	46.60	33.70	36.25	28	93
S8	14.16	10.57	13.22	25	80
S9	70.50	41.37	45.47	41	91
S10	56.57	35.10	37.14	38	95
S11	52.00	28.73	30.09	45	95
S12	86.62	49.13	45.48	43	108
S13	80.74	52.65	52.29	35	101
S14	18.23	12.35	11.57	32	107
			Average	38.36	96.43

Considering “visual outputs”, grouping participants provided successful analysis of the results where outputs of “Internal Participants” served as the reference for the best-case, while outputs of “External Participants - First Run” were indication of the pure results of the first contact with the tasks and outputs of “External Participants - Second Run” were for testing of improvement by the second attempt. Grouping the participants also provided an effective control of the gaze data obtained by the outputs. Some level of unexpected gaze data in the outputs of “External Participants”, which might be due to saccadic movement of eyes during waiting periods for loading of related screens within the tasks, were checked against their existence in the outputs of “Internal Participants”. The outputs showed similar patterns for both “external” and “internal” participants.

Some of the tasks were more serving for easiness of the operation while the others were more focused on testing of the success of the screen design. Analysis of numerical and visual outputs complemented each other and provided an overall analysis of the tasks and so COPPMAN. Analysis was reinforced with consideration of participant groups both for testing against best case and learning possibility. As a result, analysis provided successful validation through sound feedback obtained as reasonable design of the interface and acceptable level of the effort required for performing representative tasks of COPPMAN.

As another consideration for in depth investigation, analysis of questionnaires provided a final tuning in the usability analysis through the supportive results obtained by other considerations. Findings supported the points that were covered within the analysis prior to questionnaires and detailed preference data is obtained positively by exceeding the benchmark limit of “4” as evaluation score for each statement group for the attributes provided in the questionnaires.

As a result, all of the findings within the context of usability testing provided a complete recognition of COPPMAN as an acceptable tool regarding its usability metrics. The identified or stated problems were accepted to be due to first use of the tool and evaluated to be easily recovered by its further use. The performance data also served for recognition of considerable level of learnability with the tasks of COPPMAN. Problems identified with usability software and questionnaires were parallel with the problems observed in session audits and no any other considerable point was obtained through these evaluations. Main problems were identified to be related with first time contact of participants with the tool interfaces; however, problem with “loading time” might be contributed to testing environment. Consideration of “loading time” was decided to be evaluated in the further real application testing process. In addition, integration with any other tool would be decided based on evaluation after real application process. Therefore, it is accepted that usability testing was resulted with an acceptance of further testing with a real case study without need of any further improvement in the tool at this point.

6.3. Concluding Remarks

This chapter presents the usability testing undertaken with participants as the potential users of the tool. As it is demonstrated, usability testing provided a more interface-oriented diagnosis. It was an important consideration in the design of tool as the more detailed evaluation of its functionality in terms of usability capacity. There were no critical errors identified at the end of the testing process and the results were successful considering the objective, scope and the potential users of the tool. According to the results, tool is effective and easy to use, and its interface has good navigation and layout. Its interface, menus, location and types of visual elements and flow of work are all found to be acceptable and functional. The stated problems with some buttons and some of the functions are not evaluated to be critical when the easiness in learnability and the scope of the tool (will be used by specific people) is considered. Therefore, analysis provided acceptable results and the tool was decided to be proceeded with another testing process without any requirement of current update in the tool. The next chapter handles the actual implementation study undertaken within this respect as the beta testing of the tool implying its actual utilization in actual environment and with an actual case by its actual users.

CHAPTER 7

A REAL APPLICATION

Since this study is based on generation of a solution to an identified problem in practice, the ultimate proof for the success of the research is to be ensured through its application in practice. Therefore, as an initial testing of its real benefit, its trial in real setting through actual users was provided through “real application” process through analysis of a “pilot portfolio” of real projects (Fischer, 2006).

Real application process was held in two main sections as establishment of the portfolio analysis through real projects, and evaluation of the process and the tool through survey (Survey 8). The survey includes two sections, one for open questions on evaluation of tool, its possible benefits and barriers (Survey 8: Section 1) and other section for ratings on evaluation of the tool following the actual implementation process (Survey 8: Section 2). The survey is provided in Appendix K.

The established portfolio and results of the evaluation is presented in the below sections including the information on the company, details of the case and the evaluation results together with the provided update for COPPMAN.

7.1. The Company

The same power systems company (“focus group”) was selected for actual implementation process. Participation of the same professionals from the power systems company (Survey 1, 2 and 4) was provided to make their evaluations scattered to complete process of tool development at three levels as establishment of need analysis, generation of model and evaluation of the tool. Their contribution is considered to be valuable since they have established a considerable know-how about the process of tool development.

The company undertakes power plant EPC contracts, particularly in the gas combined cycle power plant arena and has important achievements in providing engineering and contracting services. It has accomplished remarkable projects in the international electricity generation market. The company has recently executed projects mainly in Middle East, Turkey, Africa and Commonwealth of Independent States (CIS). The executed projects can be grouped as follows:

- Power plants,
- Pipelines and material handling systems,
- Steam plants, and
- Other industrial projects.

The company process control mechanism consists of two main structures as “business development” and “operation control”. Reporting department presents to CEO, where strategic analysis is held in this reporting process. Performance measurement is under control of human resources department. The evaluation was held by the same professionals (focus group) from the units of:

- Business Development,
- Business Control and Risk Management, and
- Enterprise Systems

where their joint contribution is important to reflect the practices of these main units, which would be the most involved units for utilization of a portfolio management tool.

7.2. The Case/Portfolio

The case/portfolio was established with information of real projects of the power systems company. The company professionals decided to create a “sample portfolio” rather than entering all the “completed” and “active” projects of the company. The portfolio was formed with somewhat similar projects, which are mainly “combined cycle power plant projects”, to make the outputs of the tool representative with minimum information entry. Within this context, five “completed project” information with five crucial “lessons learned” in these projects were entered to the database. Among the active projects of the company, information of two “on-going projects” with two “potential projects” were provided to complete the portfolio establishment. Information of the projects have been protected with coding the “project names” and “actor names” and also adjusting the numerical figures in the financial information in the same way/ratio.

This section presents the case and includes evaluations noted during the whole process of utilization of COPPMAN in the power systems company. The portfolio analysis process is presented as grouped under the processes of “data entry”, “data analysis” and “data output” where the real time evaluations of the professionals are embedded in the presentation. Considerations of the professionals are provided following representation of each related section of the process.

7.2.1. Data Entry

Data entry process includes identification of project inputs, setting preferences, entering the project information and the lessons learned. Within this process, five completed project, two on-going and two potential project information were entered together with five lessons learned in the completed projects.

7.2.1.1. Project Inputs

The following project inputs were identified at the beginning of the process except for the inputs of "critical work packages", "critical delay causes", "technologies" and "actors", which were identified during entry of the projects:

- **Project Types:** Combined Heat and Power Plant, Combined Cycle Power Plant, Combined Cycle Cogeneration Plant, Combined Cycle Gas Turbine Power Plant, Natural Gas Fired Combined Cycle Power Plant, Diesel Power Plant, Cogeneration Power Plant, Power Plant, Electrical and Thermal Output Power Plant, Thermal Power Station Rehabilitation, Simple Cycle Electrical Power Plant, Simple Cycle Power Plant, Thermal Power Plant, and Electromechanical Installation
- **Project Delivery Systems:** EPC and Construction/Contractor
- **Contract Types:** FIDIC Silver and Client Specific
- **Contract Payment Type:** Lump Sum
- **Resource Types:** Material, Machinery and Equipment, Manpower, and Personnel
- **Partnership Types:** Consortium and Subcontractor
- **Critical Work Packages:** Mechanical Installation, Electrical Installation, Steel Structure Installation, Civil Works, and Commissioning Works
- **Critical Delay Causes:** Poor performance of the contractor, Breakdown of machine, Poor performance of the subcontractor, Unavailability of manpower due to political crisis between the countries, and Unforeseen ground conditions
- **Technologies:** Single-Shaft, Multi-Shaft, 1+1, 2+1, 9F Machine, 9H Machine, 7FA Machine, District Heating
- **Actors:** Actor information was entered as follows (Figure 7.1);

Actors

Information	Address	Operations
Name/Title: Client K **Phone:** (1234) 567 891 23 45	Address CK	Edit Remove
Name/Title: Partner K **Phone:** (2345) 678 912 34 56	Address PK	Edit Remove
Name/Title: Subcontractor K **Phone:** (3456) 789 123 45 67	Address SubK	Edit Remove
Name/Title: Supplier K **Phone:** (4567) 891 234 56 78	Address SupK	Edit Remove
Name/Title: Client Z **Phone:** (5678) 912 345 67 89	Address CZ	Edit Remove
Name/Title: Subcontractor Z **Phone:** (6789) 123 456 78 91	Address SubZ	Edit Remove
Name/Title: Designer Z **Phone:** (7891) 234 567 89 12	Address DZ	Edit Remove
Name/Title: Client R **Phone:** (8912) 345 678 91 23	Address CR	Edit Remove
Name/Title: Client B **Phone:** (9123) 456 789 12 34	Address CB	Edit Remove
Name/Title: Client H **Phone:** (1234) 567 891 23 45	Address CH	Edit Remove
Name/Title: Partner H **Phone:** (2345) 678 912 34 56	Address PH	Edit Remove
Name/Title: Client A **Phone:** (3456) 789 123 45 67	Address CA	Edit Remove
Name/Title: Client P **Phone:** (4567) 891 234 56 78	Address CP	Edit Remove
Name/Title: Client R2 **Phone:** (5678) 912 345 67 89	Address CR2	Edit Remove
Name/Title: Partner R2 **Phone:** (6789) 123 456 78 91	Address PR2	Edit Remove

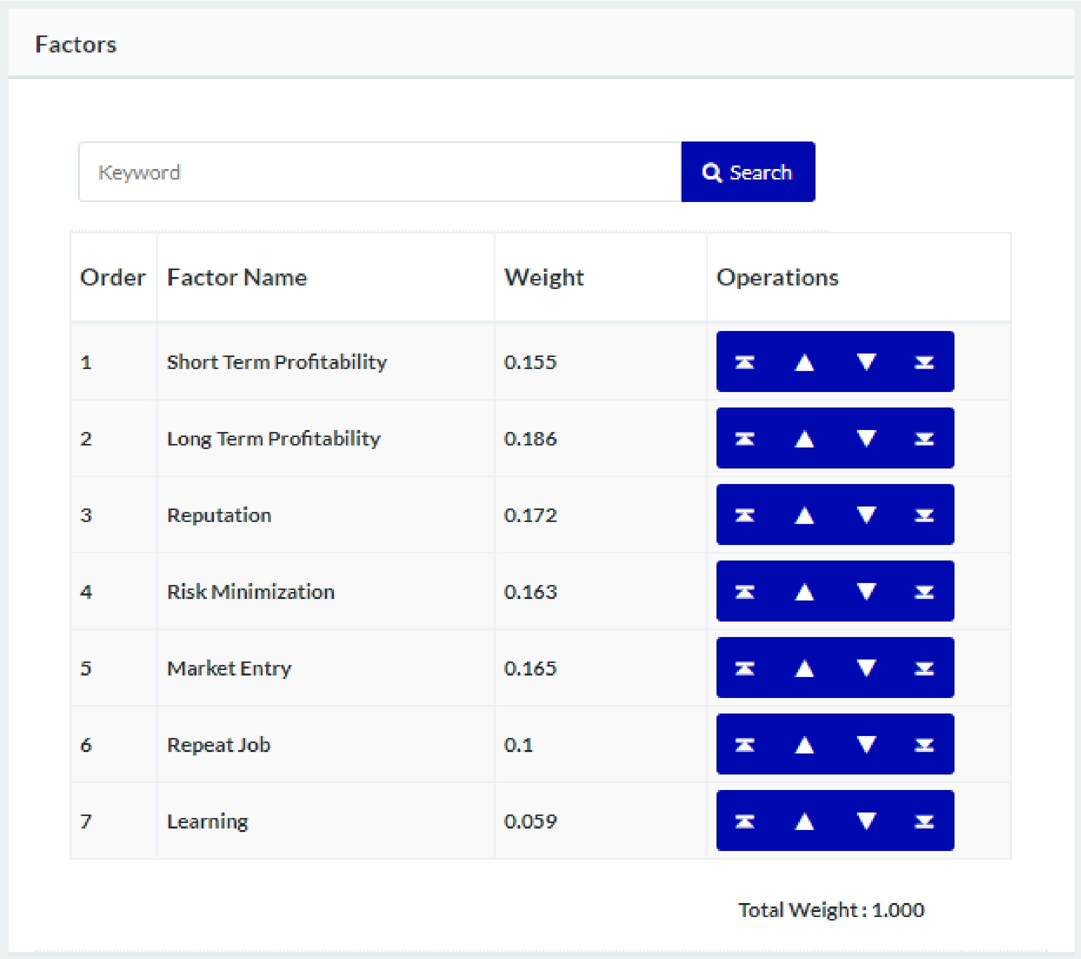
Total 15, Displayed 1-15 Range ‹ 1 ›

Figure 7.1: Entered Actor Information

Evaluation: Designation of project inputs are easy to define and edit. Interoperability may be improved to automatically define users as “actors” for utilization of the tool in big companies. Automatic data export and import mechanisms may be integrated for importing the “user information” from the “Oracle PeopleSoft Database” or “Active Directory” for the companies with 300-500 employees.

7.2.1.2. Preferences

Only evaluation factors for “strategic fit” were edited with addition of “Repeat Job” strategy to the previously identified factor set with the adjustment in the factor weights as follows (Figure 7.2):


Factors

Keyword Search

Order	Factor Name	Weight	Operations
1	Short Term Profitability	0.155	
2	Long Term Profitability	0.186	
3	Reputation	0.172	
4	Risk Minimization	0.163	
5	Market Entry	0.165	
6	Repeat Job	0.1	
7	Learning	0.059	

Total Weight : 1.000

Figure 7.2: Strategic Fit Evaluation Factors

Evaluation: Setting preferences are easy to use. The default list of the risk factors is sufficient to perform the evaluation. It handles all the structure that the company has been currently using in their evaluations in a simplified form. Free text area for the factors is useful since there may be further explanations on the factors provided to make them useful for different evaluators. If one person is responsible from the evaluation process, this form may be sufficient; but further explanation may be required for several users as indication of what score should be entered in what circumstances. The identified strategic factors are also successful to handle various strategies. “Profitability” alone does not always indicate everything, there may be excess advance payment, and the project may be undertaken just for enabling the cash flow. Therefore, it is suitable to differentiate “profitability” as “short term” and “long term”. Risk analysis is also to be made in the process, so it is possible to evaluate the “risk minimization” strategy. A project may be advantageous since it may be retaken with the same client, country, etc. A strategy factor as “repeat job” should be added to the list. Adjustment of the factors is very easy. Only automatic adjustment in factor weights when one addition or deletion is made may be considered as an inclusion to the current methodology.

7.2.1.3. Project Entry

This section presents the entered project information and includes the evaluations noted during the data entry process. Within this context, first the information of completed projects is presented, and it is followed by the information of on-going and potential projects. Effort required for project information entry (entry duration) and easiness were found sufficient by the experts as a general evaluation of the process.

7.2.1.3.1. Completed Projects

Information of the completed projects are provided in the following sections as general project information (Table 7.1), critical resource and partnership information (Table 7.2), duration, financial, dependency and technology information (Table 7.3), and Post Project Appraisal evaluation (Table 7.4 - Table 7.6).

Table 7.1: General Project Information of Completed Projects

	General Project Information				
	Project K	**Project Z**	**Project R**	**Project B**	**Project H**
Short Code	PK	PZ	PR	PB	PH
Project Type	Combined Cycle Power Plant	Combined Cycle Power Plant	Combined Cycle Power Plant	Simple Cycle Power Plant	Thermal Power Station Rehabilitation
Project Scope	840 MW	390 MW	420 MW	750 MW	200 MW
Client	Client K	Client Z	Client R	Client B	Client H
Country	Turkey	Russian Federation	Latvia	Algeria	Iraq
Project Delivery System	EPC	EPC	EPC	EPC	Construction / Contractor
Contract Type	FIDIC Silver	FIDIC Silver	FIDIC Silver	FIDIC Silver	FIDIC Silver
Contract Payment Type	Lump Sum	Lump Sum	Lump Sum	Lump Sum	Lump Sum
Currency	USD	EUR	EUR	USD	USD
Start Date	30/12/2013	01/04/2014	11/10/2010	21/10/2013	19/04/2016
End Date	30/12/2016	29/06/2017	30/07/2013	01/09/2017	29/09/2017

Evaluation: Entry of scope as text is acceptable; however, its quantification may provide more information since it may be used as a factor in grouping of countries. Client type should also be entered as “private” and “government” to increase the extent of information. “Tatarstan” is not available in the current country list; it should be included in the list. Identification of “project significance” for completed projects is required to underline the importance of that project. There should be an entry for information of “project significance” that holds the dropdown list of information like; “learning opportunity”, “new markets”, “unavailability of a material”, “no problem has encountered”, “risky project due to first implementation”, etc. “Project significance” may also be used in calculation of similarities. “Critical milestones” may be added to each project by establishing a flexible area for identification of the milestones for each type of projects. These may be useful to indicate what is done at what stage together with the duration and cost information. Thus, similar projects may be investigated also with the similar milestones. “Notes” section may be added to each project to indicate any further information or explanation regarding to the project.

Table 7.2: Critical Resource and Partnership Information of Completed Projects

<table>
<tr><th rowspan="2"></th><th colspan="2">Critical Resource Information</th><th colspan="2">Partnership Information</th></tr>
<tr><th>Resource Type</th><th>Resource</th><th>Partnership Type</th><th>Partner Company</th></tr>
<tr><td>Project K</td><td>Manpower</td><td>Subcontractor K</td><td>Consortium</td><td>Partner K</td></tr>
<tr><td rowspan="2">Project Z</td><td>Personnel</td><td>Personnel Direct</td><td rowspan="2">Consortium</td><td rowspan="2">Partner K</td></tr>
<tr><td>Manpower</td><td>Personnel Indirect</td></tr>
<tr><td>Project R</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Project B</td><td>Manpower</td><td>Subcontractor B</td><td>-</td><td>-</td></tr>
<tr><td>Project H</td><td>Manpower</td><td>Manpower Iraq</td><td>Consortium</td><td>Partner H</td></tr>
</table>

Evaluation: Current list of the resources is sufficient for a contractor company; however, “subcontractor” should be added to resources to meet the requirements of a management company.

Table 7.3: Duration, Financial, Dependency and Technology Information of Completed Projects

<table>
<tr><th rowspan="2"></th><th colspan="2">Duration Information</th><th colspan="2">Financial Information</th><th>Dependency Information</th><th>Technology Information</th></tr>
<tr><th>Planned Project Duration</th><th>Completion Percentage</th><th>Contract Price</th><th>Expected Cost</th><th>Dependent Projects</th><th>Technologies</th></tr>
<tr><td rowspan="3">Project K</td><td rowspan="3">900 days</td><td rowspan="3">100%</td><td rowspan="3">29,000,000 $</td><td rowspan="3">27,500,000 $</td><td rowspan="3">-</td><td>Multi-Shaft</td></tr>
<tr><td>9F Machine</td></tr>
<tr><td>2+1</td></tr>
<tr><td rowspan="3">Project Z</td><td rowspan="3">1096 days</td><td rowspan="3">100%</td><td rowspan="3">12,000,000 €</td><td rowspan="3">11,400,000 €</td><td rowspan="3">-</td><td>Single-Shaft</td></tr>
<tr><td>9H Machine</td></tr>
<tr><td>1+1</td></tr>
<tr><td rowspan="4">Project R</td><td rowspan="4">1024 days</td><td rowspan="4">100%</td><td rowspan="4">45,000,000 €</td><td rowspan="4">42,750,000 €</td><td rowspan="4">-</td><td>Multi-Shaft</td></tr>
<tr><td>9F Machine</td></tr>
<tr><td>2+1</td></tr>
<tr><td>District Heating</td></tr>
<tr><td rowspan="3">Project B</td><td rowspan="3">300 days</td><td rowspan="3">100%</td><td rowspan="3">50,000,000 $</td><td rowspan="3">47,500,000 $</td><td rowspan="3">-</td><td>Single-Shaft</td></tr>
<tr><td>9F Machine</td></tr>
<tr><td>1+1</td></tr>
<tr><td>Project H</td><td>590 days</td><td>100%</td><td>6,500,000 $</td><td>6,175,000 $</td><td>-</td><td>-</td></tr>
</table>

“Completion Percentage” for “completed” projects is automatically assigned as “100%”, user does not enter this information. According to the entered financial project information, the tool presents the “actual” and “expected” profits in the project cards of the projects with the “profitability” information depicted in the project symbol (it is calculated based on “actual profit” of the “completed” projects and “adapted profits” of the “on-going” and “potential” projects). Profit information of all the entered completed projects are as follows (“risk” and “strategic fit” bars in the project symbols are empty, since no evaluations have been made for completed projects in this case) (Figure 7.3, Figure 7.4, Figure 7.5, Figure 7.6, and Figure 7.7):

- Profit information of Project K
    - Actual Profit: 4,030,000.00 $ (USD)
    - Expected Profit: 1,500,000.00 $ (USD)
    - Profitability: 14.94%

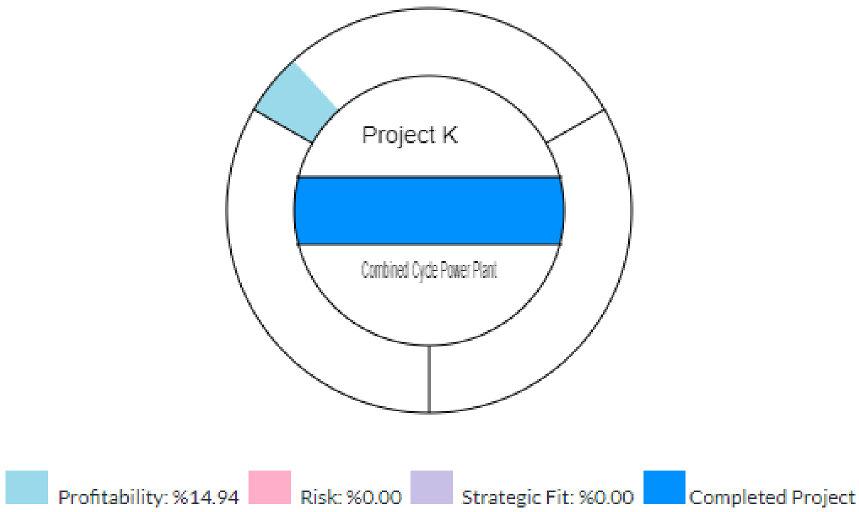


Figure 7.3: Project Symbol for Project K

- Profit information of Project Z
    - Actual Profit: -500,000.00 € (EUR)
    - Expected Profit: 600,000.00 € (EUR)
    - Profitability: 0%

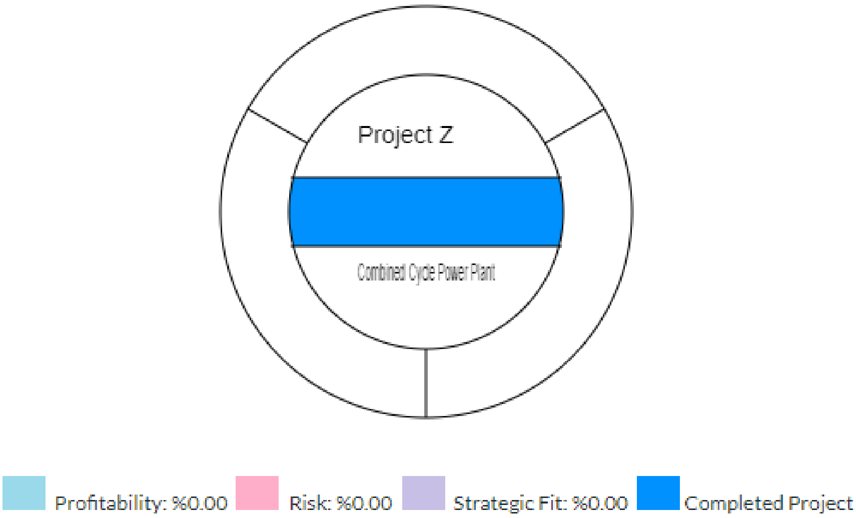


Figure 7.4: Project Symbol for Project Z

- Profit information of Project R
  - Actual Profit: 2,250,000.00 € (EUR)
  - Expected Profit: 2,250,000.00 € (EUR)
  - Profitability: 5.26%

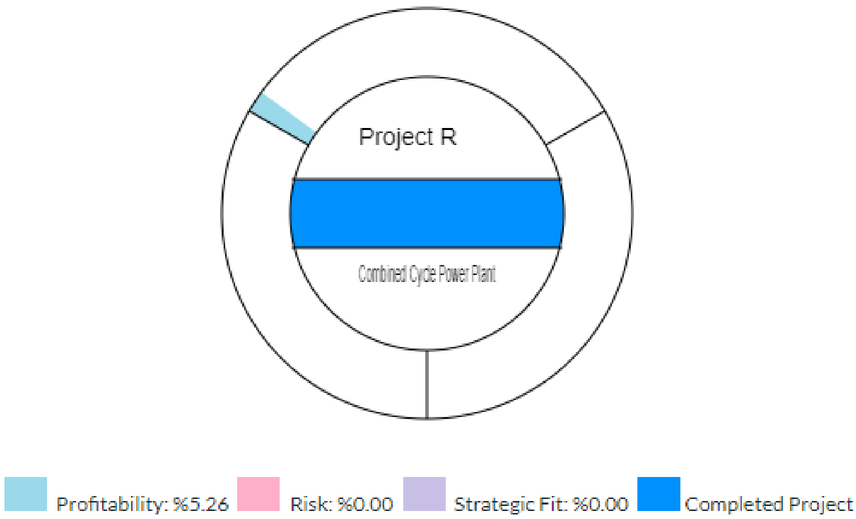


Figure 7.5: Project Symbol for Project R

- Profit information of Project B

- Actual Profit: 0.00 $ (USD)
- Expected Profit: 2,500,000.00 $ (USD)
- Profitability: 0%

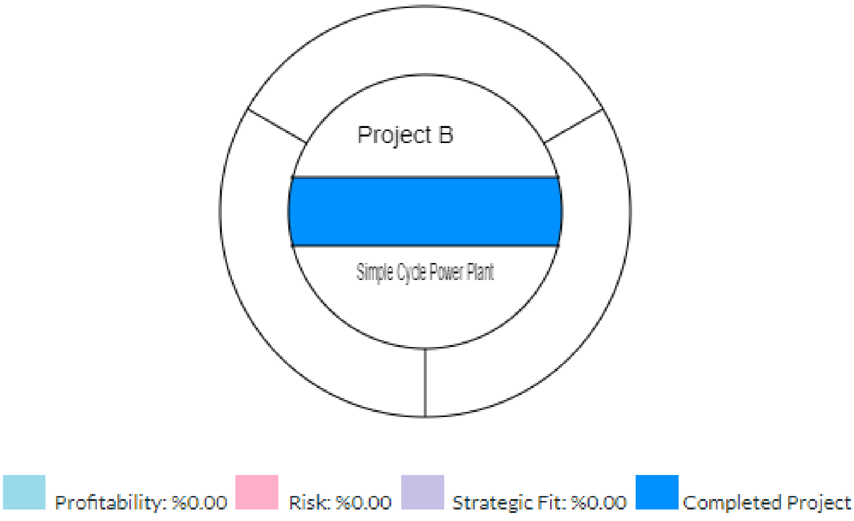


Figure 7.6: Project Symbol for Project B

- Profit information of Project H
    - Actual Profit: 680,000.00 $ (USD)
    - Expected Profit: 325,000.00 $ (USD)
    - Profitability: 11.11%

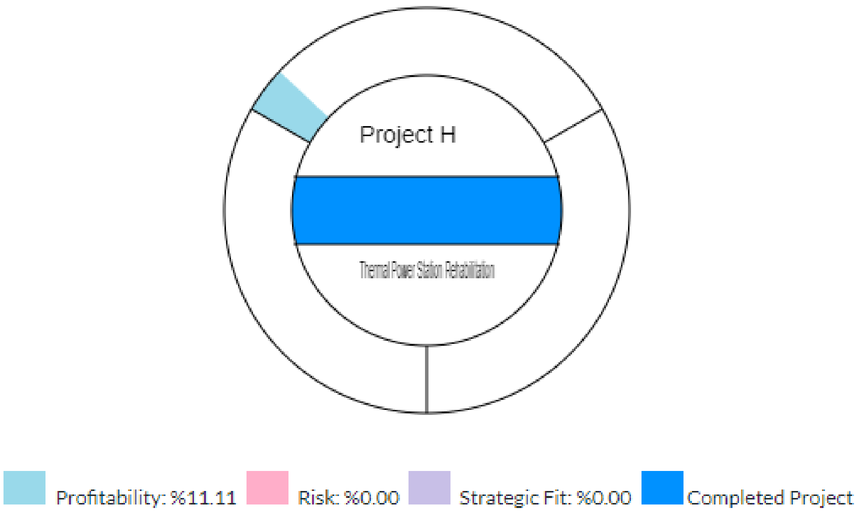


Figure 7.7: Project Symbol for Project H

Evaluation: Entry of the profits in terms of percentages would be better to observe the change in numerical figures as start and finish points rather than numerical figures as "expected cost", tool should calculate the costs based on percentages. "Expected profit" should be entered as a percentage and the expected cost should be automatically calculated. "Profitability" should also be entered/calculated as actual percentage to show the difference in expected percentage and the actual percentage.

Table 7.4: Evaluation Information in Post Project Appraisal

	Evaluation Information				
	Project K	**Project Z**	**Project R**	**Project B**	**Project H**
Actual Project Duration	1097 days	1186 days	1024 days	1412 days	529 days
Actual Cost	26,970,000 $	13,000,000 €	42,750,000 €	55,000,000 $	6,120,000 $
Extension of Time	45 days	13 days	-	611 days	-
Change in Contract Price	2,000,000 $	500,000 €	-	5,000,000 $	300,000 $
Delay	45 days	90 days	-	900 days	-
Delay Cost	6,750 $	1,750 €	-	135,000 $	-
Delay Penalty	-	-	-	-	-
Early Completion Incentive	1,000,000 $	-	-	-	350,000 $

Evaluation: "Actual duration" for completed projects should be automatically calculated according to the entered project start and end dates. "Actual cost" may be automatically calculated based on the "actual profit" percentage. "Change in contract price" allows entry of negative data, which is very reasonable since there may be fall in scope in construction projects. Incentives should not be limited with "early completion incentives", the term should be reduced to the statement of only "incentives" and explanation should be provided as notes for indication of its reason. Additionally, incentives should be included in calculation of actual profit if it would not be directly entered as actual profit percentage. Entry of project-based comments should be provided while entering the actual cost, the profit, incentives as the reasons and requirements. These comments should also be visible in the project card.

Table 7.5: Claim Information in Post Project Appraisal

	Claim Information			
	Claimed Duration	**Duration Awarded**	**Claimed Payment**	**Payment Awarded**
Project K	45 days	45 days	10,500,000 $	2,000,000 $
Project Z	13 days	13 days	3,500,000 €	500,000 €
Project R	-	-	3,500,000 €	-
Project B	611 days	-	16,000,000 $	-
Project H	-	-	-	-

Evaluation: Current claim information only holds the "owner and partner" related claims, there should also be a room for "subcontractor" claims. Because "subcontractor claims" are indicator of the success of the region, there may be fail of a party or there may be a strategy change. Reasons of claims should also be stored at least for "technical claims", "force majeure claims", and "other claims" and may be selected during information entry. Project comments should be entered to state the reasons of claims and further notes on claim results.

Table 7.6: Critical Delay Cause, Work Package and Actor Information in Post Project Appraisal

	Critical Delay Cause Information		Critical Work Package Information		Critical Actor Information	
	Delay Cause	**Effect Level**	**Work Package**	**Effect Level**	**Actor**	**Effect Level**
Project K	Breakdown of machine	1	Mechanical Installation	5	Subcontractor K	4
	Poor performance of the subcontractor	1	Electrical Installation	4		
Project Z	Poor performance of the subcontractor	4	Electrical Installation	4	Subcontractor Z	4
	Unavailability of manpower due to political crisis between the countries	3	Steel Structure Installation	3		
Project R	-	-	-	-	Client R	4
Project B	-	-	Mechanical Installation	5	-	-
			Electrical Installation	5		
			Steel Structure Installation	5		
			Civil Works	5		
			Commissioning Works	5		
Project H	-	-	-	-	-	-

Evaluation: The statement provided for impact of the critical figures as "Effect Level" should be replaced with "Level of Impact" for better representation of the required information. A tree may be provided for "delay causes" for easy entry of the case. There is no identification of direct realization of risks or achievement of strategies in the required project information, there should be provision of a quick information of what has happened due to risks rather than investigation of all the lesson details. Something that would be reflected in the project information and would easily be visible in the analysis is required. It would be important that the tool pictures the situation to anybody who was not included in the project team, so the tool should indicate the change in the expected and actual cases. The actual project risk scores and strategic fit scores should be identified and presented.

7.2.1.3.2. On-Going and Potential Projects

Information of the on-going and potential projects are provided in the following sections as general project information (Table 7.7), critical resource and partnership information (Table 7.8), duration, financial, dependency and technology information (Table 7.9).

Table 7.7: General Project Information of On-going and Potential Projects

	General Project Information			
	On-Going Projects		Potential Projects	
	Project A	Project P	Project N	Project R2
Short Code	PA	PP	PN	PR2
Project Type	Combined Cycle Power Plant	Electromechanical Installation	Combined Cycle Power Plant	Combined Cycle Power Plant
Project Scope	1800 MW	1800 MW	500 MW	450 MW
Client	Client A	Client P	Client Z	Client R2
Country	Bahrain	Saudi Arabia	Russian Federation	Tunisia
Project Delivery System	EPC	Construction / Contractor	EPC	EPC
Contract Type	FIDIC Silver	Client Specific	FIDIC Silver	FIDIC Silver

Table 7.7: General Project Information of On-going and Potential Projects (continued)

	General Project Information			
	On-Going Projects		Potential Projects	
	Project A	**Project P**	**Project N**	**Project R2**
Contract Payment Type	Lump Sum	Lump Sum	Lump Sum	Lump Sum
Currency	EUR	USD	EUR	EUR
Start Date	04/08/2016	02/07/2015	01/04/2018	01/12/2017
End Date	01/04/2019	06/12/2018	01/04/2021	01/09/2020

Evaluation: Fast decisions are undertaken in most of the projects that are already proceeding fast, and most of the parties are aware of these changes since approval process is seen as time loss. A checkpoint is required in general information to proceed with the approved changes in the portfolio. The companies executing different types of projects may also need an area for assignment of the related legislations, so an additional flexible area may be reserved for management of legislations.

Table 7.8: Critical Resource and Partnership Information of On-going and Potential Projects

	Critical Resource Information		Partnership Information	
	Resource Type	**Resource**	**Partnership Type**	**Partner Company**
Project A	Machinery and Equipment	Machinery and Equipment PA	Consortium	Partner K
Project P	Manpower	Manpower PP	-	-
Project N	Material	Material PN	Consortium	Partner K
Project R2	Material	Material PR2	Subcontractor	Partner R2

Table 7.9: Duration, Financial, Dependency and Technology Information of On-going and Potential Projects

	Duration Information		Financial Information		Dependency Information	Technology Information
	Planned Project Duration	**Completion Percentage**	**Contract Price**	**Expected Cost**	**Dependent Projects**	**Technologies**
Project A	971 days	35%	38,500,000 €	36,000,000 €	-	Multi-Shaft 9H Machine
Project P	1254 days	75%	32,000,000 $	30,000,000 $	-	7FA Machine

Table 7.9: Duration, Financial, Dependency and Technology Information of On-going and Potential Projects (continued)

	Duration Information		Financial Information		Dependency Information	Technology Information
	Planned Project Duration	Completion Percentage	Contract Price	Expected Cost	Dependent Projects	Technologies
Project A	971 days	35%	38,500,000 €	36,000,000 €	-	Multi-Shaft 9H Machine
Project P	1254 days	75%	32,000,000 $	30,000,000 $	-	7FA Machine
Project N	1097 days	0%	22,000,000 €	20,000,000 €	-	Multi-Shaft 9H Machine
Project R2	1006 days	0%	13,500,000 €	12,000,000 €	-	-

"Completion Percentage" for "potential" projects is automatically assigned as "0%", user does not enter this information. Automatically calculated values of "expected profit", "adapted profit", and "profitability" in project symbols are presented in the forthcoming section of "Project Details" in the "Data Output" section (7.2.3.3: Project Details).

Evaluation: The "on-going project" data entry form is more similar to the form of "potential project"; however, it should be more in the form of "completed project". On-going project has some indicators of direction of the project, so there should be some changes in expectations since there may be claims under negotiation or risks realized. There may be realization of mistakes in the bidding process, as well. More information should be asked for on-going projects. At least there should be an area for identification of current situation in terms of "schedule", "budget", and "scope".

7.2.1.4. Lesson Learned Entry

Five lessons learned information in four projects were entered as follows (Table 7.10):

Table 7.10: Lesson Learned Information for Completed Projects

	Lesson Learned Information				
	Project K		Project Z	Project R	Project B
Lesson Learned Name	Equipment Failure	Geotechnical Discrepancy	Electrical Design Russification	Client Relations	Geotechnical Discrepancy
Best Practice	-	-	-	-	-
Event Description	Transformer failure during pre-commissioning test	Change in geotechnical conditions	Russian standard effect on design was miscalculated	Contractual scope change, communication with the client	Unforeseen geotechnical conditions
Recommendation	Check periodically manufacturing site quality process	More detailed geotechnical investigation	Earlier review of the standards and design, proper coordination of local engineer with architectural engineer	Follow company compliance policy in all official communications	Verify the employer data
Effect on Project Duration	Very High	Very Low	High, 30 days	Low	Very High, 611 days
Effect on Project Cost	Very High	Low	Very High, 800,000 €	High, 1,000,000 €	Very High, 5,000,000 $
Actors	Supplier K	-	Designer Z	Client R	Client B
Tags	Process; Construction; Plant Equipment; Industry-Specific Manufacturing Equipment; Electrical Equipment, Appliance, and Component Manufacturing Equipment	Process, Management; Risk Management; Risk Sources; Uncertainty of Geological Problems; Uncertainty of Geotechnical Investigation	Process; Design; Design Branch; Electrical Design; Management; Time Management; Delay; Causes of Delay; External Causes; Rules and Regulations Related Causes	Actor; Client; Process; Management; Risk Management; Risk Monitoring and Control	Process; Construction; Site Works; Subsurface Investigation; Geotechnical Investigations; Geotechnical Monitoring Before Construction

Evaluation: There should be lesson entry free from the projects as an indicator of what the company has learned. “Compliance management” should be added to the tag tree provided for tagging lessons learned including the “regulations”. Improvements may be provided in labeling the required information. “Lesson learned name” should be replaced with “lesson learned title”. “Effect on Project Duration/Cost” statement should be replaced with “Impact on Project

Duration/Cost". "Effect Amount" should be simplified to "Amount". "Event Description" may be replaced with statement of "Description of the Event".

7.2.2. Data Analysis

This section includes the investigated supportive information before assessment and the applied risk and strategic fit assessments of the projects.

7.2.2.1. Supportive Information

Similar projects were obtained for each project as follows except for the Project P, which has no similar project in the database (Table 7.11):

Table 7.11: Similar Projects of On-going and Potential Projects

	Similar Projects (Similarity Scores)
Project A	Project K (59.5), Project Z (59.5), Project R (59.5), Project B (17.9), Project H (17.9)
Project P	-
Project N	Project Z (100), Project K (59.5), Project R (59.5), Project B (17.9), Project H (17.9)
Project R2	Project K (40), Project Z (40), Project R (40), Project B (17.9), Project H (17.9)

Evaluation: Presentation of similarity is successful since it demonstrates the important projects to investigate. Its presentation of the reasons of the similarity is also useful. However, there should be an update in the consideration of "technology", attribute, it seems to be not including the case for "multiple data entry". In calculation of similarity, the user may also want to include the "scope" of projects in calculation. There may be more flexible similarity calculation that would be adjusted according to preference of the user and should have the potential of matching all the project information entered. Thus, similar projects may be investigated with the similar milestones. Similarity calculation should also be based on section similarity, there should be an option for either country based or section based similarity calculation.

Lessons were retrieved for different project with random selection of the retrieval method as “filtering”, “similarity”, or “tags”. The related search information is provided in the following table (Table 7.12):

Table 7.12: Lesson Learned Retrieval for On-going and Potential Projects

	Lessons Learned		
	Filtering	**Similarity**	**Tags**
Project A	Without attribute selection: All lessons With “Combined Cycle Power Plant” project type attribute: Lessons of Project K, Z and R	Lessons of Project K, Z and R	-
Project P	-	No lesson retrieved	Search for the tag “Actor”: Lesson of Project R
Project N	With “Russian Federation” country attribute: Lesson of Project Z	Lessons of Project Z, K and R	-
Project R2	-	No lesson retrieved	Search for the tag “Risk Management”: Lessons of Project K and R

Evaluation: Lessons learned mechanism is considerably successful and useful. There may be an additional “free text search” for the lessons to allow the user search the lessons freely from the provided retrieval mechanisms.

Predictions were obtained for the projects as follows with the following options as “filtering” and “similarity” (Table 7.13):

Table 7.13: Predictions for On-going and Potential Projects

	Predictions	
	Filtering	**Similarity**
Project A	Without attribute selection: results obtained With “Combined Cycle Power Plant” project type attribute: results obtained With “Bahrain” country attribute: no result obtained	Results obtained
Project P	With “Electromechanical Installation” project type attribute: no result obtained	No result obtained
Project N	With “Russian Federation” country attribute: results obtained	Results obtained
Project R2	-	No result obtained

Evaluation: The critical figures presented in the prediction results are reasonable and useful. Numerical forecasting based on post project appraisal data captured at the end of project is valuable; however, an additional process based forecasting would be more beneficial. Forecasting should also be provided on a milestone basis as an indicator of situation of a similar project at the same completion level of its execution. Forecasting at this level would enable extraction of valuable information within the process of the project in addition to the project's end. For example, forecasting of duration and cost for the next milestone based on the company statistics may be provided. Deviations in the planned milestone durations and costs may be provided.

Learning potentials of the projects with breakdown of the obtained scores are as follows (Table 7.14):

Table 7.14: Learning Potentials for On-going and Potential Projects

Project (Learning Potential Score)	**Breakdown of the Score: Attributes (Scores)**
Project A (56.1)	Country Score (15.4), Project Type Score (6.28), Client Score (13.3), Technology Score (10.5), Contract Type Score (0), Project Delivery System Score (2.82), Partner Company Score (7.8)
Project P (84.18)	Country Score (15.4), Project Type Score (15.7), Client Score (13.3), Technology Score (15), Contract Type Score (13.5), Project Delivery System Score (11.28), Partner Company Score (0)
Project N (50.36)	Country Score (12.32), Project Type Score (6.28), Client Score (10.64), Technology Score (10.5), Contract Type Score (0), Project Delivery System Score (2.82), Partner Company Score (7.8)
Project R2 (50.8)	Country Score (15.4), Project Type Score (6.28), Client Score (13.3), Technology Score (0), Contract Type Score (0), Project Delivery System Score (2.82), Partner Company Score (13)

Evaluation: Presentation of "learning potential" is useful. It presents results in the opposite logic of similar projects, namely the project with no similar projects has the highest learning potential, which is also a useful point for successful indication of the results.

7.2.2.2. Risk and Strategic Fit Assessment

The factors including weights are presented with the results of the risk assessment as scores for each factor and the project as follows (Table 7.15):

Table 7.15: Risk Assessment of On-going and Potential Projects

Risk Assessment					
Factors	**Weights**	**Project A**	**Project P**	**Project N**	**Project R2**
Economic risk (changes in exchange rates, cash flow risk, inflation, etc.)	0.095	20	10	50	20
Political risks (changes in government, changes in international relations, etc.)	0.091	20	10	50	20
Technical risks (delays due to technical problems, etc.)	0.084	30	20	20	10
Resource risk (risks due to quality/availability of material, manpower, machinery and equipment, etc.)	0.083	60	70	30	40
Design risk (deficiency/changes in design, etc.)	0.089	30	90	10	10
Contractual risk (ambiguity in conditions, insufficient definitions, strict requirements/constraints, etc.)	0.090	30	100	10	40
Owner initiated risks (insufficient experience, delays in payments, etc.)	0.088	20	100	20	40
Bureaucratic risks (delays in permissions, etc.)	0.087	10	60	70	40
Project management risks (poor planning, insufficient experience, etc.)	0.091	40	60	50	40
Risks due to weather conditions	0.065	40	60	80	40
Risks due to ground conditions	0.071	10	10	50	20
Environmental risks (social and environmental factors)	0.066	10	10	10	10
Project Risk Score		26.83	51.11	37.07	27.69

The results of the strategic fit assessment is presented by factors including weights and the results as scores for each factor and the project as follows (Table 7.16):

Table 7.16: Strategic Fit Assessment of On-going and Potential Projects

Strategic Fit Assessment					
Factors	**Weights**	**Project A**	**Project P**	**Project N**	**Project R2**
Short Term Profitability	0.155	60	10	80	70
Long Term Profitability	0.186	60	10	80	80
Reputation	0.172	90	30	90	90
Risk Minimization	0.163	30	10	60	50
Market Entry	0.165	90	80	10	60
Repeat Job	0.100	80	10	90	50
Learning	0.059	20	70	20	20
Project Strategic Fit Score		64.86	28.53	64.37	65.44

Evaluation: Quantification of risks and strategic fits through taking the established weights as "impacts" and assigning ratings as their "probabilities" is very useful.

7.2.3. Data Output

The portfolio analysis was performed with addition of the both potential projects in the same analysis. The common currency was selected as "euro" to evaluate all the projects with differing currencies in the same currency. The portfolio results were obtained following automatic formation of the portfolio alternatives. First, the results on portfolio alternatives were investigated. Further portfolio details were explored including information of the projects in the portfolios. Finally, portfolio selection option was investigated with trial of different selection options.

General Evaluation on the Process: Reported figures are representative, especially the bubble diagrams are very helpful. Project version bubble diagram is the same with the one used in the power systems company as "know-how" and "risk" in the axes and profitability in the diameters. Diameters in the bubble diagrams indicating the "profit" is beneficial, since it is the most important criterion in the analysis. The tool is adjusting the graphs according to the data, which makes them visible in all cases. Automatic warnings/recommendations is also successful since they reveal important points to notice. The tool presents information that would be very helpful for a decision maker. However, different parties may want to focus on different portions of the information. There should be different reporting options that would each underline different portions of the results specific to the need. Reporting of portfolio alternatives is provided; however, there should be a customizable reporting mechanism that enables delivery of different report types that present the data in various forms. Evaluations that are more specific are presented below under the related outputs.

7.2.3.1. Portfolio Alternatives

Four alternatives were obtained as the current portfolio, two portfolios as the single addition of the projects to the current portfolio and final portfolio including all active projects. Numerical results were obtained as in the following figure (Figure 7.8). Due to the high profit loss in "Project Z" and limited number of projects in the portfolio, the adapted profit for "Project N" calculated based on the average becomes "-1,666,666.67 €". This negative effect decreases the portfolio profits where this project is included. Potential projects are not much risky projects and they are increasing the "strategic fit" of the portfolio and portfolio "value" as well. No selection based warning was obtained for this case, because the warning only applies for the case where every alternative has a negative portfolio value change.

Portfolios

Delete All Portfolio Alternatives

Portfolio Name	Potential Projects in the Alternative	Average Risk Score (%)	Average Strategic Fit Score (%)	Network Density	Portfolio Risk	Portfolio Success (%)	Portfolio Value	Portfolio Profit	Operations
Alt 1		38.97	46.695	0	19.485	80.515	127.21	4,146,791.60 €	Operations / Display Portfolio
Alt 2	PN,	38.3367	52.5867	0.095	20.99	79.01	131.597	2,480,124.93 €	Operations / Display Portfolio
Alt 3	PR2,	35.21	52.9433	0.074	18.912	81.088	134.031	5,646,791.60 €	Operations / Display Portfolio
Alt 4	PN, PR2,	35.675	55.8	0.122	20.009	79.991	135.791	3,980,124.93 €	Operations / Display Portfolio

Total 4, Displayed 1-4 Range

Figure 7.8: Portfolio Alternatives Table

Evaluation: The obtained figures are representative of the portfolio properties. Representation of (100 – Portfolio Risk) value is good, it is an important figure as risk purified value; however, expression of "portfolio success" does not fit with the intended meaning, it should be "portfolio potential" or "portfolio potential opportunity".

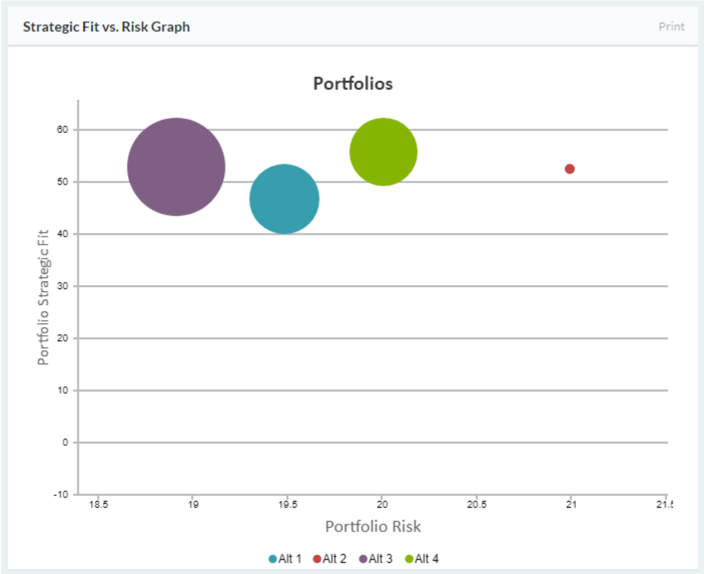


Figure 7.9: Portfolio Strategic Fit vs. Risk Bubble Graph

Evaluation: Portfolio strategic fit versus risk graph is very successful, it is meaningful, gives an idea and serves for its purpose. In the bubble diagrams, the "current portfolio" may be represented differently to ease its recognition between the selectable alternatives. Grids and threshold values may be added to the graph to ease decision-making.

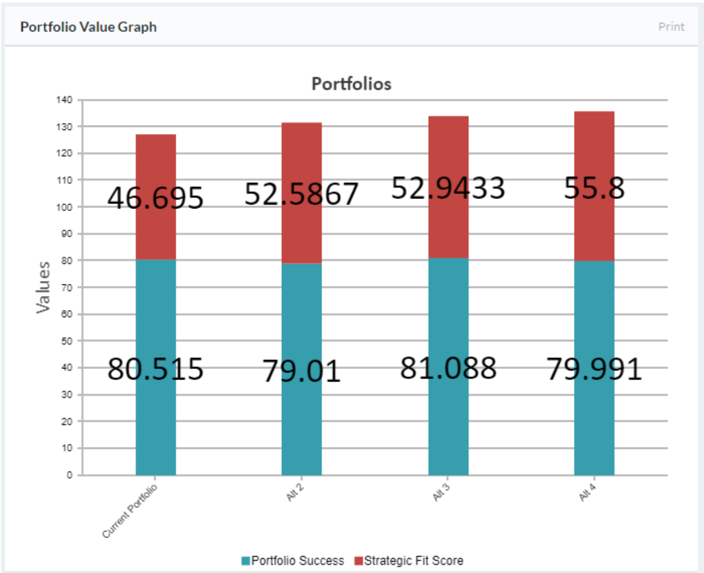


Figure 7.10: Portfolio Value Bar Chart

Evaluation: The portfolio value bar chart may be presented through juxtaposed columns of “portfolio potential (former ‘portfolio success’)” “strategic fit” and “profitability”. Strategic fit column may also represent breakdown of the strategic factors. It may be alternatively represented by spider diagram and the area of the diagram may also be representative. Calculation of the “portfolio value” should be adjusted or be flexible for company specific use. Multiplication of the “portfolio potential” and “strategic fit” may be more reasonable, since “risk” effects the “strategic fit” multiplication may better represent the “expected strategic fit” value. If flexible formulation is not possible, summation formula should be replaced with multiplication.

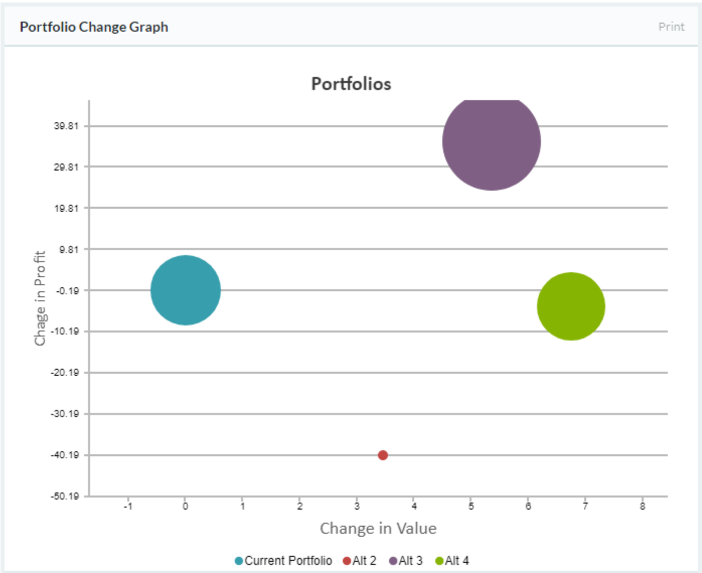


Figure 7.11: Portfolio Change Bubble Graph

Evaluation: The “current portfolio” may be represented differently to ease its recognition between the selectable alternatives, it would be more distinguishable by this way.

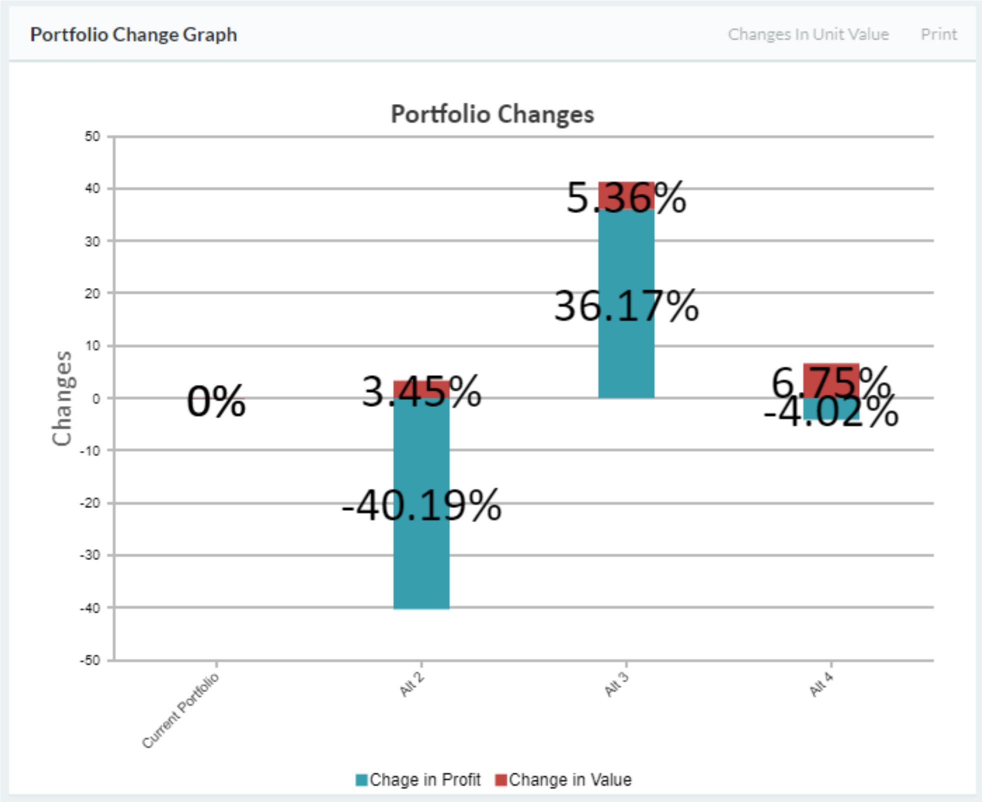


Figure 7.12: Portfolio Change Bar Graph

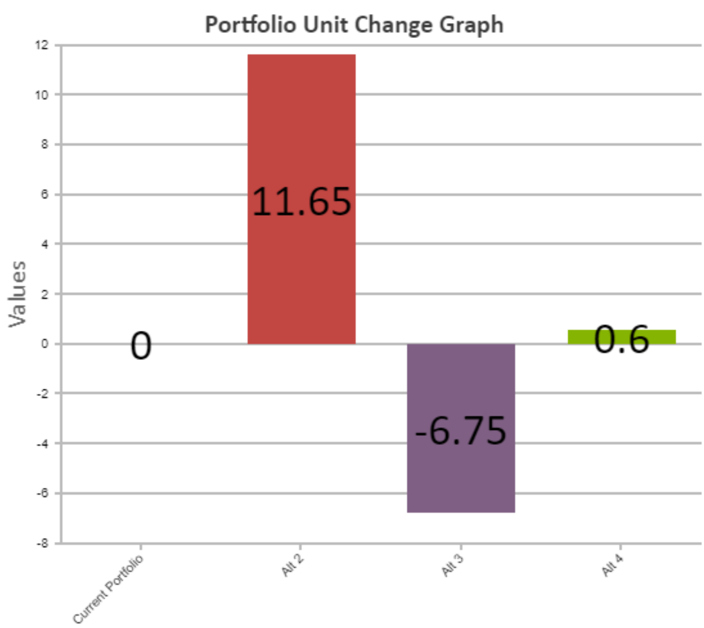


Figure 7.13: Portfolio Unit Change Bar Graph

Evaluation: Portfolio change graph would be successful to analyze the cases where all the alternatives have the same trend of change. For example, a case with all “positive profit changes” in the alternatives would be distinguishable in the “unit change bar graph” for their comparison with corresponding “changes in value”. All the analysis obtained in this case is structured on the basis of the “adapted” negative profit value of the “Project N” and this value highly impacts the results. The calculation is reasonable to reflect the experience of past in the expectation of forthcoming projects. However, this kind of special situation may be preferred to be excluded in the analysis, user may want to investigate the both situations as one it is included and one is not. Therefore, there should be identification of an “exceptional project” and an option for inclusion of the exceptional projects in the analysis or not. Data of exceptional projects should always be included in lessons learned; however, their use in prediction calculations or in the analysis should be optional. The warning on profitability presented in portfolio details seems to be working with only positive profits, it should not be presented in case of negative profits, and alternatively there may be warning of negative profit in the portfolio.

7.2.3.2. Portfolio Details

Details of the portfolio were investigated through the obtained graphs and warnings for each portfolio as presented follows.

Alternative 1: Details obtained for the “current portfolio” were as follows;

Alt 1 Projects

Name	Average Risk Score (%)	Average Strategic Fit Score (%)	Network Density	Portfolio Risk	Portfolio Success (%)	Portfolio Value	Portfolio Profit
Alt 1	38.97	46.695	0	19.485	80.515	127.21	4,146,791.60 €

No	Project	Date	Project Status	Scores	Operations
2263	Project A	**Start Date:** 04/08/2016 **End Date:** 01/04/2019	On-going	**Risk Score:** 26.83 **Strategic Fit Score:** 64.86 **Centrality Value:** 0	Detail
2264	Project P	**Start Date:** 02/07/2015 **End Date:** 06/12/2018	On-going	**Risk Score:** 51.11 **Strategic Fit Score:** 28.53 **Centrality Value:** 0	Detail

Figure 7.14: Alternative 1 Project Information

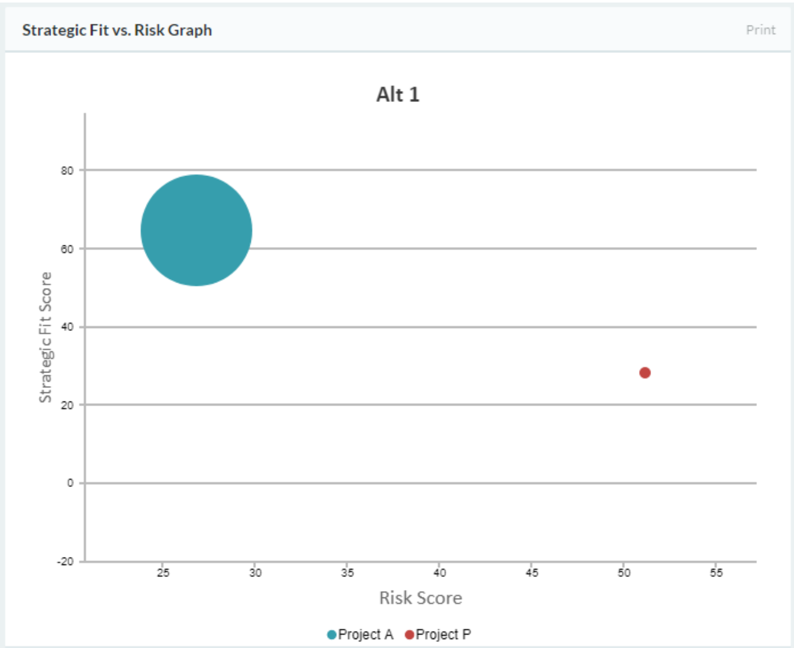


Figure 7.15: Alternative 1 Project Strategic Fit vs. Risk Bubble Graph

- Dependency network was not obtained.
- **Warnings:** were obtained as follows;
  - Portfolio profit is dependent on € (Euro) at 60.29 percentage. Fluctuations in this currency would effect the portfolio seriously. Taking into consideration of this situation and making expenses in the same currency as far as possible to reduce the financial risk are suggested.
  - Portfolio profit is 60.29 percentage financed by the Client: Client A. High dependency of the portfolio profit to this client entails financial risk.

Alternative 2: Details obtained for the alternative including "Project N" were as follows;

Alt 2 Projects

Name	Average Risk Score (%)	Average Strategic Fit Score (%)	Network Density	Portfolio Risk	Portfolio Success (%)	Portfolio Value	Portfolio Profit
Alt 2	38.3367	52.5867	0.095	20.99	79.01	131.597	2,480,124.93 €

No	Project	Date	Project Status	Scores	Operations
2263	Project A	Start Date: 04/08/2016 End Date: 01/04/2019	On-going	Risk Score: 26.83 Strategic Fit Score: 64.86 Centrality Value: 1.000	Detail
2264	Project P	Start Date: 02/07/2015 End Date: 06/12/2018	On-going	Risk Score: 51.11 Strategic Fit Score: 28.53 Centrality Value: 0	Detail
2265	Project N	Start Date: 01/04/2018 End Date: 01/04/2021	Potential	Risk Score: 37.07 Strategic Fit Score: 64.37 Centrality Value: 1.000	Detail

Figure 7.16: Alternative 2 Project Information

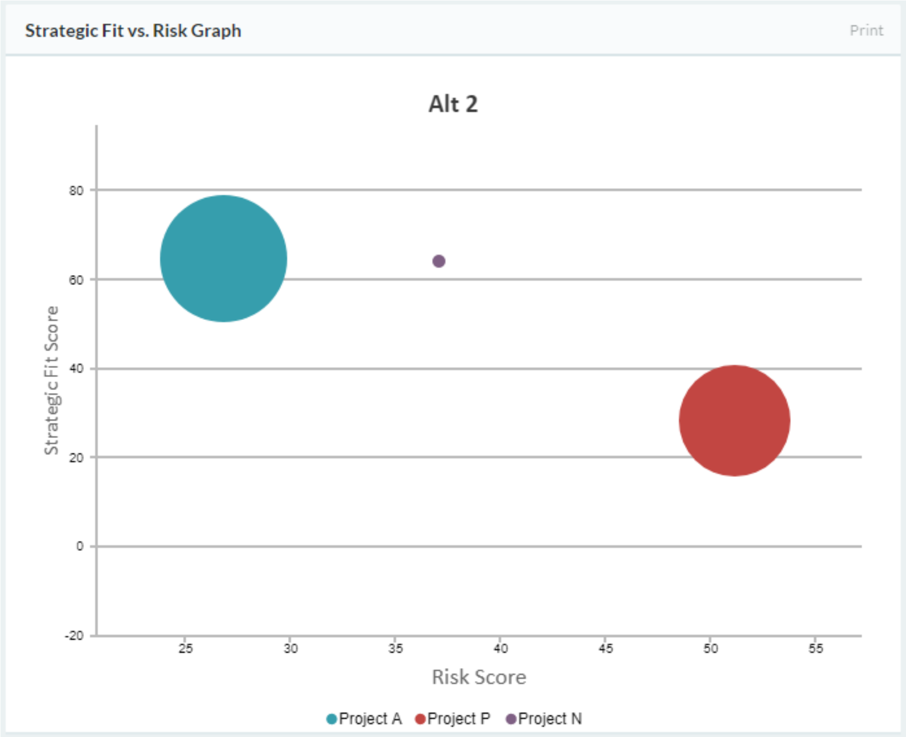


Figure 7.17: Alternative 2 Project Strategic Fit vs. Risk Bubble Graph

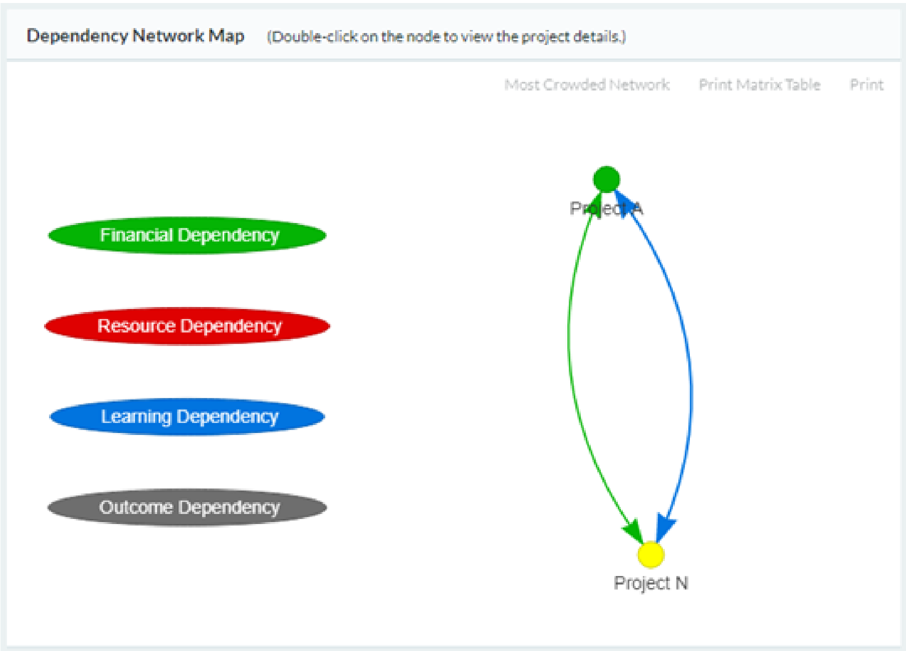
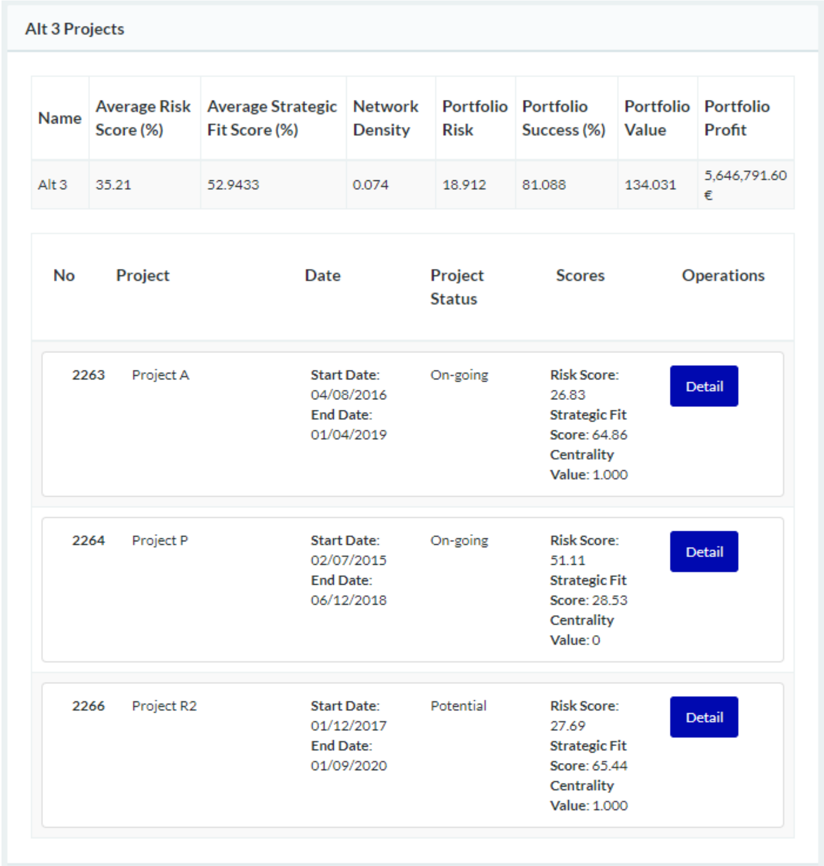


Figure 7.18: Alternative 2 Project Dependency Network Map

- **Warnings:** were obtained as follows;
  - Due to centrality of the Project A, Project N in the portfolio, the situation of the projects is at the level of affecting the portfolio situation.
  - The Project N in the portfolio is a low profit project, possible cost increases to be encountered in this project may entail damage risk to the portfolio.
  - Portfolio profit is dependent on $ (US Dollars) at 66.40 percentage. Fluctuations in this currency would effect the portfolio seriously. Taking into consideration of this situation and making expenses in the same currency as far as possible to reduce the financial risk are suggested.
  - Portfolio profit is 100.80 percentage financed by the Client: Client A. High dependency of the portfolio profit to this client entails financial risk.
  - Portfolio profit is 66.40 percentage financed by the Client: Client P. High dependency of the portfolio profit to this client entails financial risk.
  - There is high learning dependency between the projects Project A, Project N in the portfolio, establishment of the information transfer between these projects is suggested.

Alternative 3: Details obtained for the alternative including “Project R2” were as follows;



Alt 3 Projects

Name	Average Risk Score (%)	Average Strategic Fit Score (%)	Network Density	Portfolio Risk	Portfolio Success (%)	Portfolio Value	Portfolio Profit
Alt 3	35.21	52.9433	0.074	18.912	81.088	134.031	5,646,791.60 €

No	Project	Date	Project Status	Scores	Operations
2263	Project A	**Start Date:** 04/08/2016 **End Date:** 01/04/2019	On-going	**Risk Score:** 26.83 **Strategic Fit Score:** 64.86 **Centrality Value:** 1.000	Detail
2264	Project P	**Start Date:** 02/07/2015 **End Date:** 06/12/2018	On-going	**Risk Score:** 51.11 **Strategic Fit Score:** 28.53 **Centrality Value:** 0	Detail
2266	Project R2	**Start Date:** 01/12/2017 **End Date:** 01/09/2020	Potential	**Risk Score:** 27.69 **Strategic Fit Score:** 65.44 **Centrality Value:** 1.000	Detail

Figure 7.19: Alternative 3 Project Information

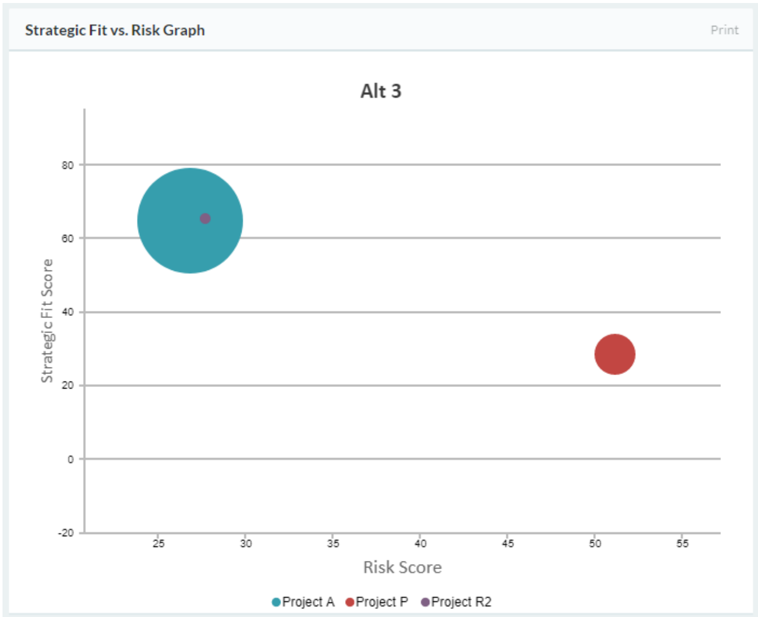


Figure 7.20: Alternative 3 Project Strategic Fit vs. Risk Bubble Graph

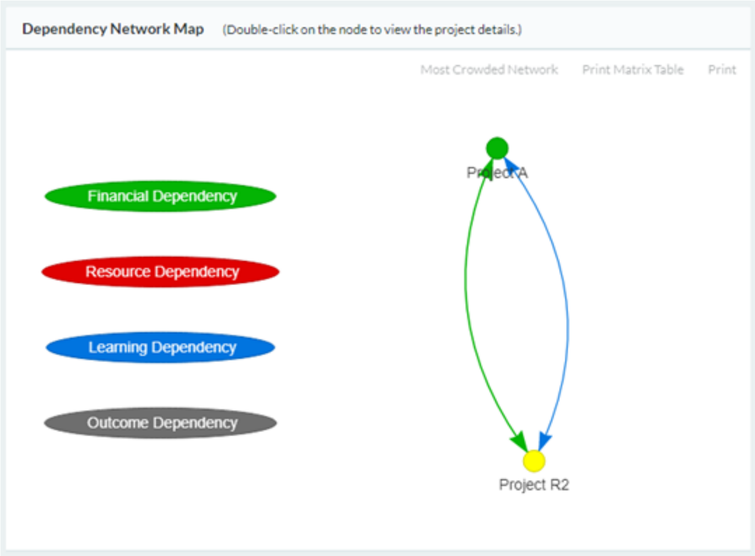
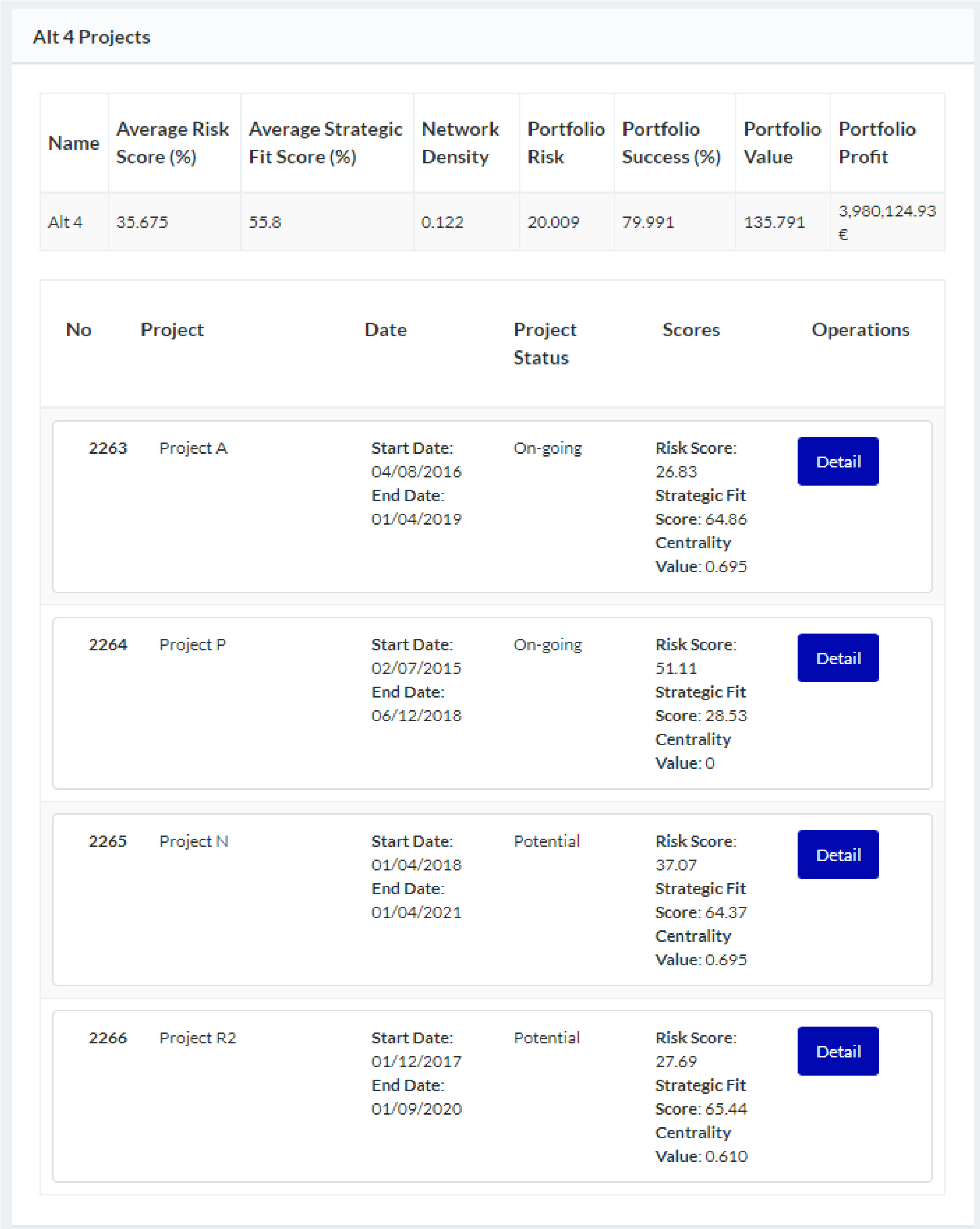


Figure 7.21: Alternative 3 Project Dependency Network Map

- **Warnings:** were obtained as follows;
  - Due to centrality of the Project A, Project R2 in the portfolio, the situation of the projects is at the level of affecting the portfolio situation.
  - Portfolio profit is dependent on € (Euro) at 70.84 percentage. Fluctuations in this currency would effect the portfolio seriously. Taking into consideration of this situation and making expenses in the same currency as far as possible to reduce the financial risk are suggested.
  - There is high learning dependency between the projects Project A, Project R2 in the portfolio, establishment of the information transfer between these projects is suggested.

Alternative 4: Details obtained for the alternative including "Project N" and "Project R2" together were as follows;



Alt 4 Projects

Name	Average Risk Score (%)	Average Strategic Fit Score (%)	Network Density	Portfolio Risk	Portfolio Success (%)	Portfolio Value	Portfolio Profit
Alt 4	35.675	55.8	0.122	20.009	79.991	135.791	3,980,124.93 €

No	Project	Date	Project Status	Scores	Operations
2263	Project A	Start Date: 04/08/2016 End Date: 01/04/2019	On-going	Risk Score: 26.83 Strategic Fit Score: 64.86 Centrality Value: 0.695	Detail
2264	Project P	Start Date: 02/07/2015 End Date: 06/12/2018	On-going	Risk Score: 51.11 Strategic Fit Score: 28.53 Centrality Value: 0	Detail
2265	Project N	Start Date: 01/04/2018 End Date: 01/04/2021	Potential	Risk Score: 37.07 Strategic Fit Score: 64.37 Centrality Value: 0.695	Detail
2266	Project R2	Start Date: 01/12/2017 End Date: 01/09/2020	Potential	Risk Score: 27.69 Strategic Fit Score: 65.44 Centrality Value: 0.610	Detail

Figure 7.22: Alternative 4 Project Information

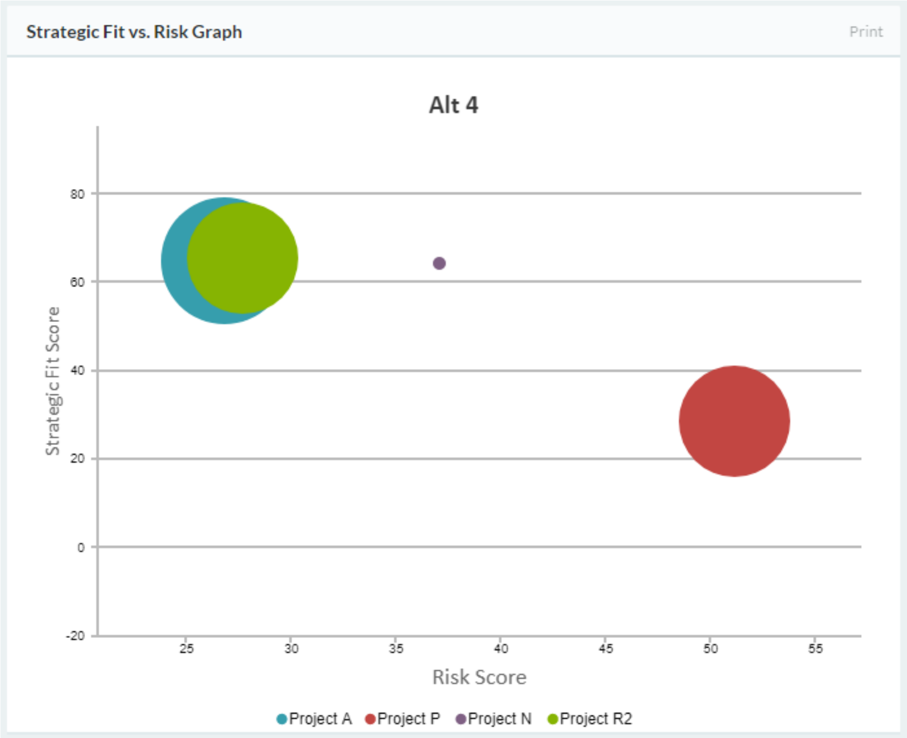


Figure 7.23: Alternative 4 Project Strategic Fit vs. Risk Bubble Graph

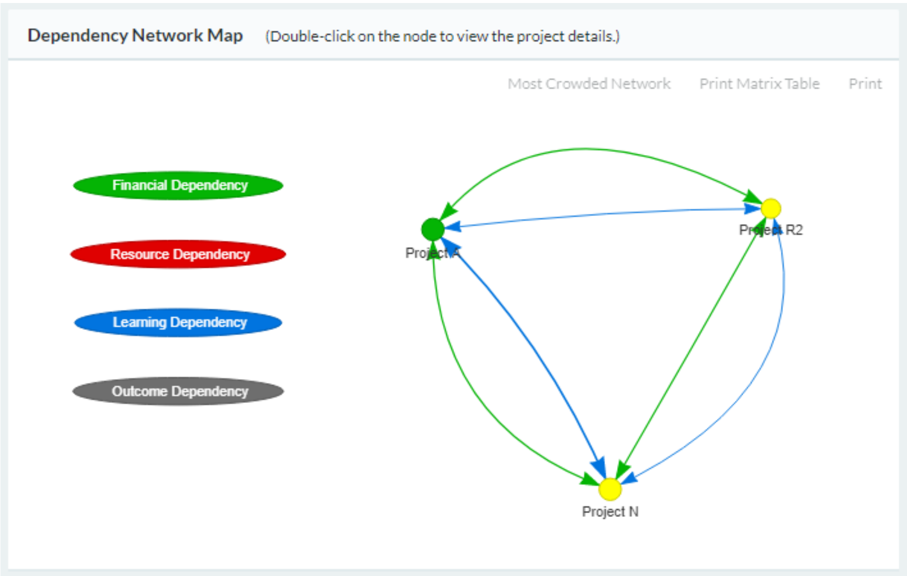


Figure 7.24: Alternative 4 Project Dependency Network Map

- **Warnings:** were obtained as follows;
  - Due to centrality of the Project A, Project N, Project R2 in the portfolio, the situation of the projects is at the level of affecting the portfolio situation.
  - The Project N in the portfolio is a low profit project, possible cost increases to be encountered in this project may entail damage risk to the portfolio.
  - Portfolio profit is dependent on € (Euro) at 58.62 percentage. Fluctuations in this currency would effect the portfolio seriously. Taking into consideration of this situation and making expenses in the same currency as far as possible to reduce the financial risk are suggested.
  - Portfolio profit is 62.81 percentage financed by the Client: Client A. High dependency of the portfolio profit to this client entails financial risk.
  - There is high learning dependency between the projects Project A, Project N in the portfolio, establishment of the information transfer between these projects is suggested.
  - There is high learning dependency between the projects Project A, Project R2 in the portfolio, establishment of the information transfer between these projects is suggested.
  - There is high learning dependency between the projects Project N, Project R2 in the portfolio, establishment of the information transfer between these projects is suggested.

7.2.3.3. Project Details

In every portfolio detail page, project details were also investigated through the project cards to recapture the project details and the profit information. The obtained project symbols indicating “status”, “risk”, “strategic fit”, and “profitability” of projects together with the calculated profit information were as follows (profitability was calculated based on "adapted profits" of the "on-going" and "potential" projects) (Figure 7.25, Figure 7.26, Figure 7.27, Figure 7.28):

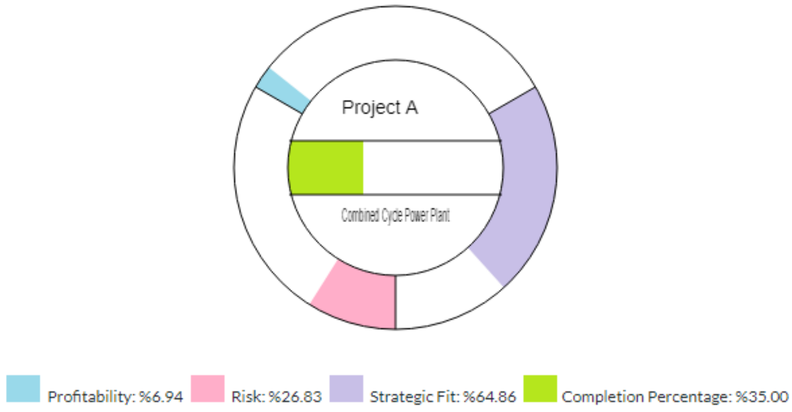


Figure 7.25: Project Symbol for Project A

Profit Information for Project A:

- Expected Profit: 2,500,000 € (EUR)
- Adapted Profit: 2,500,000 € (EUR)
- Profitability: 6.94%

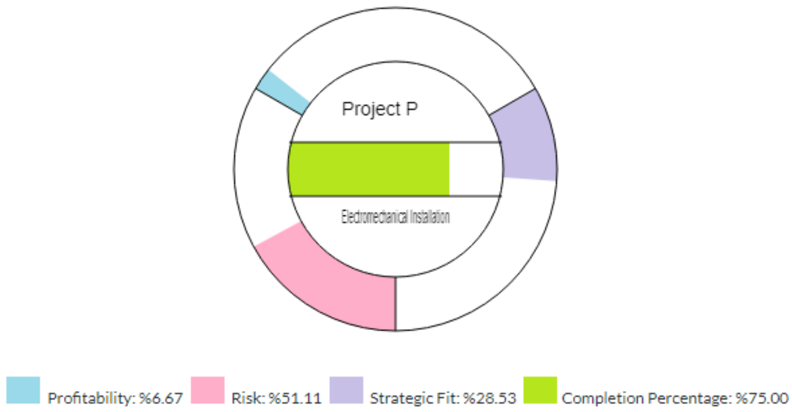


Figure 7.26: Project Symbol for Project P

Profit Information for Project P:

- Expected Profit: 2,000,000 $ (USD)

- Adapted Profit: 2,000,000 $ (USD)
- Profitability: 6.67%

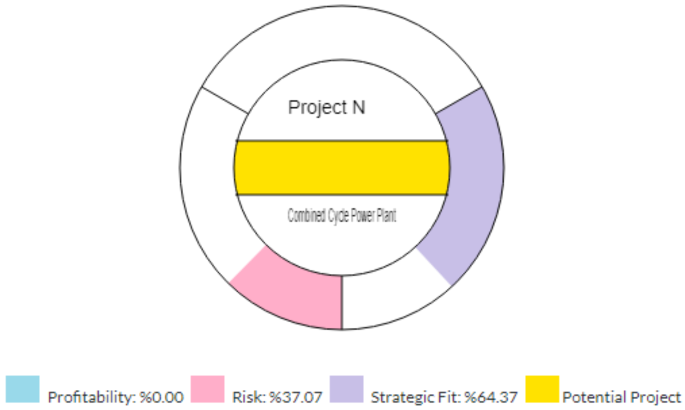


Figure 7.27: Project Symbol for Project N

Profit Information for Project N:

- Expected Profit: 2,000,000 € (EUR)
- Adapted Profit: -1,666,666.67 € (EUR)
- Profitability: 0%

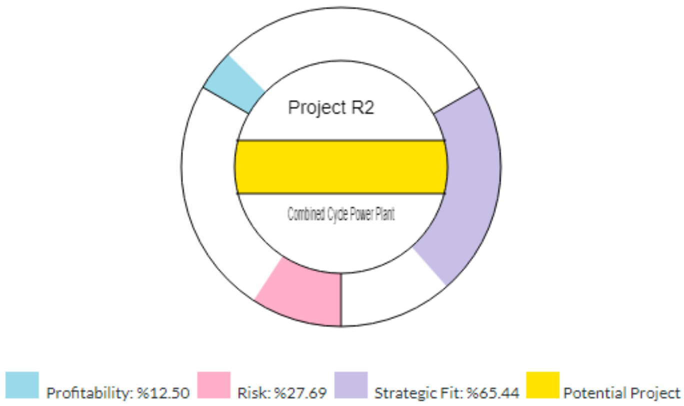


Figure 7.28: Project Symbol for Project R2

Profit Information for Project R2:

- Expected Profit: 1,500,000 € (EUR)

- Adapted Profit: 1,500,000 € (EUR)
- Profitability: 12.50%

Evaluation: Project symbols are representative for projects; however, they are presented at separate points in the analysis. It would be much better to look them on the same platform to make comparison rather than investigating them one by one. Therefore, the tool lacks a visual dashboard that may represent all the projects entered. A geographic map may be provided and it may represent the dependencies of the current portfolio. Project nodes may represent the scope or the contract value of the projects with their diameters. Geographic representation of data based on years is very important in construction industry, because the market is always changing. Scatter diagram of the projects would be very beneficial for the new personnel and may eliminate dependency on the leaving personnel. It would successfully picture the past and inform about the general situation. There is a need of a geographic map that holds the all project symbols by locations, when figures are selected the project cards may be opened. The map should be filtered by years, and the similar projects of the project at hand may also be automatically visualized. The map should provide predictions on profit margin, possible risks, milestone related information, important lessons learned, etc. based on the filtered projects on the map. The countries may be grouped under sections in the tool and the tool should present the groups on the map, and the groups should also be selectable on the map. Groups of countries should be established by indicating the reasons of similarities next to them and the similar countries should be listed under the sections with similarities.

7.2.3.4. Portfolio Selection

Portfolio selection was performed with the following selection and ordering options:

- Risk based selection in the ascending order (Figure 7.29)

- Strategic fit based selection in the descending order (Figure 7.30)
- Portfolio value based selection in the descending order (Figure 7.31)
- Profitability based selection in the descending order (Figure 7.32)

The warning on the portfolio analysis page on selection is also repeated under this section; however, no selection based warning was obtained for this case, since the warning only applies for the case where every alternative has a negative portfolio value change.

Portfolios

Name	Average Risk Score (%)	Average Strategic Fit Score (%)	Network Density	Portfolio Risk	Portfolio Success (%)	Portfolio Value	Portfolio Profit	Operations
Alt 3	35.21	52.9433	0.074	18.912	81.088	134.031	5,646,791.60 €	Operations
Alt 1	38.97	46.695	0	19.485	80.515	127.21	4,146,791.60 €	Operations
Alt 4	35.675	55.8	0.122	20.009	79.991	135.791	3,980,124.93 €	Operations
Alt 2	38.3367	52.5867	0.095	20.99	79.01	131.597	2,480,124.93 €	Operations

Figure 7.29: Risk Based Portfolio Selection

Portfolios

Name	Average Risk Score (%)	Average Strategic Fit Score (%)	Network Density	Portfolio Risk	Portfolio Success (%)	Portfolio Value	Portfolio Profit	Operations
Alt 4	35.675	55.8	0.122	20.009	79.991	135.791	3,980,124.93 €	Operations
Alt 3	35.21	52.9433	0.074	18.912	81.088	134.031	5,646,791.60 €	Operations
Alt 2	38.3367	52.5867	0.095	20.99	79.01	131.597	2,480,124.93 €	Operations
Alt 1	38.97	46.695	0	19.485	80.515	127.21	4,146,791.60 €	Operations

Figure 7.30: Strategic Fit Based Portfolio Selection

Portfolios

Name	Average Risk Score (%)	Average Strategic Fit Score (%)	Network Density	Portfolio Risk	Portfolio Success (%)	Portfolio Value	Portfolio Profit	Operations
Alt 4	35.675	55.8	0.122	20.009	79.991	135.791	3,980,124.93 €	Operations
Alt 3	35.21	52.9433	0.074	18.912	81.088	134.031	5,646,791.60 €	Operations
Alt 2	38.3367	52.5867	0.095	20.99	79.01	131.597	2,480,124.93 €	Operations
Alt 1	38.97	46.695	0	19.485	80.515	127.21	4,146,791.60 €	Operations

Figure 7.31: Portfolio Value Based Portfolio Selection

Portfolios

Name	Average Risk Score (%)	Average Strategic Fit Score (%)	Network Density	Portfolio Risk	Portfolio Success (%)	Portfolio Value	Portfolio Profit	Operations
Alt 3	35.21	52.9433	0.074	18.912	81.088	134.031	5,646,791.60 €	Operations
Alt 1	38.97	46.695	0	19.485	80.515	127.21	4,146,791.60 €	Operations
Alt 4	35.675	55.8	0.122	20.009	79.991	135.791	3,980,124.93 €	Operations
Alt 2	38.3367	52.5867	0.095	20.99	79.01	131.597	2,480,124.93 €	Operations

Figure 7.32: Profitability Based Portfolio Selection

Evaluation: Table provided on portfolio properties should also include the projects included in the portfolio alternatives as provided in the portfolio alternatives section. There may be some established criteria as a "strategic hold point" that would automatically eliminate the portfolio alternatives. The elimination and "no-bid" decision should be provided with its reason such as; "risk limit", "project limit", "profitability limit", "duration limit", "country limit", etc.

7.3. Evaluation after Actual Implementation

Evaluation following actual implementation is presented through in sections of "evaluation on strengths/shortcomings and benefits/barriers" and "general evaluation" with the "required updates" in the tool as a result of the evaluation process.

7.3.1. Evaluation on Strengths/Shortcomings and Benefits/Barriers (Survey 8 - Section 1)

Within the context of first section of Survey 8, the following information is gathered through the open questions on evaluation of COPPMAN and its benefits and possible barriers to its utilization. The information is provided in four sections as "strengths", "shortcomings/improvements", "possible benefits" and "possible barriers" as follows:

- **Strengths:** It is evaluated as a strong management tool since it encapsulates and integrates several systems (such as strategic and risk assessment, lessons learned, etc.) and builds link between the projects. Retrieval options as filtering, similarity and tag-based searching options provided in different sections of the tool are found useful. The ability of establishing the link between the past and future is evaluated as quite successful. Revealing the know-how gained in one project/section and reflecting it to future makes the tool an important management tool. Especially lesson management is stated to be very useful. Lesson identification and retrieval processes are useful and lesson information is also linked with time and cost effects, which is also beneficial to evaluate the case. Benchmarking through similarity also reveals the success/problem in similar projects is either based on a company based factor or owner based factor. Identification of similarities has the potential to remark the important projects to investigate. Presentation of learning potential and providing results in negative logic to benchmarking is successful, it draws attention on the different project between the similar ones. Numerical forecasting mechanism is stated to be very beneficial when it is compared with verbal information since it presents helpful and reasonable critical figures to the user. Predictions in terms of averages of values is also representative for the companies working with same type of projects. For other companies with various types of projects, provided alternative retrieval mechanisms for predictions would be also beneficial. Success rates for claim are found sufficient for determination of claim issues in similar projects, which may be indicator of possible claims. It is suitable to enter the change in the contract price as positively and negatively, since there may be a fall in scope as well. Quantification and numerical representation of many of the parameters and figures besides visualizing is very beneficial for representation of the information. Reporting in the analysis is found reasonable. Graphs in the analysis are meaningful and serves for the purpose and helps decision maker. Auto adjustment makes the graphs visible for all cases. Risk and strategic assessment method and the identified evaluation factors are found successful to cover the considerations in analysis. Ability of automatic warnings/recommendations is also successful since it may reveal some points that may be failed to notice. Representation of an adapted profit based on company statistics is very successful and it improves the intelligence of the tool. Data entry durations are stated as reasonable and tool is found usable in the overall.

- **Shortcomings/Improvements:** The identified shortcomings together with the possible improvements are presented in groups as follows:
    - **Extent of Information:** Captured information should be improved with identification of critical milestones, checkpoints for change, project significance, quantified scope, related legislations, client types, data of subcontractor claims, reasons of claims, risk realization and strategic achievement information for completed projects, capture of current evaluation for on-going projects, project notes, and country groups.
    - **Addition of Context:** Addition of attributes is required at several sections such as; “subcontractor” should be identified as a resource type, “Tatarstan”

should be included in country list, and “compliance management” including “regulations” should be added to the tag tree. Incentives should not be limited with only “early completion incentives”, the term should be reduced to the statement of only “incentives” to include other incentives with different reasons. Free text search for the lessons should be provided and the tool should allow lesson entry free from the projects. Statements provided for required information for entry of lessons learned should be improved.

- **Improvement in Data Entry:** Entry of delay causes and claim types may be provided through selection from trees or predefined lists. Automatic calculation of “actual duration” for completed projects. Entry of “expected profit” and “actual profit” as a percentage should be provided with automatic calculation of “expected cost” and “actual cost”. “Profitability” should also be entered/calculated as percentage. Automatic adjustment of factor weights during editing may be provided. Interoperability may be improved through automatic data export and import mechanisms.
- **Improvement in Calculations:** Similarity calculation should be flexible in selection of attributes to be included in the calculation, the “technology” attribute also needs an improvement. Attributes of “milestones”, “project significance”, “scope” and “country groups” should be selectable for inclusion in the calculation. Incentives should be included in calculation of actual profit, unless the user enters directly. Forecasting calculations may be adjusted on a milestone basis including deviations in the planned milestone durations and costs. Identification of exceptional projects and negative profits in calculations in the portfolio analysis is required. Portfolio value calculation requires an improvement or at least flexibility in calculation. Strategic hold point may be integrated for automatic elimination of the portfolio alternatives.
- **Improvement in Reporting:** Visualization ability of the tool may be improved with integration of a geographic map with project nodes. Current Portfolio in figures should be distinguishable. Grids and threshold values in

the analysis figures should be represented. Table provided in portfolio selection should represent summary of included portfolio projects information. Portfolio value representation through bar chart should be improved and "portfolio success" should be renamed as "portfolio potential". A customizable reporting mechanism is required for ensuring variety in reporting options.

- **Possible Benefits:** The tool is stated to be important at holding level or companies working with different type of projects in their portfolio. However, tool is found also valuable for the companies that are working with same kind of projects in their portfolios with the following benefits. Its expected benefits for companies in general would be facilitation of "strategic planning", "business development", "organizational learning" and "knowledge management". For all companies it would support decision-making at the top management level. It would be highly beneficial during potential project selection, enabling comparison of company statistical project values such as; profit, risk, strategy, etc. with the potential portfolio. It would help to combine the company know-how and experience in a visual platform. Specifically for the company under investigation, main possible benefits are stated as assistance in the management decisions and enhancement in strategic planning, which may result in improved quality of decisions and achievement of strategic objectives in the company.
- **Possible Barriers:** The main barrier is stated that the tool requires a single professional that would control all the process and utilization of the tool. Strong coordination by different divisions is required since they should enter information to the same platform. Thus, possible barriers may be data collection from previous projects and requirement of data refining by a unique department.

7.3.2. General Evaluation on Tool (Survey 8 - Section 2)

The following information is obtained as ratings on the provided statements of evaluation on a Seven-Point Likert Scale ranging from "strongly disagree (1)" to “strongly agree (7)” (Appendix K). In addition to statements, a checklist is also provided to identify the possible benefits of utilization of the tool (Survey 8: Section 2):

Table 7.17: General Evaluation on COPPMAN

Statement	Rating
1. COPPMAN tool provides an effective portfolio management.	6.00
2. We are satisfied with the COPPMAN implementation.	5.67
3. We are satisfied with the features/components of COPPMAN tool.	6.33
4. COPPMAN tool is useful for organizational learning.	4.67
5. COPPMAN tool is useful for portfolio risk evaluation.	5.67
6. COPPMAN tool facilitates strategic evaluation of the portfolio	6.00
7. COPPMAN tool supports effective reporting and documentation.	6.33
8. COPPMAN tool facilitates visualization of the portfolios.	6.33
9. COPPMAN tool provides adequate warnings regarding the portfolios.	5.33
10. COPPMAN tool eases selection of the right projects.	6.00
11. COPPMAN tool facilitates decision-making for managers.	7.00
12. COPPMAN tool provides support for short and long term planning.	5.67
13. COPPMAN tool is user-friendly.	5.67
14. COPPMAN tool does not require extra burden (additional cost / workload or legal issues) for implementation.	4.00
15. COPPMAN tool would be implementable in our organization.	5.00
16. COPPMAN tool would be implementable in similar construction organizations.	5.67
17. Possible benefits with utilization of COPPMAN in your company: i. All respondents: ✓achievement of strategic objectives ✓selection of right projects (optimum portfolio) ✓better knowledge management and organizational learning ✓better strategic planning ✓better communication within the company ✓better documentation and reporting ii. One respondent: ✓minimization of risk ✓better long term profitability	

The respondents are satisfied with “implementation” process and COPPMAN is evaluated as “effective” in portfolio management with its adequate “features/components” and “user-friendly” structure. All the respondents agree with all the positive statements except for the “requirement of extra burden for implementation”, which is neither agreed nor disagreed. The effort required may be establishment of the database with all the required information, which may be the reason of this result. The most important capability is appreciated to be “support of the tool in decision-making”. Abilities of “better visualization of the portfolios” and "effective reporting and documentation" are identified as the prominent ones among the others. Other remarkable abilities of the tool are observed as its support in "strategic evaluation", "selection of the right projects", "portfolio risk evaluation", and "short term and long term planning". The least agreement points are got for its contribution in "organizational learning". This evaluation may be due to requirement of combined effect of technologic and cultural support for organizational learning, where tool may be insufficient on its own. The tool is stated to be "implementable" in the company of investigation and also in similar construction companies. Regarding the checklist for "possible benefits" of utilization of COPPMAN, all the respondents have achieved consensus on the benefits in "strategic planning and strategic achievement", "project selection and portfolio optimization", "knowledge management and organizational learning", and improvements in "communication, documentation and reporting". One respondent also underlines possible benefits in "risk minimization" and "long term profitability". Therefore, evaluation process reveals that COPPMAN has the potential to serve successfully for the expected purpose and has considerable potential benefits for construction companies.

7.3.3. Required Updates

Following the evaluation process, the updates required in the tool are determined and presented under the following main items:

- **Notes Entry and Representation (for all projects):** Notes section should be reserved as a whole section, or different sections for scope, profit, actual cost, claim, incentive or any other area should be identified. Entered notes should also be visible on project cards. It should be at the bottom of all project entry sections and project cards with the heading of "Project Notes" (multiple-optional entry).
- **Scope Quantification (for all projects):** The scope identification through free text should be changed to a dropdown list and the list should be identified through "project inputs" (identification location: "project inputs" under "project type"

with the name “project scope”, entry location: single-mandatory entry replaced with current “scope” free text in project information entry for all types of projects). Scope may be quantified through identification by abbreviation of “very small” to “very big” in addition to text that may specify any other property of the project. Then direct matching of the list item including the project type and the scale should be provided for similarity calculation (alternatively use of a “very small” to “very big” scale may be provided in addition to free text; however, this may result in mismatching with different types of projects, user can identify scopes for different type of projects in the other option).

- **Client Type Identification (for all projects):** “Client Type” identification in “project inputs” as dropdown list should be provided (identification location: “Project Inputs” above “Partnership Types”, entry location: single-mandatory entry below “client” in project information entry for all types of projects).
- **Claim Type Identification (for all projects):** “Claim Types” identification in “project inputs” as dropdown list for claims should be provided (identification location: “Project Inputs” below “Partnership Types”, entry location: multiple-optional entry over claim cost and duration information).
- **Project Significance Identification (for all projects):** Significance of each project should also be identified in “project inputs” and entered in project information section through selection from dropdown list and represented also in project card (identification location: “Project Inputs” below “Project Scope”, entry location: multiple-optional entry between the “project scope” and “owner” in project information entry for all types of projects). Significance should also be included in similarity calculation.
- **Milestone Identification and Update in Post Project Appraisal and Predictions (for completed and on-going projects):** Milestone identification should be provided in project inputs and should be assigned to project types through selection from dropdown list (multiple-optional entry) and related cost and duration values for each milestone should be entered in “post project appraisal” section for completed projects and “periodic evaluation” section for on-going projects and represented also in project card (identification location:

"Project Inputs" above "Project Types" with the name of "Project Milestones"). Entry of milestone based cost and duration information for completed projects together with critical milestone identification should be provided (single-optional entry location for completed projects: in the "Post Project Appraisal" section over "Evaluation Information" it would be the first section with the name of "Milestone Information") (single-optional entry location for on-going projects: in the "Periodic Evaluation" section over "Evaluation Information" it would be the first section with the name of "Milestone Information"). "Cost" and "Duration" information entry (in percentages or in days and monetary values) should be provided (single-optional entry) next to each identified milestone and selection of critical milestones (multiple-optional entry) from the dropdown list should be provided. Milestone based cost and duration forecasts for active projects based on completed project data should be provided in addition to forecasts based on project end in "Predictions" section. Warning should be provided in Portfolio Analysis for the on-going projects based on milestone based prediction. Similarity calculation should also include milestone similarity.

- **Periodic Evaluation Information (for on-going projects):** Current information on "schedule, budget, scope, claim, delay, critical actor and critical work package" should be recorded with date and presented in the project card for "on-going projects" and also in the project card for "completed projects" once they are recorded and the project status is has changed to "completed" (location: above "Post Project Appraisal" section with the name of "Periodic Evaluation"; multiple-optional entry recorded with dates). Once the project is changed to "completed project" the other mandatory areas should be included and taken in the calculation of predictions. Information of "on schedule", "on budget", "on scope" should be included with the level of "negative", "neutral " and "positive", and "current claim" (as in updated version), "current delay", "current critical actor" and "current critical work package" should be selected as in post project appraisal section and these information should also be presented on the project card. The required information is as follows (information excluding the first three item should be entered as in Post Project Appraisal Section):

    - "On Schedule": (selectable information) Negative / Neutral / Positive,
    - "On Budget": (selectable information) Negative / Neutral / Positive,
    - "On Scope": (selectable information) Negative / Neutral / Positive,
    - "Current Claim Information" (in separated form for two claim types),
    - "Current Critical Delay Causes",
    - "Current Critical Actors",
    - "Current Critical Work Packages".
- **Risk and Strategy Information:** For completed projects, addition of an information for "realization of risks" and "achievement of strategies" that would be selected as "very low", "low", "medium", "high", and "very high" and would be represented in the project cards. Information of "planned/expected" and "actual" project "risk" and "strategic fit" scores should be captured and presented in the project cards as planned/expected and actual values (single mandatory-entry). Planned/expected values should be automatically taken from the analysis (the initial evaluation) if they have been evaluated for on-going and potential projects (otherwise user will enter), whereas the actual values should be entered by the user (user may change the expected value manually) (location: in the "Post Project Appraisal" section between "Evaluation Information" and "Claim Information" it should be the section with name: "Risk and Strategy Information"; the location is also the same in project cards). The summary of the required information is as follows:
    - "Overview"
        - "Realization of Risks": (selectable information) Very Low / Low / Medium / High / Very High
    - "Achievement of Strategies": (selectable information) Very Low / Low / Medium / High / Very High
    - "Score Overview"
    - "Expected Risk Score": (the score of the first risk assessment made for the on-going or potential project will be taken automatically (the user may change this obtained value); otherwise user should enter manually)
        - "Actual Risk Score": (the user should enter manually)

    - "Expected Strategic Fit Score": (same as in "Expected Risk Score")
    - "Actual Strategic Fit Score": (same as in "Actual Risk Score")
- **Claim Update in Post Project Appraisal and Predictions:** Separation of "owner and partner" claims and "subcontractor" claims in cost and duration entry for claims is required and predictions should be calculated for each type separately (current system may be provided twice under headings of "owner and partner" claims and "subcontractor" claims separately, both of the would be optional areas, separate representation in project cards) (multiple-optional entry for claims, whereas single-optional entry for costs and durations).
- **Exceptional Project Identification and Calculations (for completed projects):** "Exceptional project" should be identified in the data entry process for completed projects through an area to be ticked also represented in project cards and calculations should be made by excluding data of exceptional projects (location: in the "Post Project Appraisal" section with the name of "Exceptional Project" next to "Critical Work Packages", optional selection, if it is not selected it means the project is not "exceptional").
- **Change Management Integration (for all projects):** Checkpoint section should be provided for all project types where a change comment is identified by one user, notified to another user(s) and approved by the user(s) and notified to selected users (location: above "Post Project Appraisal" or "Periodic Evaluation" with heading "Change Checkpoint", multiple-optional entry).
- **Legislation Identification:** Related legislations may be identified (optionally not mandatory) and uploaded at "preferences" section for specific project types and user may be automatically warned about legislation consideration according to the project type ("Legislations" menu list should be provided above the menu item of "Edit Library", multiple-optional entry).
- **Country Groups Identification:** Sections should be editable to identify groups of countries in "preferences" section (optional identification, location: "Preferences" above "Tag Tree" it should be the first section with name: "Country Groups"). User can identify various groups with specific names where countries

are assigned. Relation/Belonging level of each country to the group should also be assigned while establishing the country groups. Notes section should be provided for each group to explain why this specific country is included in this group and should be depicted in groups info together with the belonging levels of the countries. Country group can be used in similarity calculation as an alternative/addition to country similarities.

- **Strategic Hold Point Identification:** There should be optional identification of strategic hold points, a radio button (Activate/Deactivate) should be provided for deactivation of the warnings for strategic hold points. The limits should be set next to each item in preferences in “Threshold Values” section (optional identification, location: “Preferences” under “Evaluation Factors” there should be section with name: “Calculations” including “Threshold Values”), where the button may also be provided.
- **Similarity Calculation:** Calculation should be adjustable in the preferences section (location: “Preferences” under “Evaluation Factors” there should be section with name: “Calculations” including “Similarity Calculation”). The other attributes that should be added to the current attributes are: “scope”, “owner type”, “partnership type”, “contract payment type”, “project significance”, “project milestones”, “project delivery system”, “currency”, “country group” (“Project Similarity Coefficients” should be removed from the “Coefficient Constants”).
- **Updates in Corporate Memory:** Project free lesson entry should be provided under the menu list of “Corporate Memory” with the “Lesson Learned Entry” option (project selection should be optional and project free lessons should be visible in retrievals other than similarity such as filtering with no attribute selection or tag/free text search). Free text searching in lessons should be provided including the lesson title, description, recommendation, actor, and tags (all entered information). There should be an e-mailing option for an open operation for approval of lessons, and approval of the lesson should be e-mailed to the related users. Request for approval and approval of the lesson by each user should be listed in the lesson cards with the related user information. Statements of

required information should be replaced with more representative ones as "Lesson Learned Title", "Description of the Event", "Impact on Project Duration/Cost", and "Amount".

- **Updates in Bubble Graphs:** Grids should be added to bubble charts, and threshold values should be depicted as thicker/darker lines. Threshold values should be set for portfolio and project risks and strategic fits in the preferences section as "Risk Threshold" and "Strategic Threshold" separately for project and portfolio (location: "Threshold Values"). Warnings on these threshold values should also be made in warning sections. Different representation of "current portfolio" from the alternatives in the bubble graphs is required.
- **Portfolio Value Calculation and Representation:** The bar chart may be juxtaposed with columns of "portfolio potential", "portfolio strategic fit" and "portfolio profit". Strategic fit column should represent breakdown of the evaluated strategic factors through pop-up information box. It should also be represented through a spider diagram, and area of the triangle obtained in the diagram should also be represented. The area may also represent an alternative to the portfolio value. The calculation should be flexible including summation or multiplication of the two values and should be set in the preferences (location: "Preferences" under "Evaluation Factors" there should be section with name: "Calculations" including "Portfolio Value Calculation").
- **Negative Adapted Profit:** When there is an alternative with negative adapted profit, the warning of negative profit should be provided and this project should be eliminated from the current "currency/client dependency" warning and its calculation.
- **Geographic Map:** Map should locate all the project symbols of active and past projects together with the warnings and forecasts on current projects on the map (location: "Portfolio Management" under "Portfolio Selection" there should be section with name: "Overall Portfolio Map"). The countries and identified country groups should be selectable on the map, and the map should have the zooming in/out capability. The projects on map should be filtered according to years, year intervals, selected country sections, and the selected countries. Similar

projects of the project at hand may also automatically visualized. The map should provide predictions in a table at the right bottom in terms of profit margin, possible risks, milestone related information, important lessons learned, etc. based on the filtered projects on the map. Dependencies of the current analysis should be presented on the map between the projects, and only the "outcome dependency" between the past projects should be presented as long as they are filtered on the map. Project symbols should be sized according to the contract values or scope of the projects (it should be set through preferences with the name of "Project Nodes (Overall Portfolio Map)" sizes based on selection of "Contract Values" or "Scope").

- **Reporting:** should be more flexible and there may be ready formats as report modules, which are showing only the portfolio alternative, all portfolio alternatives, only dependencies, only risk/strategic fit histories, only lessons learned/predictions based on some filtering, project comparisons with some criteria, etc. These modules should be combined in one report upon selection for inclusion ("Reporting" menu list should be provided between "Portfolio Management" and "Library"). There should be an e-mailing option of the reports to the related users and the reports should be saved as "Portable Document Format (PDF)" and should also be printable.
- **Interoperability:** Ability of importing/exporting, project data, lesson data, actor data, etc.
- **Others:** may be listed as follows;
    - Subcontractor should be added as a resource type
    - "Compliance management" should be added to the tag tree
    - "Tatarstan" should be added to country list.
    - Tree may be provided for "Delay Causes" as an optional area for either direct entry as in current situation or selection from tree
    - Automatic calculation of "actual" (for completed projects) and "planned" (for on-going and potential projects) project durations
    - Entry of "planned profit" and "actual profit" by percentages and automatic calculation of "expected cost" and "actual cost"

- Inconsistency with the use of “middle/medium”, “employer/client” and “construction model/project delivery system” should be finalized as usage of only “medium”, “client” and “project delivery system” throughout the tool processes
- “Early Completion Incentive” statement should be updated
- “Effect level” in post project appraisal section should be changed to “Impact level”
- “Portfolio Success” in portfolio analysis should be changed to “Portfolio Potential”
- Automatic adjustment of weights (risk, strategic fit, resource dependency, similarity calculation) through a button when user does not prefer to enter manually
- Portfolio selection table should include the column of included potential projects

The updated “Menu List” of the tool according to the required changes together with their contents should be as in the following table (Table 7.18). The revised sections are presented in highlighted form in the table.

The required changes in “Calculations” of the tool according to the updates should be as follows:

- **Duration Calculation:** calculation of “actual” (for completed projects) and “planned” (for on-going and potential projects) project durations as days from the entered start and finish dates (should be automatically written in the project entry form)
- **Cost Calculation:** Entry of “expected profit percentage” and “actual profit percentage” and automatic calculation of “expected cost” (for all project types) and “actual cost” (only for completed projects) is required, also representation in project cards should be provided (project symbol profitability, adapted profitability and prediction calculations should be based on previous calculations including “expected/actual” profits/costs)

Table 7.18: Updated Menu List according to Required Changes

Menu List Item (in its hierarchy)			Content
Project Inputs			
	Project Milestones		Default List: "framing", "concrete pouring", "mechanical installation", "electrical installation", "interior finishing", "exterior finishing"
	Project Types		
	Project Scope		Default List: "Type 1 - Very Small", "Type 1 - Small", "Type 1 - Medium", "Type 1 - Big", "Type 1 - Very Big" (Type section should be automatically assigned as "Project Type", user should only select "Very Small" – "Very Big" options)
	Project Significance		Default List: "Learning opportunity", "New markets", "Unavailability of resource-x", "No problem has encountered", "Risky project due to first implementation"
	Project Delivery Systems		
	Contract Types		
	Contract Payment Types		
	Resource Types		
	Client Types		Default List: "Private", "Government"
	Partnership Types		
	Claim Types		Default List: "Extension of time claims", "Force majeure claims", "Liquidated damages claims", "Technical claims", "Other claims"
	Critical Work Packages		
	Critical Delay Causes		
	Technologies		
	Actors		
User Preferences			
	Country Groups		
	Tag Tree		
	Delay Causes Tree		
	Evaluation Factors		
	Calculations		
		Similarity Calculation	
		Portfolio Value Calculation	
		Other Calculations (former "Coefficient Constants")	"Learning Coefficients" "Project Dependency Coefficients" "Financial Dependency Coefficients"
		Threshold Values	"Project Nodes (Overall Portfolio Map)" "Warning Limits for Portfolio Properties" (former "Warning Limits") "Thresholds for Projects/Portfolios": "Risk Threshold" and "Strategic Threshold" "Strategic Hold Points"
		Exchange Rate Constants	
	Legislations		
	Edit Library		
	User Management		
	Access and Authorization		
Projects			
Corporate Memory			
Predictions			
Portfolio Management			
	Portfolio Analysis		
	Current Portfolio		
	Portfolio Selection		
	Overall Portfolio Map		
Reporting			Results for a single "portfolio alternative", Results for "all portfolio alternatives", Results for "portfolio selection", Results for "dependencies" (dependency map) for a portfolio alternative including the dependency matrix, "Project card" of a project alternative, "Risk/strategic fit histories" of a project alternative, "Similar projects" for a project alternative, "Retrieved lessons learned results" based on some query, "Lesson cards" based on some query/selection, "Learning potential results and content" based on some query/selection, "Predictions" based on some query, "Project symbols combined" according to results based on some query, "Overall portfolio map" screenshot and notes based on some section or query
Library			

    - Expected Cost = Contract Price / (1 + Expected Profit Percentage / 100)
    - Actual Cost = (Contract Price + Change in Contract Price) / (1 + Actual Profit Percentage / 100)
- **Negative Profit:** The current “currency/client dependency” warning calculation should exclude data of any project with “negative adapted profit” value in the portfolio.
- **Milestone-based Prediction:** Milestone-based cost and duration forecasts should be calculated as averages for each milestone for that project type. Predictions should be presented for on-going and potential projects based on completed project data. Calculation of predictions should be based on matching of the “project types” in addition to all the other filtering or similarity based criteria for the project in question (the project that the predictions are presented for). If no duration or cost have been entered to a specific milestone, the duration and cost values will not be evaluated as “0” they will not be included in the calculation.
- **Exceptional Project Calculations:** There should be a radio button (option) in the areas where predictions displayed as “include/exclude exceptional projects”, and also an option in portfolio analysis where the projects and the currency selected. When these options are selected all the predictions (all calculations) and portfolio analysis results (in terms of “adapted profit” and warnings on “critical actors”) should exclude data of these projects.
- **Similarity Calculation:** The previous similarity calculation system should be preserved (except for the “technology” attribute) (false positives should be prevented, namely if there is no entry for an attribute, this would not be included as indication of similarity). The existing attributes should be mandatory, whereas the new ones should be optional. The previous similar attribute addition to calculation will stay valid for “country”, “project type” and “client”. Attributes may be listed with optional selection for inclusion in the calculation (The section preserved for assigning coefficients “Project Similarity Coefficients” should be removed from “Coefficient Constants”

section – the current “Other Calculations” section). Each factor may be listed with the required coefficient. User may enter “0” to the weight of the attribute to simplify the calculation. The final order for similarity calculation attributes should be (this page should be designed to have the identified factor weights for the existing attributes, and “0” weight for the newly identified attributes in its default):

- “Same/Similar Country”: current calculation preserved,
- “Same Country Group”: exact matching of “country group”,
- “Same/Similar Project Type”: current calculation preserved,
- “Same Project Scope”: exact matching of “scope” (in terms of “project type + scale”),
- “Same Project Significance”: same “significance” count assigned to each project/“significance” count identified*100 (in percentage),
- “Same Project Milestone”: same “milestone” count assigned to each project/“milestone” count identified*100 (in percentage),
- “Same/Similar Client”: current calculation preserved,
- “Same Client Type”: exact matching of “client type”,
- “Same Partnership Type”: exact matching of “partnership type”,
- “Same Technology”: current calculation should be changed to same “technology” count assigned to each project/“technology” count identified*100 (in percentage),
- “Same Project Delivery System”: exact matching of “project delivery system”,
- “Same Contract Type”: current calculation preserved,
- “Same Contract Payment Type”: exact matching of “contract payment type”,
- “Same Currency”: exact matching of “currency”.

- **Portfolio Value Calculation:** should be optional, the current calculation (option 1) should be set as default. The provided options should be:
  - **Option 1:** PV = Portfolio Strategic Fit Score + Portfolio Potential
  - **Option 2:** PV = Portfolio Strategic Fit Score * Portfolio Potential

- **Option 3:** PV = Portfolio Strategic Fit Score + Portfolio Potential + Portfolio Profit Utility * 100
- **Option 4:** PV = Portfolio Strategic Fit Score * Portfolio Potential * Portfolio Profit Utility * 100

  Profit Utility = Portfolio Alternative Profit / Maximum [Profit of Portfolio Alternatives in the Analysis]

  Risk neutral utility function (Figure 7.33), where k = 1 / Maximum [Profit of Portfolio Alternatives in the Analysis]

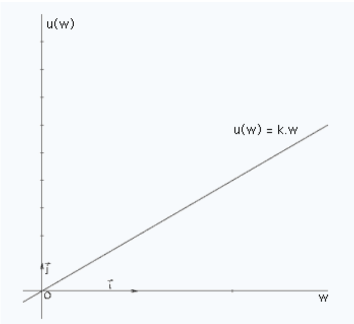


Figure 7.33: Risk Neutral Utility Function

The changes in “Warnings” of the tool according to the required updates should be as follows:

- “Warning Limits” under Coefficient Constants should be transferred to the “Threshold Values” section and should be named as “Warning Limits for Portfolio Properties”.
- Current warning on “Project Risk Limit” should be removed (its warning limit “Project Risk Limit” should also be removed from the “Warning Limits” list).
- Warnings based on the threshold values should be made in warning on the “portfolio alternative” ([Project X, Y, and Z has/have risk/strategic fit value(s) over/below the threshold value.] or [Portfolio X has risk/strategic fit value over/below the threshold value.]).

- Warnings for portfolios based on the threshold values should also be made in warning on the "portfolio analysis" and "portfolio selection" pages ([Portfolio X, Y, and Z has/have risk/strategic fit value(s) over/below the threshold value.]).
- Warnings for strategic hold points should be provided both under warnings for "portfolio alternative" and "portfolio analysis and portfolio selection". Warnings should be stated as: "Project abc" exceeds/does not meet the strategic hold point limit for "hold point abc" or "Portfolio abc" exceeds/does not meet the strategic hold point limit for "hold point abc". Strategic hold points should be identified as follows together with the default limits, and the user should set the limits for each of them;
    - "Portfolio Value Limit" (if < limit = "130"): ("Portfolio abc" does not meet the strategic hold point limit for "portfolio value".)
    - "Project Count Limit" (if > limit = "3"): ("Portfolio abc" exceeds the strategic hold point limit for "project count".)
    - "Portfolio Profit Limit" (if < limit = "3,000,000 Euro"; should be converted to the currency used in the analysis): ("Portfolio abc" does not meet the strategic hold point limit for "portfolio profit".)
    - "Project Duration Limit" (if > limit = "2,000 days"): ("Project abc" exceeds the strategic hold point limit for "duration".)
    - "Country Count Limit" (if > limit = "3"): ("Portfolio abc" exceeds the strategic hold point limit for "country count".)
- Warning of predictions based on milestones (for on-going projects in the portfolio alternative) should be provided in the warnings for the "portfolio alternative" as "The "abc" duration/cost milestone ("abc value") for "Project abc" is exceeding the average duration/cost value ("abc")."
- Warning for legislation consideration according to the project type (for on-going and potential projects in the portfolio alternative) should be provided in warnings for "portfolio alternative" as "Legislation(s) "abc", "abc", "abc" should be taken into consideration for "Project abc"."

- Warning of a negative adapted profit in the portfolio alternative should be provided as "Project X, Y, and Z in the portfolio has/have negative adapted profit(s)" in case of existence of a negative adapted profit in the portfolio analysis results. This project should also be eliminated from the current "Currency/Client dependency" warnings and the current warnings should be changed in this case as "Portfolio profit (excluding "Project abc") is "abc percentage" financed by the Client: Client abc. High dependency of the portfolio profit to this client entails financial risk" or "Portfolio profit (excluding "Project abc") is dependent on "abc currency" at "abc percentage". Fluctuations in this currency would affect the portfolio seriously. Taking into consideration of this situation and making expenses in the same currency as far as possible to reduce the financial risk are suggested.".

7.4. Update

In the light of the obtained evaluations, an update on the beta version of COPPMAN was produced as a result of discussions and joint effort by the software developer company. As initial response to remarks on "loading time" received in "usability testing" and non-critical disturbance in the real application process, a general improvement was made on COPPMAN. Within this context application technology was migrated to the "ASP.NET MVC" structure and developments that will provide flexibility in the relational database structure was made. Code quality was improved using the "Entity Framework" in the data access layer. Bootstrap infrastructure was used and "HTML5" support was increased. Additionally, switch to a more responsive design was made to ensure that the designed screens can be easily operated on mobile devices and dynamism of system parameters was increased by ensuring more user-friendly control on their identification/edit. An additional common "project layer" in the form of more dynamic "project card" was designed to combine all the "displaying" and "editing" options of a project on a single screen.

In addition to the overall improvement, the noted requirements identified in the previous section were provided in the following order were additional features on “geographic map” and “reporting” ability were structured with discussion on the opportunities provided by the developer company. Details of the update process in the form of gradual improvements can be summarized as follows.

1. **Phase 1:** Portfolio map was integrated with the properties of showing all projects through nodes indicating scope/status by bubble size while depicting dependencies between projects through colored arrows in parallel with the “dependency map” (entry of outcome dependencies for the “completed projects” was also provided). The portfolio map presents summary project information boxes on “lessons learned”, “predictions”, and “warnings” through combinations of required information according to the filtered projects on the map. Zooming ability on the map is provided together with the abilities of clicking on nodes to open/display the project figures, cards and link to other operations through one-click, double-click and right-click options. The projects on map are further to be filtered as a result of the operations such as result of dependency search. Two filtering options on the map is provided based on “project attributes” and “portfolio projects”. “Project attributes” based search provides single or combined selection of the attributes (project status, project name, project type, contract type, client, partner company, project start/finish year – further options on selection of year or year interval, country groups). Portfolio projects based filtering provides filtering the projects of the selected portfolio where “current portfolio” is depicted when there is no analysis made. In addition to portfolio map, identification of the country groups was provided in line with the identified properties. Reporting ability was structured in two sections as “overview” and “custom” reporting based on selection of modules to be included in the report while providing printing, PDF, and e-mailing options. “Overview” section provides general results upon selection of ready templates as modules of the report such as, “actor search”, “project search”, “lesson retrieval”, “portfolio analysis results”, etc. with extending option of the details of listed results.

“Custom” section includes “report” button at the end of pages for various operations to add the current results on the screen to the report in addition to the results added by the “overview” section. This phase of updates also included identification of “milestones” and “critical milestones” and generation of milestone-based predictions.

2. **Phase 2:** The following phase of the updates were for identification of exceptional project and related update in required calculations, update in required project information and project cards, improvement of similarity calculation by providing an optional extended list of attributes, update in the calculations of warnings and portfolio value, integration of change management section through checkpoint identification, improvement on the corporate memory by free text search on the lessons, entry of lessons regardless of projects, entry of quality effect and provision of e-mailing options for approval of lessons.
3. **Phase 3:** In the last phase of the updates, the remaining considerations were realized such as,
   - identification of project notes, strategic hold points, and legislations
   - generation of import/export ability for actors
   - automatic calculation of profits (based on entered percentages) and planned/actual costs, automatic normalization of weights with equal figures
   - generation of a tree for delay causes
   - changes in graphics and tables considering discrimination of current portfolio, provision of grid lines for threshold values, inclusion of juxtaposed and spider graphs for portfolio value, re-presenting the tables for portfolio properties in the portfolio selection page
   - Final tuning for the failing points of the beta version such as restructuring some of the expressions, inclusion of “Tatarstan” in the country list, etc.

7.5. Concluding Remarks

This chapter reveals the details of the final testing of COPPMAN as the actual implementation. It has a vital contribution to the study to assess its expected benefits. The study has ended with appreciation of the current version and a final update in the tool, details of which are given under this chapter. The next chapter concludes the study with discussion on outcomes of the study together with possible future work.

CHAPTER 8

CONCLUSIONS

Today's construction projects are much more complicated than before, and the managers have been under pressure of complex strategies employed. Besides its realistic management style as management of set of projects rather than individual projects, link of the management process to organizational strategy also reveal the importance of portfolio management for project-based industries. When multi-project environment of construction industry is considered, the requirement of successful strategies and effective project portfolio management implementation emerges. Literature has been very alive in studies undertaken on project portfolio management; however, studies focusing on construction industry has been very limited. Accordingly, more interest on portfolio management of construction projects is required in the academic studies and their use by construction organizations should be encouraged to increase the rate of successful construction portfolios and organizations in the industry. In this study, generation of a construction management tool for construction companies is hypothesized to be responsive for construction companies to address this need. Following the needs analysis (first objective), a novel process model was generated, and this model was completely realized through generation of the tool (second objective). The performance of the tool was initially tested for its practicality through usability testing and real application in a construction company with a real portfolio of projects (third objective). The tool was validated with its potential benefits in portfolio management for construction companies where additional improvement was provided to foster its current benefits (major aim).

The overall research process is summarized in the following “horseshoe” model (Figure 8.1) indicating the main points on the presented details as the research background, aim and objectives, scope and methodology with the links of each step to the outcome of the research as the findings, contributions and predicted impact (Fischer, 2006). Within the context of this study, as the main outcome, a project portfolio management tool (COPPMAN - COnstruction Project Portfolio MANagement) was developed to meet the existing deficiencies and requirements in construction sector and portfolio management literature. In order to develop the tool, literature review was carried out in the field of project portfolio management and needs analysis was reinforced with explorative study by construction company professionals. In the light of this investigation, a process model was generated by adapting the portfolio management processes to construction management processes with the help of questionnaires distributed to company professionals and detailed evaluations provided by other professionals. At the end, COPPMAN was generated through the technical support provided by a professional software company. Outcomes of the “needs analysis” and the “process model” can also be deemed as by-products of the study with their contribution to portfolio management body of knowledge specific to construction industry and other project-based industries as the basis of further studies that may be held.

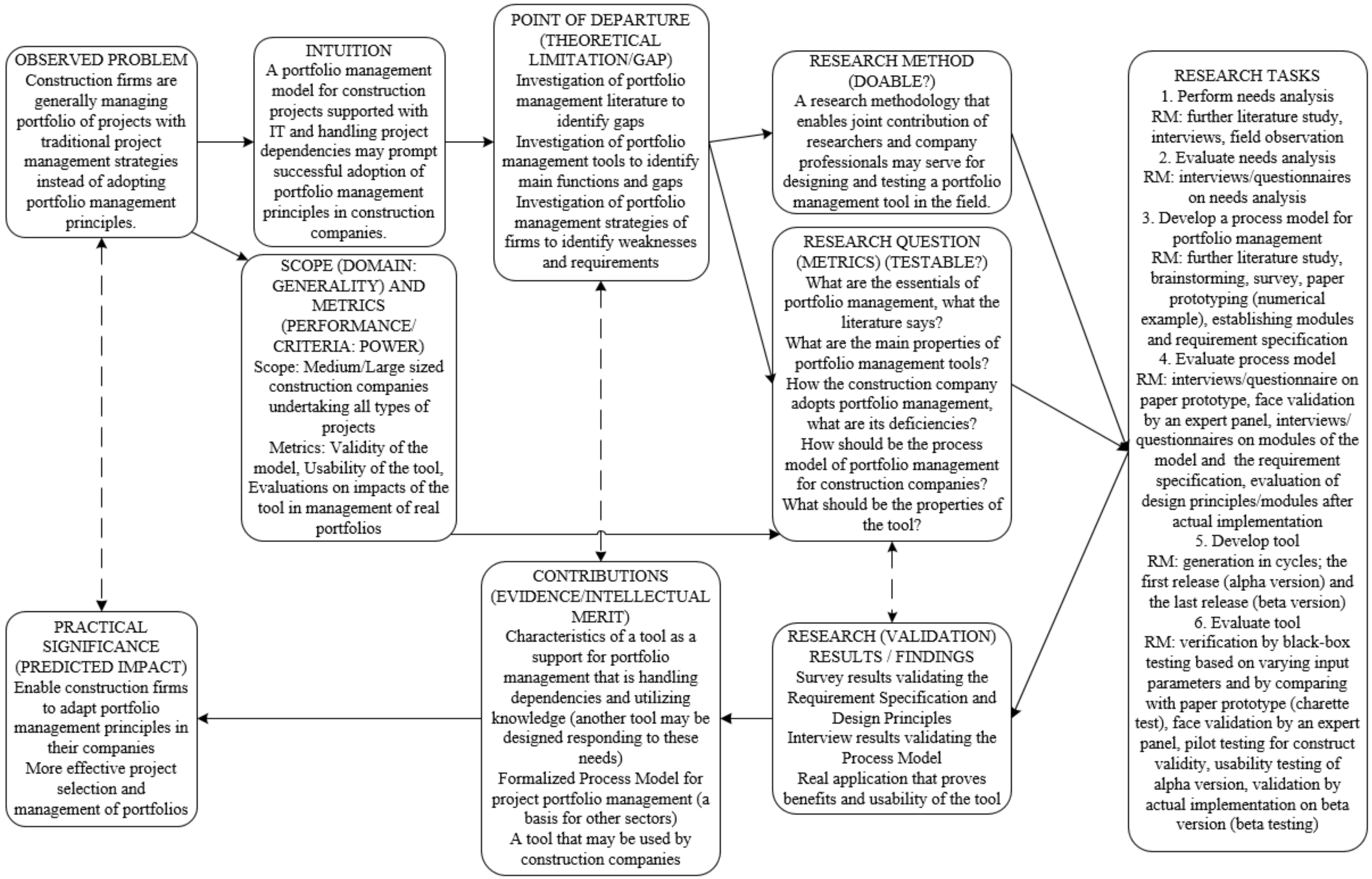


Figure 8.1: Research Outline

Major aim of COPPMAN is to support portfolio management processes in construction companies by adapting the project portfolio management perspective to the construction projects and handling projects within portfolios. Contrary to most project portfolio management applications, the tool automatically calculates the dependencies between projects (inter-project relationships) and incorporates them into the portfolio analysis while allowing the use of the past project information for evaluation of the current/future projects. COPPMAN integrates knowledge management to the process, it provides establishment of corporate memory within the tool and able to present predictions based on the past project data. It supports evaluation process of the user with extraction of company specific information and increases the learning opportunity. In this respect, the tool offers a comprehensive database structure that allows the projects to be evaluated as a whole, as well as in detail of each project. Project information is stored within the tool including some level of post project appraisal information and lessons learned in course of projects, and this knowledge is revealed to the user in a refined form while making project evaluations for portfolio analysis. The tool provides similarity, filtering and tag-based search capabilities to achieve extraction of the related information effectively. The tool can automatically calculate dependencies between projects by using the project information and visualize the dependencies through dependency (network) maps and consider the dependencies in the risk analysis at the portfolio level. It uses the network map features to integrate the cumulative effects of these dependencies to calculation of portfolio risk and so to portfolio analysis. User is only asked to make evaluations at the project level and the tool automatically creates portfolios and depicts different scenarios through portfolio level properties and visualizations. It can offer a portfolio management system that can ensure that the portfolio selection is to be made appropriately for the company according to the company's strategy, portfolio level risk, portfolio value and profitability. Portfolio analysis involves measurement of dependencies, company's strategic goals, project risks, profitability of projects, and predictions obtained from past projects together with lessons learned. Projects and portfolios are visualized with their properties through the project symbol, summarized information in tables, bubble and bar diagrams indicating different aspects of projects/portfolios. As a result of the analysis, the tool offers automatic warnings on portfolio selection and management based on identified dependencies, project data and project/portfolio properties. Thus, it has a potential to provide decision support in the management of risks and resource allocation, also to facilitate learning opportunity between the projects based on the identified project dependencies. All data entries are provided in an updatable or re-definable format to ensure that the tool is dynamic. The company can set its own risk and strategic fit assessment criteria according to its own structure or changes foreseen, can change all the weight and limit values used in algorithms of the tool and can keep the lessons learned database free from invalid information and keep it up to date. In addition to this dynamic structure, the tool also provides a warning to the user to renew the evaluation of the past risk assessments that are over 3 months period to keep the risk assessment up to date. With the scenario analysis, each new project is evaluated in its portfolio through analysis of its contribution to strategic targets, risk, profitability, and its effect on portfolio. The tool also provides feedback on the actions of the user and warns the user for the incorrect and intermittent operations. Therefore, the presented features all serve for the intended main properties of COPPMAN as being visual, intelligent and dynamic tool as it is expected. It is believed that the tool can help medium to large-scaled construction companies successfully manage their portfolios, so that the management focus of the companies can be transformed from the success of individual projects to success of the company. Thus, the tool can make construction companies to create and manage efficient portfolios, which may foster strategic management of the companies as well. Therefore, achievement of portfolio management by construction companies can keep them one-step ahead in the possibility of gaining competitive advantage.

The study has been completed within an iterative process of evaluations by the mutual commitment of the research team and construction professionals in terms of identification of the needs analysis and generation of the possible solutions (as the process model and the tool) including contributions of the software company. The following sections report the “major findings” obtained in different stages of the study together with the "contributions" and "practical significance" of the study. Finally, possible "future work" is also handled as further improvement areas of the study.

8.1. Major Findings

Major findings in the light of the objectives as well as main steps undertaken in the methodology are provided in the following sections on "needs analysis", "process model" and "tool".

8.1.1. Needs Analysis

In the first objective the main interest was establishment of the need and the initial requirements through discussions on the need where literature and field investigation was held to pave the way for a practical and useful solution.

Literature Review: Investigation of literature survey ended up with structuring the initial context of the study by revealing that a portfolio management tool for construction companies is needed that would be able to make "dynamic analysis" of portfolios through evaluation of portfolio alternatives by "scenario analysis", where the alternatives are to be analyzed and visualized considering "dependencies" between projects and different measures as "risk", "strategic fit" and "value" of portfolios while providing knowledge support through different "data retrieval mechanisms" in terms of "predictions" and also "warnings" for decision-making based on the past project data and identified portfolio properties.

Field Investigation: As a supportive process to literature review, the findings obtained through the study with "focus group" on needs analysis mainly indicates the qualitative evidence of requirement of a portfolio management tool in the construction companies similar to this one, which is a leading construction company acting in many branches in the international market. Investigation in company mainly reinforced that there is a need of a “common platform” that would combine all “project level” functions and link them to “portfolio level” considerations where a strong “database” and “data capturing mechanism” is provided to enable converting the “data to knowledge” through “benchmarking” (i.e., similarity analysis) and “forecasting” ability by integrating “numerical/statistical analysis” of the project data and “visualization” ability. The integrated framework should enable systematic management of group of projects considering the interrelations/dependencies cost, time, performance of projects, changes, strategic objectives, resources, capabilities of the company. Therefore, flexibility and dynamism are needed to meet the changing conditions at both company and environmental level. Findings of this study also underline the importance of “portfolio level risk and strategic analysis”. Within the context of further results of this in depth investigation, an attention can be drawn for “lessons learned management” where strong lesson evaluation, categorization and retrieval mechanism is needed. The interviews with the “focus group” underlined the potential benefits of a portfolio management tool at “holding level” where variety of projects are to be undertaken, so the tool should be “flexible” to respond all types of projects to support effective evaluation and decision processes for “project selection” and should require “effortless” process to also be usable by the companies undertaking single types of projects.

Initial Requirements: Evaluation of the overall need analysis process by the “focus group” as ranking of the “initial requirements” resulted in the following ranking where the most important ones are identified as integration of “IT support”, “strategic assessment”, “resource allocation”, “portfolio optimization”, “knowledge management”, and “risk assessment”, which are followed by “dependency analysis”, “project selection”, “portfolio visualization”, “flexible and dynamic analysis”, and “intelligence” (Table 8.1).

Table 8.1: Importance of Initial Requirements

Requirement	Rating
▪ The established system needs to be IT supported. ▪ Portfolio management tool for construction projects should support strategic choices. ▪ Portfolio management tool for construction projects should support resource allocation decisions. ▪ Portfolio management tool for construction projects should support balancing the projects and resources/capabilities. ▪ Portfolio management tool for construction projects should incorporate past project data into portfolio analysis. ▪ Portfolio management tool for construction projects should incorporate risk assessment into portfolio analysis.	7.00
▪ Portfolio management tool for construction projects should handle dependencies between projects. ▪ Portfolio management tool for construction projects should support project selection decisions. ▪ Portfolio management tool for construction projects should enable visualization of portfolios. ▪ Portfolio management tool for construction projects should be flexible and dynamic. ▪ Portfolio management for construction projects should be intelligent and should provide advice/warnings about portfolio decisions.	6.67
▪ Development of a portfolio management tool for construction organizations is required. ▪ There is lack of an appropriate portfolio management framework and tools in construction companies.	6.33
▪ Portfolio management process needs to be established/re-engineered.	6.00

Therefore, as the main finding of this section, the identified "initial requirements" are responding generation of "process models" and also "tools" that would be serving for the intended purpose.

8.1.2. Process Model

Concerning the second objective of the research as generation of the "process model", the evaluation provided by the "focus group" on the "process model" showed that the generated model suits with the identified requirements as well as being supported with a reasonable algorithm where functions responding considerations of different departments are provided with the support of retrieval options which are serving for benchmarking as well. Attention should also be drawn to the fact that the algorithm is based on utilization of default values as results of the extensive analysis from questionnaire responded by “108” construction company professionals. Therefore, the process model was accepted to be serving for generation of a usable tool that may foster its benefits. As initial step for development of the tool, formalization of the model and improving its details were intended through generation of its “modules” and “requirement specification” as further outputs as provided below.

Modules: Evaluation of the modules by the “focus group” revealed that the complete set of the provided modules through the identified principles is responsive to adequately meet the requirements of a portfolio management tool. The most improved module was identified as “Knowledge Management Module”, which includes both the management of “lessons learned” and the “supportive information” including “predictions”. Therefore, this reveals that the provided system is capable to integrate the “knowledge support” for portfolio analysis, which is stated to be one of the major drawbacks of most of the portfolio management initiatives. “Portfolio Analysis Module” was also found successful, which means that the it will be important for the tool to be capable of providing analysis and selection of portfolios through the support provided with visualization. The remaining modules were also appreciated with their acceptable level evaluations that shows that they are also fitting for the purpose. The success of the modules in the order of their adequateness to meet requirements of a portfolio management tool are provided as follows (Table 8.2).

Table 8.2: Success of Modules of COPPMAN

Modules of COPPMAN	**Rating**
Knowledge Management Module	6.33
Portfolio Analysis Module	6.00
Strategic Assessment Module	5.67
Risk Assessment Module	5.33
System Management Module	5.00

Therefore, the modules provides a successful structure where further studies in construction industry or in other industries may be handled through adaption of the successful modules in accordance with the special requirement. Similarly, the overall structure may be adopted and supported with further improvement in specific modules of the tool.

Requirement Specification: The findings of the evaluation of the "requirements" by "focus group" reveals a successful set of identified requirements in generation of a portfolio management tool through investigation of both literature and problem in field. These requirements resulted in generation of COPPMAN as a result of the joint effort of the contributors of the study; however, the identified requirements have also a value in the construction management and portfolio management literatures since they may serve for generation of any other tool through the identified requirements. The order of the importance of the requirements reveal that handling of "knowledge" (through consideration of "lessons learned", "predictions", "tagging system", "similarity assessment") and "project dependencies" were appreciated to be the most important requirements as well as the "risk and strategic assessments" provided. This finding also reinforces that complete response of the tool to these requirements would be the distinctive feature of the tool. The other identified requirements were evaluated to be important as they are typical processes expected from a portfolio management tool such as "accessibility options for different users", "entry of different project types", "filtering based capabilities", "automatic portfolio formation", "visualization of portfolio properties" and "automatic warnings" were the second group of important requirements. The supportive requirements as "ready-to-use project inputs" and "project symbol" seem to be relatively less important since they constitute "project level" considerations in the overall as well as "learning potential" of projects. The grouping of the importance of the requirements are as provided below (Table 8.3).

Table 8.3: Importance of Requirements

Requirement	Rating
▪ Menu for entry of lessons learned, together with view and query options is an important feature ▪ Calculation of dependencies between projects and visualization of dependencies with a dependency map is an important feature	7.00
▪ Calculation and presentation of predictions for the on-going and potential projects through use of information of completed projects is an important feature ▪ Tagging system for entry of lessons learned, including editing options for the tag tree and tag-based query is an important feature ▪ Establishment of project similarity based search and calculation capabilities is an important feature ▪ Menu for evaluation of risk and strategic fit factors, including editing of the factors and calculation of scores is an important feature	6.67
▪ Establishment of filtering based search and calculation capabilities is an important feature ▪ Calculation of portfolio attributes and depiction of results through tables, bubble diagrams and bar charts is an important feature ▪ Menu for entry of different types of projects, together with view and query options is an important feature	6.33
▪ Identification of different users in tool with different accessibility options to the tool menu/operations is an important feature ▪ Automatic formation of the portfolio alternatives through addition of potential project combinations to on-going projects is an important feature ▪ Establishment of an automatic warning system for current portfolios is an important feature	6.00
▪ Identification of ready-to-use project inputs is an important feature ▪ Development of a project representation to be used in visualizations is an important feature	5.67
▪ Calculation and presentation of learning potentials for the on-going and potential projects is an important feature	5.33

8.1.3. Tool

All of the validation studies undertaken for tool validation served for investigation of the major objective of the study by testing the “usability” and “usefulness” of the tool, where they were all testing these two measures at different degrees. Findings from evaluation of the tool are provided below in detail in accordance of each process.

Expert Panel: “Expert panel” was the first analysis of the tool where the version was presented by the research team to the experts. This study mainly served for investigation of “usefulness” of the tool, where some “usability” issues are also questioned through the visible capacity of the tool by exemplification of its utilization by the research team. “Expert Panel” was also the first study that underlined the importance of the methodology for handling dependencies and the use of corporate memory as a stand-alone separate tool for construction companies while also appreciating the complete system as a successful example for other industries. Therefore, this finding offers new insight into the construction and portfolio management literature where this measurement model and overall architecture may be integrated to different studies. Interviews with the “expert panel” revealed that the tool is appreciated to serve as a complete system responding to the need with the detailed functions provided. The tool was appreciated for project selection process including measurement of dependencies, numerical past project data, useful visual graphics, provision of warnings through a familiar and functional user interface. The evaluation provided some level of improvement in the usability of the tool where functionality of the graphics and flexibility of the tool were increased together with developments in the lessons learned management system especially improving the lesson categorization process. The findings also extend to possible future work as integration of resource management ability, optimization of the portfolio selection process, codification of portfolio selection histories and adoption of the overall process to different sectors.

Pilot Study: “Pilot study” mainly confirmed the transition between the processes testing with “demonstration” and testing with “utilization by actual users”. It served almost equally for “usefulness” and “usability” of the tool where the tool was used by two different company professionals under control of the research team. It showed that the hypothetical portfolios based on real projects can be successfully utilized and analyzed within the tool. The potential benefits of the tool in analysis of portfolios was firstly approved in this study through direct utilization by the professionals. The appreciated features of the tool were “web-based tool”, “algorithm”, “user-friendly interface design and visual outputs – specifically the ‘dependency network map’ and ‘project symbol’”, “automatic creation of portfolios by gradual inclusion of the potential projects”, “flexibility and extent of the risk and strategic fit assessment processes”, “comparison of different alternatives through different measures and graphics”, “project selection process supported with predictions” and “flexibility of the tool”. The findings also underline that the tool has the potential to be used for management of the projects as a portfolio by considering “dependencies” even if there is no project selection strategy of the company as proposed in the tool. The “database” and “lessons learned management system” and the “predictions” provide a potential for the tool to also be used also by small to medium-sized construction companies. This study ended with some minor fine-tuning in the interface of the tool.

Usability Testing: Following determination of the tool was ready for further testing through direct utilization by its users, “usability testing” was performed to investigate “usability” of the tool in full detail as its name implies. Minor testing in its “usefulness” was also provided through qualitative investigation where usefulness of some minor details were asked in questionnaires. All of the participants could successfully complete the tasks and some minor problems were totally corrected in the second run with some of the participants, which also makes a promise in “learnability” of the tool. The results demonstrated that the current version of the tool is mainly appreciated for its user-friendly interface and easy-to-follow functions and representations. The obtained quantitative/qualitative data and numerical/visual outputs from the usability software also demonstrate the objective evidence of the success of the tool interface, which may not be obtained completely without support of technology for investigation. Therefore, the tool was found to be successful to proceed with further testing through “real application” without consideration of further update at the end of this evaluation process.

Real Application: In addition to validation studies by direct utilization of the tool as the “pilot study” and “usability testing”, “real application” was the study contributing the most for mainly testing the “usefulness” of the tool while also undertaking some “usability” concerns. The importance of this testing mainly lies in actual utilization by actual users in its actual environment. This study proved that the tool successfully serves for the identified functions generated with the help of IT in accordance with modules and requirement specification identified. Considering its improvement the findings of this study suggest some improvements in “extent and context of the provided information”, “data entry process”, “calculations” and “reporting ability”. Within this context, the findings highlight the requirement of a “geographical map” as a unified depiction of the overall projects where all projects of the company are depicted through nodes with some additional informative figures listed beneath. Reporting ability of the tool should also be improved through integration of “customizable reports” according to the need and also “interoperability” capability should be brought in. An ability for “country grouping” and “milestone identification” for projects are also required for handling the data together with integration of “change management” and “compliance management” initiatives. Considering the to be implied improvements, “similarity calculation” was also stated to be more “flexible” through identification of the concepts to be taken into consideration by the user itself where the additional figures as “country groups”, “milestones”, etc. are to be considerable in its calculation. Similarly, an update for calculation of “predictions” through provision of “milestone-based forecasts” was suggested. Supportive abilities for portfolio analysis as provision of flexibility in calculation of “portfolio value”, identification of “exceptional projects” to provide an option for excluding the projects from the portfolio analysis process and also identification of “strategic holdpoints” for facilitating the analysis of the projects were proposed.

Especially, “real application” revealed that COPPMAN has a potential to be utilized by different-scaled construction companies with different focus of adoption as follows.

- COPPMAN may serve at full-capacity for the large-scaled companies working with different types of projects through main support at decision-making at the holding level where its total benefits may be fostered through its utilization.
- COPPMAN may also be valuable for medium-scaled companies or the companies that are working with same type of projects in their portfolios. For all companies it may provide consolidating the company know-how and experience in a visual platform and support decision-making at the top management level through facilitation of “strategic planning”, “business development”, “organizational learning”, and “knowledge management”.
- Specifically for the company under investigation and also in similar construction companies, main possible benefits can be support in the “management decisions” and enhancement in “strategic planning”, which may further provide improved decisions and achievement of strategic objectives in the company.

The findings clearly demonstrate the capability of COPPMAN “decision support” for construction companies through its “features/components” and appreciated abilities of “better visualization of the portfolios” and “effective reporting and documentation”. The respondents were satisfied with “implementation” process and COPPMAN was evaluated to be “implementable in similar construction companies” through its “user-friendly design” and support in “effective portfolio management” through capabilities in “strategic evaluation”, “selection of the right projects”, “portfolio risk evaluation”, “short/long term planning”, and “warnings” provided as “effective” in portfolio management with its adequate “features/components” and “user-friendly” structure. Results of the evaluation also reveal the consideration of “requirement of extra burden for implementation” since establishment of a strong database is required where there may also be barriers for “data collection” and “data refining” through requirements of a single professional/department for controlling the overall process for utilization of the tool and strong coordination by different divisions for data entry. Additionally, COPPMAN could provide a successful means for “organizational learning”; however, there is also a strong requirement for support of technologic solutions with a responsive cultural environment to achieve organizational learning (Table 8.4).

Table 8.4: Overall Evaluation on COPPMAN

Statement	Rating
▪ COPPMAN tool facilitates decision-making for managers.	7.00
▪ We are satisfied with the features/components of COPPMAN tool. ▪ COPPMAN tool supports effective reporting and documentation. ▪ COPPMAN tool facilitates visualization of the portfolios.	6.33
▪ COPPMAN tool provides an effective portfolio management. ▪ COPPMAN tool facilitates strategic evaluation of the portfolio ▪ COPPMAN tool eases selection of the right projects.	6.00
▪ We are satisfied with the COPPMAN implementation. ▪ COPPMAN tool is useful for portfolio risk evaluation. ▪ COPPMAN tool provides support for short and long term planning. ▪ COPPMAN tool is user-friendly. ▪ COPPMAN tool would be implementable in similar construction organizations.	5.67
▪ COPPMAN tool provides adequate warnings regarding the portfolios.	5.33
▪ COPPMAN tool would be implementable in our organization.	5.00
▪ COPPMAN tool is useful for organizational learning.	4.67
▪ COPPMAN tool does not require extra burden (additional cost / workload or legal issues) for implementation.	4.00

The findings on possible benefits of the current (beta) version of COPPMAN highlight that it may be applicable for this kind of a construction company through the most expected benefits of “strategic planning and strategic achievement”, “project selection and portfolio optimization”, “knowledge management and organizational learning”, and improvements in “communication, documentation and reporting” while some level of “risk minimization” and “long term profitability” may also be achieved.

In the light of the provided evaluation, as the main outcomes, the “real application” study ended up appreciating the possible benefits of COPPMAN together with the “provided update” for the “beta version” where the functions of the tool were improved based on the requirements identified in the real setting. As a result of this improvement, a general improvement on the existing functions is obtained.

Additionally, COPPMAN is equipped with visual depiction of all portfolios on a single geographic map and phased project information is integrated as an initial consideration in supporting scheduling and resource planning related decisions. Project information detail and visibility is increased through further status information for easing performance checking and reporting ability is improved for fostering sharing and control of status and information. Flexibility of the tool is improved through optional calculations provided and intelligence is also increased by improvements in warnings based on added properties.

8.2. Contributions of the Study

Although project portfolio management has been often studied in the literature, existing studies are mostly focused on the telecommunications and defense sector. In this context, this study has a potential to respond the current need in the construction sector. The major contribution of the study is that, it adds to project portfolio management body of knowledge through identification of needs analysis as identification of characteristics of the tool that would serve for class of field problems regarding "portfolio management for construction organizations" and development of a formalized model serving to the identified need. The main theoretical contribution is framing of the need by joint effort of literature and field studies, which constitutes an essential start required for any research in this field. Generated process model can also be used in further research, where development of other tools and integration of the model to other project-based industries may also be achieved. Main contribution also lies with generation of a tool as exemplification of the potential benefits, together with its current potential to be directly adopted by construction companies. Besides responding to very limited initiatives in construction industry, COPPMAN is designed to overcome existing problems in project portfolio management applications by highlighting the current issues. The main drawback in most of the portfolio management initiatives has been identified as poor handling of dependencies between projects. The fact is that there has been a significant deficiency in the literature for quantifying the dependencies between the projects. There have been researches about focusing project selection in the literature, but there have been no studies measuring the interrelationships between projects and their priorities at the stage of project selection. In addition, in the related studies that consider dependencies as part of portfolio management; dependencies are generally defined as subjective, and there have not been mathematical models for estimating/calculating the size of relationships are not covered. The study provides a model for measurement of dependencies with their importance/priority and strength of the relationships. It adopts visualization with network where different types of dependencies are represented by indication of their magnitudes. This network map further provides measures for integrating accumulated effects of these dependencies to portfolio risk and providing decision support on how specific dependencies could be managed. Project priorities and the company's strategic orientation can be included in the model and projects can be evaluated along with the importance/priority and strength of the relationships between them. Especially with regard to portfolio management, integration of dependency assessment constitutes the original value of this study. Additionally, differently from most of the other related work, the study integrates knowledge management to portfolio management process, where project similarities, learning potential of projects, related lessons learned and predictions as calculated measures based on past project data are represented to user for investigation while making risk and strategic fit evaluations in the analysis. User makes the assessments at the "project level" and automatically obtains measures at the "portfolio level" where the tool delivers them within different portfolio scenarios. As another concern, dynamic analysis is provided where evaluations are designed to be compatible with the changing conditions and company preferences. Additionally, an intelligent decision support system is provided where the user can obtain warnings for portfolio selection and management based on the dependencies and project/portfolio measures calculated. The tool is designed to be "visual" by supporting visualizations at project and portfolio level; "intelligent" by providing automatic dependency analysis, portfolio formation and warnings; and "dynamic" by responding company and project specific changes. Therefore, as a summary, contribution of the study mainly lies in its following properties: utilization of previous project knowledge to portfolio analysis, similarity and dependency analysis between projects, analysis of risks at the portfolio level by integration of dependencies, incorporation of strategic fit into analysis of portfolio value, and dynamic and visual analysis of portfolios by scenario analysis supported with warnings.

8.3. Practical Significance

Fundamentally, the tool is structured to enable construction companies adopt portfolio management solutions and therefore provide more effective management of portfolios. In line with the provided properties of COPPMAN, it is considered that construction companies can establish a customized information management system and corporate memory according to the company's preferences and evaluate their projects within the framework of portfolio management principles. In brief, COPPMAN can support analysis by establishing portfolios based on information and evaluations at project level, and integrating past project information and project dependencies to the analysis. The tool delivers an easy-to-use process to its users, since processes prior to analysis requires considerations only at project level and user obtains portfolio level measures within scenario analysis. User is asked to evaluate projects prior to analysis and all the portfolio parameters are automatically established by the tool and resubmitted to the user in a representable form for further analysis. Therefore, “current projects” of the company including “potential projects” to be undertaken are presented within different possible portfolio scenarios that can be selected by management level professionals following the analysis. Considering the presented functions, the tool can provide support for either revealing the current portfolio or selecting a new project/portfolio with its ability to display portfolios. The overall method can be utilized for identification of critical measures in the portfolio together with reasoning between portfolio alternatives created with different “potential projects”. The tool offers a considerable support for identifying the critical dependencies between the projects within a portfolio and evaluating the different scenarios generated based on various attributes including the project dependencies. It integrates dependency analysis to portfolio analysis where its users can measure dependencies between projects for different purposes such as risk assessment, resource planning, assessment of project/portfolio complexity, etc. The tool also guides the user for management of a specific portfolio or selection of portfolios by the warnings based on past project knowledge and some specific project/portfolio properties. Accordingly, the user has possibility of analyzing the projects within a portfolio by considering available knowledge and effects of the projects to each other, while utilizing available resources in accordance with the company capabilities. Thus, it is expected that these companies can use their knowledge to demonstrate a sense of management in the direction of their strategies, and indirectly to make production and resource management processes more productive. Considering the presented focus of the tool, COPPMAN has a potential to make construction companies select their projects from a portfolio point of view and adopt portfolio management principles. It is believed that the developed tool can be an innovative application especially for medium to large-sized construction companies operating in international markets and having to manage large portfolios. Utilization of the proposed method and the tool may help development and management of successful project portfolios and the companies, which are more focused on project management in the present situation, can gain a portfolio management perspective. Thus, utilization of the tool may provide companies to acquire and use their knowledge to manage their portfolios in accordance with the strategies, which may further provide efficient construction and resource management. In this way, it may be possible for companies to gain competitive advantage in the increasingly competitive construction industry by selection of the right projects/portfolio for the company and effective management as well. The tool process and design may also be adapted to other project-based sectors, since they include an easy to follow project-based procedure and have an originality in integration of dependency assessment and knowledge management to portfolio management.

8.4. Recommendations for Future Studies

As a drawback of COPPMAN, it provides warnings on resource management; however, lacks a complete “resource management system”, which may be included in the further studies on the tool. Additionally, integration of “schedule” of projects to the process may also provide an automatized update in “dependencies” and “risk levels” of the projects/portfolios. Clustering analysis may be integrated to identify the “attribute similarities” and “country grouping”, which are subjectively assessed and manually assigned by the users currently. Portfolio selection is based on evaluation of measures separately, therefore a means that would unify the overall evaluation such as integration of “multi-criteria decision-making or optimization methods” to increase decision support ability of COPPMAN. “Knowledge of portfolio selection” may also be integrated as a mechanism where capturing and presenting the data of “portfolio selection histories” to support analysis of “portfolio performance” are provided. The study also highlighted the potential of “adaption of overall process/architecture to different project-based sectors” with minor changes due to its easy-to-follow and project-based process.

8.5. Concluding Remarks

A portfolio management tool for construction projects has been generated according to literature review and with the help of company professionals to respond to the current need in the industry for management of simultaneous projects as portfolios. Testing for its usability and a real application process in a construction company have appreciated the current benefits of the tool while revealing the further considerations for its improvement. Adoption of the tool by construction companies and its actual utilization in management processes may reveal potential improvements required for maximizing its benefits for effective management of portfolios as well as strategic management of companies. This version of the tool is believed to serve as a benchmark for development of any further studies in the construction industry and in other project-based industries as well.

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APPENDIX A

A. SURVEY 1 - NEEDS ANALYSIS

Practitioner Information
Title:
Education:
Experience:
Use of Company Specific Tools:
Knowledge in Information Technology: High / Medium / Low
Knowledge in Portfolio Management: High / Medium / Low
Form Outline
Open-Ended Questions
In this section you are asked to evaluate current practices of your organization regarding portfolio management.

OPEN-ENDED QUESTIONS

- Please indicate your "portfolio management" perspective (its aim, functions etc.). How do you define "portfolio management"?

- What should a construction organization do to establish a portfolio management system? What kind of framework is required for establishing a portfolio management system?

- Please indicate your current practices in your organization regarding "portfolio management". Please briefly explain whether you have tools, specific reporting mechanisms etc. to support portfolio management? What are the limitations/rooms for improvement of the current practices, if any?

- If there is a requirement for a specific "portfolio management" tool/decision support system, what should be the basic functions/capabilities of the tool?

APPENDIX B

B. SURVEY 2 - INITIAL REQUIREMENTS

Practitioner Information
Title:
Education:
Experience:
Use of Company Specific Tools:
Knowledge in Information Technology: High / Medium / Low
Knowledge in Portfolio Management: High / Medium / Low
Form Outline
Ratings
In this section you are asked to evaluate the initial requirements of a portfolio management tool for construction organizations regarding its: 1. Need 2. Processes 3. Requirements by indicating the ratings to the provided statements.

EVALUATION OF INITIAL REQUIREMENTS

In this section you are asked to evaluate the requirements of establishment of portfolio management initiatives in construction companies.

RATING SCALE

1	2	3	4	5	6	7
Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
(DDD)	**(DD)**	**(D)**	**(N)**	**(A)**	**(AA)**	**(AAA)**

For each statement given below, circle the number to the right that best fits your level of agreement. Use the rating scale to select the number.

Statement	**Scale**						
	DDD	**DD**	**D**	**N**	**A**	**AA**	**AAA**
1. There is lack of an appropriate portfolio management framework and tools in construction companies.	1	2	3	4	5	6	7
2. Portfolio management process needs to be established/re-engineered.	1	2	3	4	5	6	7
3. The established system needs to be IT supported.	1	2	3	4	5	6	7
4. Development of a portfolio management tool for construction organizations is required.	1	2	3	4	5	6	7
5. Portfolio management tool for construction projects should handle dependencies between projects.	1	2	3	4	5	6	7
6. Portfolio management tool for construction projects should support strategic choices.	1	2	3	4	5	6	7
7. Portfolio management tool for construction projects should support project selection decisions.	1	2	3	4	5	6	7
8. Portfolio management tool for construction projects should support resource allocation decisions.	1	2	3	4	5	6	7
9. Portfolio management tool for construction projects should support balancing the projects and resources/capabilities.	1	2	3	4	5	6	7
10. Portfolio management tool for construction projects should incorporate past project data into portfolio analysis.	1	2	3	4	5	6	7
11. Portfolio management tool for construction projects should incorporate risk assessment into portfolio analysis.	1	2	3	4	5	6	7
12. Portfolio management tool for construction projects should enable visualization of portfolios.	1	2	3	4	5	6	7
13. Portfolio management tool for construction projects should be flexible and dynamic.	1	2	3	4	5	6	7
14. Portfolio management for construction projects should be intelligent and should provide advice/warnings about portfolio decisions.	1	2	3	4	5	6	7

APPENDIX C

C. SURVEY 3 - FUNCTIONAL REQUIREMENTS

Development of an IT-Based Tool for Portfolio Assessment and Management for Construction Companies
Voluntary Participation Form
This survey has been developed within the context of a research project titled "Development of an IT-Based Tool for Portfolio Assessment and Management for Construction Companies" supported by Scientific and Technological Research Council of Turkey (TUBITAK). The information that will be gathered through this survey will be used in scientific publications. Completion of the survey will take approximately 10-15 minutes. Thank you in advance for your participation. For more information about the study, please contact Gozde Bilgin (Room: K1407; Tel: 0 312 210 7483; Email: gbilgin@metu.edu.tr) and Gorkem Eken (Room: K1407; Tel: 0 312 210 7483; Email: eken@metu.edu.tr) as the research assistants of Middle East Technical University, Department of Civil Engineering, Construction Engineering and Management Division or contact Beste Ozyurt (Room: K1407; Tel: 0 312 210 7483; Email: besteozyurt@gmail.com) as the project assistant. Project Management Team: Prof. Dr. Irem Dikmen Toker, METU Assoc. Dr. Beliz Ozorhon Orakcal, Bogazici University Prof. Dr. M. Talat Birgonul, METU It is important that you complete the work in one session and without interruption. I'm participating totally voluntarily to this work and I know that I can leave the survey when I want. I agree that the information I provide can be used in scientific publications. ☐ No ☐ Yes

Personal Information

Education: ☐ PhD ☐ MSc ☐ BSc

Title:

Professional Experience:
- ☐ 0-5 years
- ☐ 6-10 years
- ☐ 11-15 years
- ☐ 16-20 years
- ☐ 21 years and more

Annual return of the company that you have been currently working for:
- ☐ 0-100 million TL
- ☐ 100-500 million TL
- ☐ 500 million TL and more

Fields of activity of the company (you can select more than one option):
- ☐ Housing
- ☐ Commercial buildings (hotel, shopping center, etc.)
- ☐ State buildings (school, dormitory, etc.)
- ☐ Transportation structures
- ☐ Energy structures (HEPP, energy transmission lines, etc.)
- ☐ Water structures (dam, irrigation, etc.)
- ☐ Industrial plants (factory, etc.)
- ☐ Other

Type of the company:	Age of the company:
☐ Contractor	☐ 0-10 years
☐ Client / Investor	☐ 11-20 years
☐ Design / Project company	☐ 21-30 years
☐ Consultancy firm	☐ 31-40 years
☐ Other	☐ 41 years and more

Portfolio is “*a component collection of programs, projects, or operations managed as a group to achieve strategic objectives*” (Project Management Institute, 2013). Project portfolio management is “*The centralized management of one or more portfolios, which includes identifying, prioritizing, authorizing, managing, and controlling projects, programs, and other related work to achieve specific strategic business objectives*” (Project Management Institute, 2008).

What level of knowledge / experience do you have about "Portfolio Management"?

☐ Low ☐ Medium ☐ High

Aim of the Study

The aim of the study is to develop a portfolio management tool for construction projects.

One of the main functions of the portfolio management tool is to create a “portfolio value” for each new project that reflects the contribution of the project to the portfolio. When the portfolio value is calculated, project’s

1. contribution to strategic objectives, and
2. impact on change in portfolio risk

will be evaluated.

In this context, the survey contains questions about the strategic objectives (Section 1) and the risk assessment (Section 2) sections. In addition, there is also a section (Section 3) to investigate similarities between the project candidate and the past projects to ensure that the tool is able to learn from the past projects. Within this contexts sections are provided for evaluation as:

1. Section 1: Strategic Objectives
2. Section 2: Risk Assessment
3. Section 3: Similarity Assessment

EVALUATION SCALE

You are asked to evaluate the importance/effectiveness of the following identified factors in each section.

RATING SCALE

1	2	3	4	5
Not at all Important / Effective	Slightly Important / Effective	Important / Effective	Fairly Important / Effective	Very Important / Effective
(NI / NE)	**(SI / SE)**	**(I / E)**	**(FI / FE)**	**(VI / VE)**

For each statement given in the below sections, circle the number to the right that best fits your consideration. Use the rating scale to select the number.

SECTION 1: STRATEGIC OBJECTIVES					
Section 1.1: Importance of Strategic Objectives					
What is the level of importance of the following strategic objectives while determining the importance / value of a new project for the portfolio?					
Strategic Objective	**Scale**				
	NI	**SI**	**I**	**FI**	**VI**
1. Maximization of Short Term Profitability	1	2	3	4	5
2. Maximization of Long Term Profitability	1	2	3	4	5
3. Gaining Reputation	1	2	3	4	5
4. Achievement of Learning / Gaining Experience	1	2	3	4	5
5. Risk Minimization	1	2	3	4	5
6. Entering New Markets	1	2	3	4	5
7. Other: *please indicate and rate*	1	2	3	4	5
Section 1.2: Learning Potential					
Contribution of a project to the learning potential of the company is important. Please evaluate the potential for creation of learning opportunity of the following factors.					
Factor	**Scale**				
	NI	**SI**	**I**	**FI**	**VI**
1. To enter a new country	1	2	3	4	5
2. To gain experience in a new project type	1	2	3	4	5
3. To work with a new client	1	2	3	4	5
4. To use a new construction technology	1	2	3	4	5
5. To work with a new contract type	1	2	3	4	5
6. To work with a new project delivery system (design-build, build-operate-transfer, etc.)	1	2	3	4	5
7. To work with a new project partner	1	2	3	4	5
8. Other: *please indicate and rate*	1	2	3	4	5

SECTION 2: RISK ASSESSMENT					
Section 2.1: Effect of the Risk Factors					
How much the following risk factors may affect a construction project (in terms of duration, cost) in case of their occurrence?					
Risk Factor	**Scale**				
	NE	**SE**	**E**	**FE**	**VE**
1. Economic risk (changes in exchange rates, cash flow risk, inflation, etc.)	1	2	3	4	5
2. Political risks (changes in government, changes in international relations, etc.)	1	2	3	4	5
3. Technical risks (delays due to technical problems, etc.)	1	2	3	4	5
4. Resource risk (risks due to quality/availability of material, manpower, machinery and equipment, etc.)	1	2	3	4	5
5. Design risk (deficiency/changes in design, etc.)	1	2	3	4	5
6. Contractual risk (ambiguity in conditions, insufficient definitions, strict requirements/constraints, etc.)	1	2	3	4	5
7. Owner initiated risks (insufficient experience, delays in payments, etc.)	1	2	3	4	5
8. Bureaucratic risks (delays in permissions, etc.)	1	2	3	4	5
9. Project management risks (poor planning, insufficient experience, etc.)	1	2	3	4	5
10. Risks due to weather conditions	1	2	3	4	5
11. Risks due to ground conditions	1	2	3	4	5
12. Environmental risks (social and environmental factors)	1	2	3	4	5
13. Other: *please indicate and rate*	1	2	3	4	5

Section 2.2: Project Dependencies					
Section 2.2.1: Importance of Project Dependencies Each new project will impact portfolio risk. Relationships between the projects should be considered when calculating the portfolio risk. When calculating the portfolio risk, which of the dependencies between the projects would be more important?					
Project Dependency	**Scale**				
	NI	**SI**	**I**	**FI**	**VI**
1. Financial Dependency	1	2	3	4	5
2. Resource Dependency	1	2	3	4	5
3. Learning Dependency	1	2	3	4	5
4. Outcome Dependency	1	2	3	4	5

SECTION 2: RISK ASSESSMENT

Section 2.2: Project Dependencies

Section 2.2.2: Measurement of Project Dependencies

In the course of measuring the dependencies, the following factors will be considered as how much the factors are matching for each project pair. What are the importance of the following factors in measuring financial and resource dependencies?

Factor for Financial Dependency	Scale				
	NI	**SI**	**I**	**FI**	**VI**
1. Client	1	2	3	4	5
2. Currency	1	2	3	4	5

Factor for Resource Dependency	Scale				
	NI	**SI**	**I**	**FI**	**VI**
1. Construction Materials	1	2	3	4	5
2. Critical Machinery and Equipment	1	2	3	4	5
3. Manpower	1	2	3	4	5
4. Qualified Personnel (Project Management)	1	2	3	4	5

SECTION 3: SIMILARITY ASSESSMENT

Similarities between the projects will be used to make predictions for new projects by using completed project information. Evaluate the significance of the following criteria for measuring the similarity of two projects.

Criterion	Scale				
	NI	**SI**	**I**	**FI**	**VI**
1. Being in the same / similar country	1	2	3	4	5
2. Same / similar project type (housing, infrastructure, etc.)	1	2	3	4	5
3. Having the same / similar client	1	2	3	4	5
4. Use of the same construction technology	1	2	3	4	5
5. Having the same contract type	1	2	3	4	5
6. Other: *please indicate and rate*	1	2	3	4	5

APPENDIX D

D. SURVEY 4 - MODEL DETAILS

Practitioner Information
Title:
Education:
Experience:
Use of Company Specific Tools:
Knowledge in Information Technology: High / Medium / Low
Knowledge in Portfolio Management: High / Medium / Low
Form Outline
Section 1 – Open-Ended Questions
In this section you are asked to evaluate the prototype of the proposed portfolio management tool (COPPMAN).
Section 2 – Ratings
In this section you are asked to evaluate the initial design of the tool through its "modules" and the "requirements specification" of COPPMAN under sections of: 1. Modules 2. Requirements/Features Specification by indicating the ratings to the provided statements for each section.

SECTION 1 – OPEN-ENDED QUESTIONS

- Please indicate your general comments about the prototype. What did you like most?

- What is the major shortcoming/weakness of the model? Please indicate any consideration that needs to be changed in the model or be added to the model.

SECTION 2: RATINGS

SECTION 2.1: EVALUATION OF THE MODULES

In this section you are asked to evaluate how much the modules of the tool are adequate to meet the proposed system requirements:

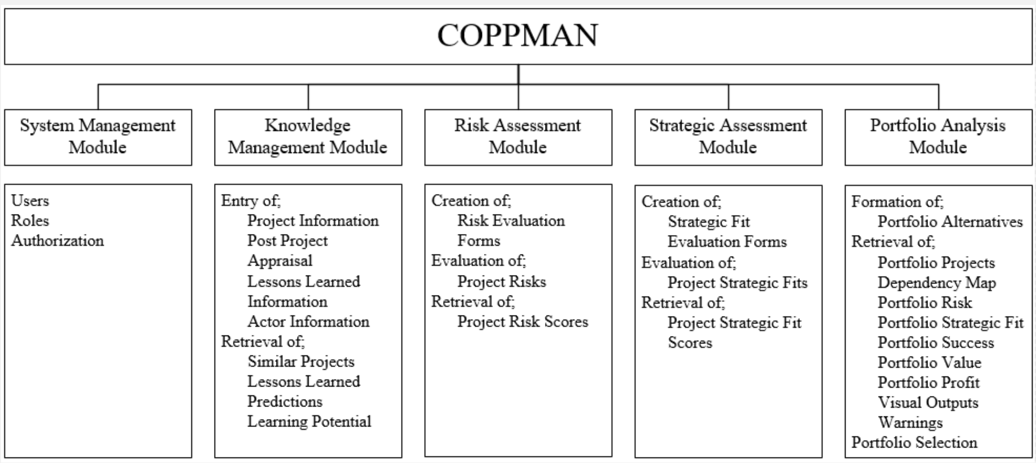
- **System Management Module:** is required to establish a user management system including defining specific roles, users and their authorization to support establishment of a system to successfully utilize the tool.

- **Knowledge Management Module:** encapsulates the requirements for managing both explicit and tacit knowledge in terms of post project information and lessons learned from projects. Various data retrieval options are to be provided as predictions for specific project (based on post project review information) and related lessons learned. Further information of similar projects and learning potential of each project are to be provided for investigation before assessment of projects.

- **Risk Assessment Module:** provides customizable risk evaluation forms to assess risk of each project, and these risk scores would be further utilized in portfolio risk. Risk evaluation histories of projects would also be kept for evaluation upon request and a system for keeping risk evaluations up-to-date at the time of analysis would also be included.

- **Strategic Assessment Module:** provides customizable strategic fit evaluation forms to assess strategic fit of each project, and these strategic fit scores would be further utilized in portfolio strategic fit as in risk assessment module. Strategic fit evaluation histories of projects would also be kept for evaluation upon request.

- **Portfolio Analysis Module:** enables automatic formation of portfolios. Following this, project and portfolio properties together with dependency maps of each portfolio would be presented through tables, bubble diagrams and bar charts, together with warnings on portfolios upon either selection or management of portfolios.



SECTION 2: RATINGS

SECTION 2.1: EVALUATION OF THE MODULES

RATING SCALE

1	2	3	4	5	6	7
Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
(DDD)	**(DD)**	**(D)**	**(N)**	**(A)**	**(AA)**	**(AAA)**

For each statement given below, circle the number to the right that best fits your level of agreement. Use the rating scale to select the number.

Statement	Scale						
	DDD	**DD**	**D**	**N**	**A**	**AA**	**AAA**
1. The structure of the “system management module” is adequate for a construction project portfolio management tool.	1	2	3	4	5	6	7
2. The structure of the “knowledge management module” is adequate for a construction project portfolio management tool.	1	2	3	4	5	6	7
3. The structure of the “risk assessment module” is adequate for a construction project portfolio management tool.	1	2	3	4	5	6	7
4. The structure of the “strategic assessment module” is adequate for a construction project portfolio management tool.	1	2	3	4	5	6	7
5. The structure of the “portfolio analysis module” is adequate for a construction project portfolio management tool.	1	2	3	4	5	6	7

SECTION 2: RATINGS

SECTION 2.2: EVALUATION OF THE REQUIREMENTS/FEATURES SPECIFICATION

RATING SCALE

1	2	3	4	5	6	7
Strongly Disagree **(DDD)**	Disagree **(DD)**	Somewhat Disagree **(D)**	Neither Agree nor Disagree **(N)**	Somewhat Agree **(A)**	Agree **(AA)**	Strongly Agree **(AAA)**

For each statement given below, circle the number to the right that best fits your level of agreement. Use the rating scale to select the number.

Statement		**Scale**						
		DDD	**DD**	**D**	**N**	**A**	**AA**	**AAA**
1.	Identification of different users in tool with different accessibility options to the tool menu/operations is an important feature	1	2	3	4	5	6	7
2.	Menu for entry of different types of projects, together with view and query options is an important feature	1	2	3	4	5	6	7
3.	Identification of ready-to-use project inputs is an important feature	1	2	3	4	5	6	7
4.	Calculation and presentation of predictions for the on-going and potential projects through use of information of completed projects is an important feature	1	2	3	4	5	6	7
5.	Menu for entry of lessons learned, together with view and query options is an important feature	1	2	3	4	5	6	7
6.	Tagging system for entry of lessons learned, including editing options for the tag tree and tag-based query is an important feature	1	2	3	4	5	6	7
7.	Calculation and presentation of learning potentials for the on-going and potential projects is an important feature	1	2	3	4	5	6	7
8.	Establishment of project similarity based search and calculation capabilities is an important feature	1	2	3	4	5	6	7
9.	Establishment of filtering based search and calculation capabilities is an important feature	1	2	3	4	5	6	7
10.	Menu for evaluation of risk and strategic fit factors, including editing of the factors and calculation of scores is an important feature	1	2	3	4	5	6	7
11.	Calculation of dependencies between projects and visualization of dependencies with a dependency map is an important feature	1	2	3	4	5	6	7
12.	Development of a project representation to be used in visualizations is an important feature	1	2	3	4	5	6	7
13.	Automatic formation of the portfolio alternatives through addition of potential project combinations to on-going projects is an important feature	1	2	3	4	5	6	7
14.	Calculation of portfolio attributes and depiction of results through tables, bubble diagrams and bar charts is an important feature	1	2	3	4	5	6	7
15.	Establishment of an automatic warning system for current portfolios is an important feature	1	2	3	4	5	6	7

APPENDIX E

E. SURVEY 5 - EXPERT EVALUATION

Expert Information
Title:
Education:
Experience:
Use of Company Specific Tools:
Knowledge in Information Technology: High / Medium / Low
Knowledge in Portfolio Management: High / Medium / Low
Form Outline
Section 1 – Ratings
Within this evaluation form you are asked to evaluate the tool in six sections in terms of: 1. Completeness / Coverage 2. Suitability / Accuracy 3. Usefulness 4. Usability 5. Receptiveness 6. Overall by indicating the ratings to the provided statements for each section.
Section 2 – Open-Ended Questions
Following the rating process, you will be provided open-ended evaluation section.

SECTION 1: RATINGS

SECTION 1.1: COMPLETENESS / COVERAGE

In this section you are asked to evaluate how much the sections of the tool are complete or cover all the related information.

RATING SCALE

1	2	3	4	5	6	7
Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
(DDD)	**(DD)**	**(D)**	**(N)**	**(A)**	**(AA)**	**(AAA)**

For each statement given below, circle the number to the right that best fits your level of agreement. Use the rating scale to select the number.

	Statement	Scale						
		DDD	**DD**	**D**	**N**	**A**	**AA**	**AAA**
1.	The identified project attributes for entry are adequate for codification of information for different kind of projects.	1	2	3	4	5	6	7
2.	The identified dependencies are adequate for presentation of dependencies between projects.	1	2	3	4	5	6	7
3.	The identified attributes for calculation of dependencies are adequate for quantification of dependencies between projects.	1	2	3	4	5	6	7
4.	The identified attributes for similarity calculation are adequate for quantification of similarities between projects.	1	2	3	4	5	6	7
5.	The identified attributes for learning potential calculation are adequate for quantification of learning potentials of projects.	1	2	3	4	5	6	7
6.	The identified project attributes for post project appraisal are adequate for codification of information for project evaluation.	1	2	3	4	5	6	7
7.	The identified lesson learned attributes for entry are adequate for codification of knowledge accumulated during course of projects.	1	2	3	4	5	6	7
8.	The calculated predictions according to the captured information are adequate for presenting expectations for a project under evaluation.	1	2	3	4	5	6	7
9.	The supportive information content provided for investigation as a reference before risk and strategic fit assessments is adequate.	1	2	3	4	5	6	7
10.	The portfolio analysis results and graphs are adequate to display information regarding a project or portfolio under evaluation.	1	2	3	4	5	6	7
11.	The library is adequate to provide help and present glossary.	1	2	3	4	5	6	7
12.	The feedback mechanism provided in the tool is adequate.	1	2	3	4	5	6	7
13.	The identified filtering attributes are adequate.	1	2	3	4	5	6	7
14.	The provided warnings are adequate.	1	2	3	4	5	6	7

SECTION 1: RATINGS

SECTION 1.2: SUITABILITY / ACCURACY

In this section you are asked to evaluate how much the sections of the tool are suitable or accurate to perform the intended operation.

RATING SCALE

1	2	3	4	5	6	7
Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
(DDD)	**(DD)**	**(D)**	**(N)**	**(A)**	**(AA)**	**(AAA)**

For each statement given below, circle the number to the right that best fits your level of agreement. Use the rating scale to select the number.

Statement	Scale						
	DDD	**DD**	**D**	**N**	**A**	**AA**	**AAA**
1. The proposed project symbol in the project card is representative in condition of a project under evaluation at a glance.	1	2	3	4	5	6	7
2. The proposed dependency calculation process is suitable for calculating dependencies between projects.	1	2	3	4	5	6	7
3. The proposed similarity calculation process is suitable for indicating similarities between projects.	1	2	3	4	5	6	7
4. The proposed prediction calculations are suitable for presenting expectations for a project.	1	2	3	4	5	6	7
5. The proposed learning potential calculation is suitable for reflecting learning potential of a project.	1	2	3	4	5	6	7
6. The provided capacity for potential project limit as four is enough for a construction company for evaluating project alternatives at one analysis.	1	2	3	4	5	6	7
7. The proposed portfolio risk evaluation process (including effect of project dependencies) is suitable for handling risks at portfolio level considering the dependencies of projects.	1	2	3	4	5	6	7
8. The proposed portfolio value calculation process is suitable for evaluation of different portfolio alternatives.	1	2	3	4	5	6	7
9. The proposed project and portfolio property calculations are suitable for indication of properties of projects and portfolios.	1	2	3	4	5	6	7
10. The proposed portfolio selection process is suitable for selection of right project alternatives.	1	2	3	4	5	6	7
11. The warning limits and calculations provided for selection and management of portfolios are suitable.	1	2	3	4	5	6	7
12. The proposed tool environment is suitable for supporting a knowledge management system that enables online information submission from different users.	1	2	3	4	5	6	7

SECTION 1: RATINGS

SECTION 1.3: USEFULNESS

In this section you are asked to evaluate how much the sections of the tool are useful; namely please evaluate the sections in terms of ease of understanding, ease of use and practical applicability in actions of construction managers in portfolio management.

RATING SCALE

1	2	3	4	5	6	7
Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
(DDD)	**(DD)**	**(D)**	**(N)**	**(A)**	**(AA)**	**(AAA)**

For each statement given below, circle the number to the right that best fits your level of agreement. Use the rating scale to select the number.

Statement	**Scale**						
	DDD	**DD**	**D**	**N**	**A**	**AA**	**AAA**
1. It is useful for construction managers to capture project knowledge in terms of post project appraisal and live capture of lessons learned as it is provided in the tool.	1	2	3	4	5	6	7
2. It is useful for construction managers to visualize dependency information of projects through a dependency map as it is provided in the tool.	1	2	3	4	5	6	7
3. It is useful for construction managers to visualize portfolio analysis results through bubble and bar chart diagrams as it is provided in the tool.	1	2	3	4	5	6	7
4. It is useful for construction managers to get warnings while decision-making process as it is provided in the tool.	1	2	3	4	5	6	7
5. It is useful for construction managers to print out visual diagrams and dependency matrix as it is provided in the tool.	1	2	3	4	5	6	7

SECTION 1: RATINGS

SECTION 1.4: USABILITY

In this section you are asked to evaluate how much the tool is usable; namely please evaluate the tool in terms of ease of learning, customizability, calibrability, and interoperability.

RATING SCALE

1	2	3	4	5	6	7
Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
(DDD)	**(DD)**	**(D)**	**(N)**	**(A)**	**(AA)**	**(AAA)**

For each statement given below, circle the number to the right that best fits your level of agreement. Use the rating scale to select the number.

Statement	**Scale**						
	DDD	**DD**	**D**	**N**	**A**	**AA**	**AAA**
1. The proposed tool provides ease of learning since it ensures uniformity and consistency in system interactions and tool interfaces.	1	2	3	4	5	6	7
2. The proposed tool provides ease of learning since it includes feedback mechanism and library as help menu.	1	2	3	4	5	6	7
3. The proposed tool provides customizability through user preferences menu since it provides definition of company specific evaluation systems and user management.	1	2	3	4	5	6	7
4. The proposed tool provides calibrability through project inputs menu since it provides flexibility in definition of company specific attributes and weights.	1	2	3	4	5	6	7
5. The proposed tool provides interoperability since it operates in most of the web browsers and operating systems, and provides printable outputs.	1	2	3	4	5	6	7
6. The proposed tool provides usability since it is generated in two languages.	1	2	3	4	5	6	7
7. The proposed tool provides usability since it enables selection of predefined attributes and recall of entries with keyword search.	1	2	3	4	5	6	7
8. The proposed tool provides usability since it is generated as a web based tool.	1	2	3	4	5	6	7
9. The proposed tool has a user-friendly interface.	1	2	3	4	5	6	7

SECTION 1: RATINGS

SECTION 1.5: RECEPTIVENESS

In this section you are asked to evaluate how much the tool is likely to be used.

RATING SCALE

1	2	3	4	5	6	7
Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
(DDD)	**(DD)**	**(D)**	**(N)**	**(A)**	**(AA)**	**(AAA)**

For each statement given below, circle the number to the right that best fits your level of agreement. Use the rating scale to select the number.

Statement	**Scale**						
	DDD	**DD**	**D**	**N**	**A**	**AA**	**AAA**
1. A need exists to integrate project portfolio management thinking as a tool into construction management literature.	1	2	3	4	5	6	7
2. The proposed tool would enhance adaptation of construction project portfolio management.	1	2	3	4	5	6	7
3. The proposed tool would improve knowledge management.	1	2	3	4	5	6	7
4. The proposed tool would improve project management.	1	2	3	4	5	6	7
5. The proposed tool is implementable in my company.	1	2	3	4	5	6	7

SECTION 1: RATINGS

SECTION 1.6: OVERALL

In this section you are asked to evaluate the tool in overall.

RATING SCALE

1	2	3	4	5	6	7
Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
(DDD)	**(DD)**	**(D)**	**(N)**	**(A)**	**(AA)**	**(AAA)**

For each statement given below, circle the number to the right that best fits your level of agreement. Use the rating scale to select the number.

Statement	Scale						
	DDD	**DD**	**D**	**N**	**A**	**AA**	**AAA**
1. My overall impression about the tool is positive.	1	2	3	4	5	6	7
2. Methodology undertaken during construction of the tool is reliable.	1	2	3	4	5	6	7
3. The proposed tool provides reasonable level of robustness in case of unexpected action of the user through limitations in data entry, given feedbacks, and the use of back button of the web browser as undo.	1	2	3	4	5	6	7
4. The proposed tool provides reasonable level of dependability since it would be accessible as long as the server and domain are available.	1	2	3	4	5	6	7
5. The proposed tool provides reasonable level of security since it provides confidentiality and authentication through definition of different user accounts with different accessibility options protected under passwords.	1	2	3	4	5	6	7
6. The proposed tool requires reasonable response time (latency) for user actions and analyses.	1	2	3	4	5	6	7
7. The interface of the tool is successful since it is clear, coherent and concise.	1	2	3	4	5	6	7

SECTION 2 – OPEN-ENDED QUESTIONS

- Please indicate your general comments about the tool. What did you like most? What did not you like most?

- Please indicate any item/property that needs to be changed in the tool or be added to the tool.

APPENDIX F

F. SURVEY 6 - PILOT TESTING

Company Professional Information
Title:
Education:
Experience:
Use of Company Specific Tools:
Knowledge in Information Technology: High / Medium / Low
Knowledge in Portfolio Management: High / Medium / Low
Form Outline
Section 1 – Ratings
Within this evaluation form you are asked to evaluate the tool in six sections in terms of: 1. Completeness / Coverage 2. Suitability / Accuracy 3. Usefulness 4. Usability 5. Receptiveness 6. Overall by indicating the ratings to the provided statements for each section.
Section 2 – Open-Ended Questions
Following the rating process, you will be provided open-ended evaluation section.

SECTION 1: RATINGS

SECTION 1.1: COMPLETENESS / COVERAGE

In this section you are asked to evaluate how much the sections of the tool are complete or cover all the related information.

RATING SCALE

1	2	3	4	5	6	7
Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
(DDD)	**(DD)**	**(D)**	**(N)**	**(A)**	**(AA)**	**(AAA)**

For each statement given below, circle the number to the right that best fits your level of agreement. Use the rating scale to select the number.

	Statement	Scale: DDD	DD	D	N	A	AA	AAA
1.	The identified project attributes for entry are adequate for codification of information for different kind of projects.	1	2	3	4	5	6	7
2.	The identified dependencies are adequate for presentation of dependencies between projects.	1	2	3	4	5	6	7
3.	The identified attributes for calculation of dependencies are adequate for quantification of dependencies between projects.	1	2	3	4	5	6	7
4.	The identified attributes for similarity calculation are adequate for quantification of similarities between projects.	1	2	3	4	5	6	7
5.	The identified attributes for learning potential calculation are adequate for quantification of learning potentials of projects.	1	2	3	4	5	6	7
6.	The identified project attributes for post project appraisal are adequate for codification of information for project evaluation.	1	2	3	4	5	6	7
7.	The identified lesson learned attributes for entry are adequate for codification of knowledge accumulated during course of projects.	1	2	3	4	5	6	7
8.	The calculated predictions according to the captured information are adequate for presenting expectations for a project under evaluation.	1	2	3	4	5	6	7
9.	The supportive information content provided for investigation as a reference before risk and strategic fit assessments is adequate.	1	2	3	4	5	6	7
10.	The portfolio analysis results and graphs are adequate to display information regarding a project or portfolio under evaluation.	1	2	3	4	5	6	7
11.	The library is adequate to provide help and present glossary.	1	2	3	4	5	6	7
12.	The feedback mechanism provided in the tool is adequate.	1	2	3	4	5	6	7
13.	The identified filtering attributes are adequate.	1	2	3	4	5	6	7
14.	The provided warnings are adequate.	1	2	3	4	5	6	7

SECTION 1: RATINGS

SECTION 1.2: SUITABILITY / ACCURACY

In this section you are asked to evaluate how much the sections of the tool are suitable or accurate to perform the intended operation.

RATING SCALE

1	2	3	4	5	6	7
Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
(DDD)	**(DD)**	**(D)**	**(N)**	**(A)**	**(AA)**	**(AAA)**

For each statement given below, circle the number to the right that best fits your level of agreement. Use the rating scale to select the number.

Statement	Scale						
	DDD	**DD**	**D**	**N**	**A**	**AA**	**AAA**
1. The proposed project symbol in the project card is representative in condition of a project under evaluation at a glance.	1	2	3	4	5	6	7
2. The proposed dependency calculation process is suitable for calculating dependencies between projects.	1	2	3	4	5	6	7
3. The proposed similarity calculation process is suitable for indicating similarities between projects.	1	2	3	4	5	6	7
4. The proposed prediction calculations are suitable for presenting expectations for a project.	1	2	3	4	5	6	7
5. The proposed learning potential calculation is suitable for reflecting learning potential of a project.	1	2	3	4	5	6	7
6. The provided capacity for potential project limit as four is enough for a construction company for evaluating project alternatives at one analysis.	1	2	3	4	5	6	7
7. The proposed portfolio risk evaluation process (including effect of project dependencies) is suitable for handling risks at portfolio level considering the dependencies of projects.	1	2	3	4	5	6	7
8. The proposed portfolio value calculation process is suitable for evaluation of different portfolio alternatives.	1	2	3	4	5	6	7
9. The proposed project and portfolio property calculations are suitable for indication of properties of projects and portfolios.	1	2	3	4	5	6	7
10. The proposed portfolio selection process is suitable for selection of right project alternatives.	1	2	3	4	5	6	7
11. The warning limits and calculations provided for selection and management of portfolios are suitable.	1	2	3	4	5	6	7
12. The proposed tool environment is suitable for supporting a knowledge management system that enables online information submission from different users.	1	2	3	4	5	6	7

SECTION 1: RATINGS

SECTION 1.3: USEFULNESS

In this section you are asked to evaluate how much the sections of the tool are useful; namely please evaluate the sections in terms of ease of understanding, ease of use and practical applicability in actions of construction managers in portfolio management.

RATING SCALE

1	2	3	4	5	6	7
Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
(DDD)	**(DD)**	**(D)**	**(N)**	**(A)**	**(AA)**	**(AAA)**

For each statement given below, circle the number to the right that best fits your level of agreement. Use the rating scale to select the number.

Statement	Scale						
	DDD	**DD**	**D**	**N**	**A**	**AA**	**AAA**
1. It is useful for construction managers to capture project knowledge in terms of post project appraisal and live capture of lessons learned as it is provided in the tool.	1	2	3	4	5	6	7
2. It is useful for construction managers to visualize dependency information of projects through a dependency map as it is provided in the tool.	1	2	3	4	5	6	7
3. It is useful for construction managers to visualize portfolio analysis results through bubble and bar chart diagrams as it is provided in the tool.	1	2	3	4	5	6	7
4. It is useful for construction managers to get warnings while decision-making process as it is provided in the tool.	1	2	3	4	5	6	7
5. It is useful for construction managers to print out visual diagrams and dependency matrix as it is provided in the tool.	1	2	3	4	5	6	7

SECTION 1: RATINGS

SECTION 1.4: USABILITY

In this section you are asked to evaluate how much the tool is usable; namely please evaluate the tool in terms of ease of learning, customizability, calibrability, and interoperability.

RATING SCALE

1	2	3	4	5	6	7
Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
(DDD)	**(DD)**	**(D)**	**(N)**	**(A)**	**(AA)**	**(AAA)**

For each statement given below, circle the number to the right that best fits your level of agreement. Use the rating scale to select the number.

	Statement	**Scale**						
		DDD	**DD**	**D**	**N**	**A**	**AA**	**AAA**
1.	The proposed tool provides ease of learning since it ensures uniformity and consistency in system interactions and tool interfaces.	1	2	3	4	5	6	7
2.	The proposed tool provides ease of learning since it includes feedback mechanism and library as help menu.	1	2	3	4	5	6	7
3.	The proposed tool provides customizability through user preferences menu since it provides definition of company specific evaluation systems and user management.	1	2	3	4	5	6	7
4.	The proposed tool provides calibrability through project inputs menu since it provides flexibility in definition of company specific attributes and weights.	1	2	3	4	5	6	7
5.	The proposed tool provides interoperability since it operates in most of the web browsers and operating systems, and provides printable outputs.	1	2	3	4	5	6	7
6.	The proposed tool provides usability since it is generated in two languages.	1	2	3	4	5	6	7
7.	The proposed tool provides usability since it enables selection of predefined attributes and recall of entries with keyword search.	1	2	3	4	5	6	7
8.	The proposed tool provides usability since it is generated as a web based tool.	1	2	3	4	5	6	7
9.	The proposed tool has a user-friendly interface.	1	2	3	4	5	6	7
10.	Navigation through the tool was easy.	1	2	3	4	5	6	7
11.	I was satisfied with the amount of time I spent for completing the operations and easiness of the operations.	1	2	3	4	5	6	7
12.	I am satisfied with the loading time of the interfaces.	1	2	3	4	5	6	7
13.	The terminology was easy to understand, clear and consistent.	1	2	3	4	5	6	7
14.	The tool provides user control and freedom through its cancel and back options.	1	2	3	4	5	6	7

SECTION 1: RATINGS

SECTION 1.5: RECEPTIVENESS

In this section you are asked to evaluate how much the tool is likely to be used.

RATING SCALE

1	2	3	4	5	6	7
Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
(DDD)	**(DD)**	**(D)**	**(N)**	**(A)**	**(AA)**	**(AAA)**

For each statement given below, circle the number to the right that best fits your level of agreement. Use the rating scale to select the number.

Statement	**Scale**						
	DDD	**DD**	**D**	**N**	**A**	**AA**	**AAA**
1. A need exists to integrate project portfolio management thinking as a tool into construction management literature.	1	2	3	4	5	6	7
2. The proposed tool would enhance adaptation of construction project portfolio management.	1	2	3	4	5	6	7
3. The proposed tool would improve knowledge management.	1	2	3	4	5	6	7
4. The proposed tool would improve project management.	1	2	3	4	5	6	7
5. The proposed tool is implementable in my company.	1	2	3	4	5	6	7

SECTION 1: RATINGS

SECTION 1.6: OVERALL

In this section you are asked to evaluate the tool in overall.

RATING SCALE

1	2	3	4	5	6	7
Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
(DDD)	**(DD)**	**(D)**	**(N)**	**(A)**	**(AA)**	**(AAA)**

For each statement given below, circle the number to the right that best fits your level of agreement. Use the rating scale to select the number.

Statement	Scale						
	DDD	**DD**	**D**	**N**	**A**	**AA**	**AAA**
1. My overall impression about the tool is positive.	1	2	3	4	5	6	7
2. The proposed tool provides reasonable level of robustness in case of unexpected action of the user through limitations in data entry, given feedbacks, and the use of back button of the web browser as undo.	1	2	3	4	5	6	7
3. The proposed tool provides reasonable level of dependability since it would be accessible as long as the server and domain are available.	1	2	3	4	5	6	7
4. The proposed tool provides reasonable level of security since it provides confidentiality and authentication through definition of different user accounts with different accessibility options protected under passwords.	1	2	3	4	5	6	7
5. The proposed tool requires reasonable response time (latency) for user actions and analyses.	1	2	3	4	5	6	7
6. The interface of the tool is successful since it is clear, coherent and concise.	1	2	3	4	5	6	7

SECTION 2 – OPEN-ENDED QUESTIONS

- What did you like most about the tool?

- What did you like least about the tool?

- Was there any task that was difficult for you to do?

- What else should be included in the tool to make it more usable?

- Would you like to make any comments or suggestions about the tool?

- If you are not likely to use the tool, why?

APPENDIX G

G. COPPMAN USER INSTRUCTIONS

Considering the listed details of COPPMAN process, the provided functions in the tool are described in this section through their location in the tool interface where different pages provided under different parts of the tool menu that all build up COPPMAN. Therefore, this section presents COPPMAN within the context of possible "instructions for its use" through the following sections of "access" and "entry" to COPPMAN, including further information on its "user homepage and access to features", "navigation menu", and "feedback messages".

1. Access to COPPMAN

To access COPPMAN, the server on which the system is running should be accessed by opening a web browser program on a computer with network access. Following that, the network address of COPPMAN should be written in the address line of the web browser program. COPPMAN's network address can vary depending on installation, so the IT administer should inform the address that applies to specific installation. Throughout the work held within the research study, the address of "www.coppman.com" has been used, which is planned to be accessible during further studies with COPPMAN.

2. Entry to COPPMAN

Entry to COPPMAN is done by writing the “username” as e-mail address and “password” information in the fields on the screen. If the password required for login to COPPMAN is not remembered, user can click on the “Forgot My Password” link provided on the login screen to reset the password by entering the e-mail address in the corresponding field.

3. User Homepage and Access to Features

The “homepage” screen that will be displayed to the user after login to COPPMAN is shown in the following figure (Figure G.1). System entrance includes mainly “links” to “menu and sub-menu operations” where a main “dashboard” is provided that would be presented specifically in its specific design responding the need of specific operation. On the screen display there is a “navigation menu” with access to COPPMAN features in the left panel, which remains fixed within the “black left panel” in all screens provided under COPPMAN; however, it is automatically hided when the web browser is minimized upto a certain level. Access to the respective screens of COPPMAN is provided via the main and sub-menu links listed in the “navigation menu”. Through the “navigation menu”, the user can access the main functions of COPPMAN through “Project Inputs”, “User Preferences”, “Projects”, “Corporate Memory”, “Predictions”, “Portfolio Management”, and “Library”. Above the “navigation menu”, there is the “Homepage” link, which provides returning to the homepage whenever required. Additionally, logout option is also provided under the “navigation menu” through “Logout” link as an alternative option to the one provided in the “User Operations” on the upper right corner. The white and gray based main “dashboard” is the area that includes quick links to the operations that would be utilized most, which are grouped under boxes for “Add Project”, “Project Operations”, “Portfolio Management” and “Library” (Figure G.1).

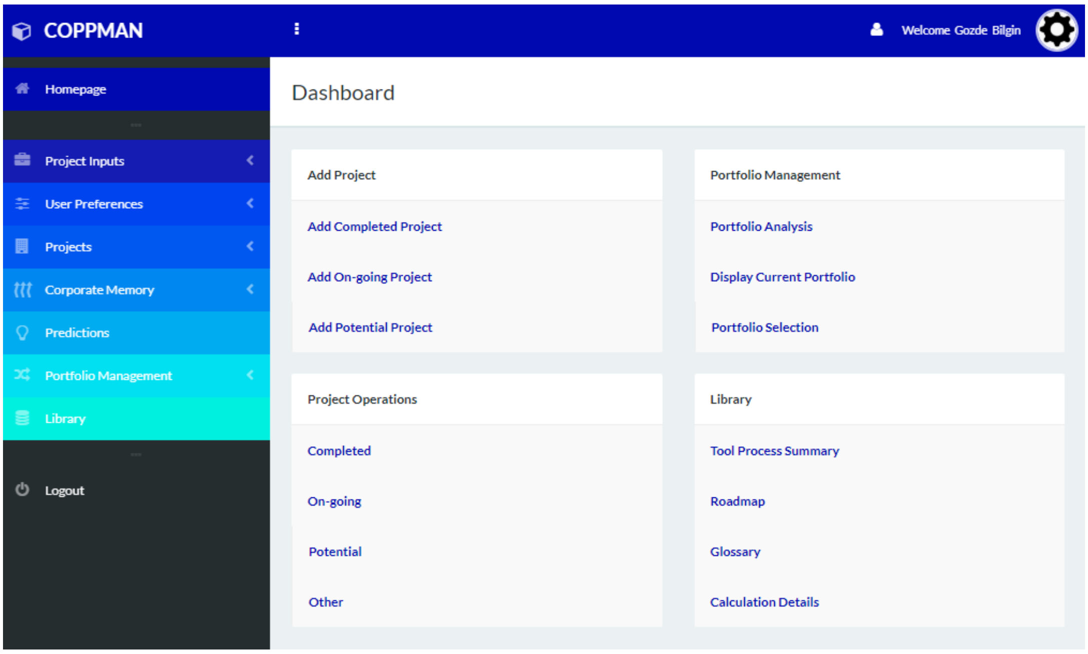


Figure G.1: Homepage and Main Menu Functions

The display of the "User Operations" menu is provided via the link in the upper right corner of the screen through the figure provided for indication of settings, which always remains fixed within the "blue top banner" including the expression of "COPPMAN" on the left side. This menu provides access to the screens for "Settings" and "Change Password" where also the link to "Logout" option is provided to terminate the session that the user has opened in COPPMAN.

The "Settings Screen" provides setting on the maximum number of the listed items in a single operation in the system-wide lists through "Displayed Record Count" option and choice of interface language as "English/Turkish" through "Displayed Language" option where the current settings are achieved through saving. "Displayed Record Count" is provided as "free-text" entry while "Displayed Language" selection is to be made through "drop-down list".

"Change Password Screen" enables change of the own password for the logged in user through proofing the "old password" and verification of the "new password" by confirmation. The new password is to be set once it is saved.

4. Navigation Menu

Access to all screens providing the use of the features of COPPMAN is provided via "navigation menu" links presented on the left panel (Figure G.1). Seven main menu headings provided in the navigation menu where each heading is also the container of the sub-headings related to it as presented in the following sections.

a) Project Inputs

Project attributes to be presented through "drop-down lists" during project information entry can be edited and defined through this menu. The project inputs submitted to be described under this menu are, "project types", "project delivery systems", "contract types", "contract payment types", "resource types", "partnership types", "critical work packages", "critical delay causes", "technologies", and "actors". In the light of this information, content provided below constitutes the menu links and their explanations under the main menu heading of "Project Inputs" in COPPMAN.

"Project Types" sub-menu link provides access to the screen for "adding", "editing" and "removing" project types through the buttons of "Add", "Edit", and "Remove" respectively where entries are to be made in the form of "free-text". Same screen and related options are also provided for the following sub-menu links as "Project Delivery Systems", "Contract Types", "Contract Payment Types", "Partnership Types", "Critical Work Packages", "Critical Delay Causes", and "Technologies" where the screens for "Resource Types" and "Actors" are differing in identification style.

The screen provided through "Resource Types" link for "adding", "editing" and "removing" resource types is also equipped with identification of the weights to be used in calculation of "resource dependencies". Therefore, user is expected to define the "resource type" together with the related weight in calculation through the coefficient section where entries are provided to be through "free-text".

The menu provided for “Actors” for “adding”, “editing” and “removing” actors is also equipped with “displaying” actors. Therefore, the menu includes sub-menu items as “Add Actor” and “Display Actors”. The “Add Actor” link provides access to the screen for “adding/defining actors” while the “Display Actors” link provides access to the screen for “displaying”, “searching”, “editing” and “removing actors”. “Add Actor” screen opens up with possibility of adding actors as both “individual” and “corporation”. The actor information is recorded through the “free-text” entry spaces for the information of “name/title”, “phone” (through descriptive sections for national destination code and digits), “address”, and “detail” (for entry of further information). The type of the actor as “individual/corporation” is entered through the provided “Radio” button. Actor information is to be recorded once the user saves the operation. “Display Actors” screen lists all the entered actor information through different pages that meets the limit for the “maximum number of listed items” through “User Operations”. All of the identified actors can be searched through entry of a “keyword” as “free-text” where the results may also be filtered in accordance with the “actor type” selected from the “drop-down” list. The actor information is summarized through only “name/title”, “phone” and “address” where “editing” and “removing” operations are provided through the “Edit” and “Remove” buttons next to the actor information.

b) User Preferences

The user has the flexibility to use the fields that are designed to fit the specific requirements of the user. Through this section, the user can arrange the necessary “tags”, “evaluation factors, their weights, and evaluation scales”, together with the “coefficient constants” and “exchange rate constants” to be utilized in the operation of the tool. Besides these, sections for “editing library”, “user management” for identification and editing the users and management of the “access and authorization” for assigning the roles of these users are also provided under this menu to establish a company-specific information management system by ensuring that the tool provides access to its users only for the menu items that they are responsible to deal with in the light of the assigned roles to the users. Content provided below constitutes the menu links and their explanations under the main menu heading of “User Preferences” in COPPMAN.

“Tag Tree” menu link provides access to the screen where tags to be used in the lesson learned management system can be identified, updated and removed within the hierarchy provided in the form of taxonomy. Clicking of the “parent” tag opens up the “child” tag available on the tag tree where right click provides the buttons of “Add” and “Remove” for adding a specific child tag for the selected tag or removing the tag itself respectively. Drag and drop ability is also provided on the tag tree to enable changing the hierarch through replacing the parent or child tags. “Reset Tag Tree” link provided in the upper right corner of the “Tag Tree” group box enables undoing all the changes made on the tag tree (as long as they have not been assigned as “default tags”) and turns it back to its default version. Adding a tag option opens a group box where free-text entry of a tag is provided through indication of “Default Tag” radio button, which serves for addition of a tag while also changing the “default tag tree” or not. The provided “Save” button adds the related tag on the tree, whereas “Cancel” button withdraws the operation.

“Evaluation Factors” menu link provides access to the screen where the identifications required for Risk and Strategic Fit Assessments for the projects as editing “factor sets” and “evaluation scales” are made available. The screen opens up with the “Evaluation Factors” group box where different factor sets are to be identified. The upper box provides identification of a “factor set” through entry of the set name by “free-text” and selection of the factor type as “Risk Evaluation/Strategic Fit Evaluation” from the provided “drop-down list”. The lower box includes the identified factor sets where a free-text search option is provided in the first row to filter the intended factor sets. The first row also summarizes “active factor sets” as listing them through their names together with indication of the factor set type. Therefore, user can assign a factor set to be active through the radio button provided as “Active/Passive” which means that all the evaluations must be completed for the selected specific factor set before portfolio analysis. The tool enforces the user to make all the evaluations through the active set of factors, and does not perform portfolio analysis otherwise. COPPMAN automatically makes the other sets within the same factor set type “Passive” once a specific factor set is selected to be “Active” among all. Since user is expected to make changes based on previous factor sets, “Copy” button is provided for copying an overall factor set, where its name (“Edit Name”) and content (“Edit Factor”) is to be changed and user can also completely remove a specific factor set from the list (“Remove”). “Edit Factor” option opens an evaluation factor set where further editing is provided for the “factors” (name/order), “factor weights”, and the “evaluation scale” required for evaluation of the projects and latter calculation of overall score. Within the selected “factor set” user can add a new factor through the section provided below where the “factor name” and its corresponding “weight” in the overall is to be entered through “free-text”. Alternatively, user can search for a specific factor through entry of the keyword through “free-text”, edit a pre-defined factor through the “Edit” button provided in the row of the related factor, while also remove it through the “Remove” button provided next to it. Additionally user can change the order of the factors through the “Arrow” buttons provided next to each factor for moving “to the top of the list”, “one row up”, “one row down”, or “to the end of list”. Finally through the “Edit Factor Weights” button, user can update the existing weights or change them to make the overall sum “1” once an addition/deletion is made on the current factor list. The evaluation scale provided in the form of rating scale for the factors is also editable. User can assign a score text (e.g., low/medium/high or direct numerical figures) and its corresponding “numerical value” to be used in calculations. User should once assign the overall evaluation list “Add” and “Remove” buttons to add a new item by its corresponding name on the list and removing an item from the list respectively. Following finalizing the overall list, user can edit both the “text” as the name of the item and “scores” as the corresponding numerical values through the “Edit” button provided.

“Coefficient Constants” menu link provides access to the screen where the “constants” or “limits” to be used in different sections of the overall tool process can be edited by the user. The screen opens up with the group boxes and the assigned default weights/limits for each attribute for “Learning Coefficients”, “Warning Limits”, “Project Similarity Coefficients”, “Project Dependency Coefficients”, and “Financial Dependency Coefficients”. Attributes pre-defined in the boxes are provided with the corresponding weights that are all adding up to “1” in the group set through “Project Similarity Coefficients”. The attributes provided for coefficient constants are fixed, therefore user can only edit the weights for the pre-defined attributes by pushing the “Save” button where a warning is provided when the overall weights do not exactly sum up to “1”.

“Exchange Rate Constants” menu link provides access to the screen where exchange rate can be defined through “Add” button in terms of the “shortening”, “name”, “symbol”, and “equivalent in Turkish Liras” where “free-text” spaces are provided for their entries through the upper box. The other box is located for listing the currencies through the entered information where “editing” and “removing” are also provided through the buttons of “Edit” and “Remove” provided next to the related currency.

“Edit Library” menu link provides access to the screen where a library item can be defined through “Save” button in terms of the “subject” (in both languages) and the option to “Show on Dashboard” or not which provides listing of the specific library item on the homepage through the group box provided for Library. Once the subject and preference on dashboard is finalized, user can upload the related files in “Portable Document Format (PDF)” format through the “File Upload” button. Additionally, user can “Edit” or “Remove” specific library item through the button provided next to it and also change the order of the items through the “Arrow” buttons provided.

“User Management” menu link provides access to identification of the “Users” to be identified within the system. Therefore, the menu includes sub-menu items as “Add User” and “Users”. The “Add User” link provides access to the screen for “adding/defining users” while the “Users” link provides access to the screen for “displaying”, “searching”, “editing”, and “removing” users, together with “assigning a role to the user” and “resetting their passwords”. “Add User” screen opens up section for adding users with the information recorded through the “free-text” entry spaces for the information of “username”, “name”, “last name”, “password”, and “password confirmation”. User information is to be created once the user hits the “Save” button or the process is withdrawn when the “Cancel” button is used. “Users” screen lists all the entered user information through their information of “username”, “name” and “last name”. All of the identified users can be searched through entry of a “keyword” as “free-text”. Operation for “editing” and “removing” are provided through the “Edit” and “Remove” buttons next to the user information in addition to the further operations on “assigning a role” and “resetting the password” through the buttons of “Assign a Role to the User” and “Reset Password” respectively.

“Access and Authorization” menu link provides access to identification of the “Roles” and assignment to the “Users” where further authorization is to be made for “Operation” and “Menu” items by linking these with specific “Roles”. Therefore, the menu includes sub-menu items as “Roles”, “Add Role”, “Authorization”, and “Menu Role Relations”. The “Roles” link provides access to the screen for “displaying, editing and removing the roles”, “Add Role” link provides access to the screen for “identification of a new role to be used in the system”, “Authorization” link provides access to the screen for “authorizing operations to the specific roles”, while the “Users” link provides access to the screen for “authorizing/relating menu items to the specific roles”. “Roles” screen opens up section for listing the previously identified roles and provides operations for “editing” and “removing” through the small buttons provided next to each role. Addition of a “role” can be made through the link provided as “Add New Role” on the upper right corner of the “All Roles” group box. “Add New Role” link directs the user to the “Add Role” screen. “Add Roles” screen opens up with a section for defining roles through “free-text” entry. Once the user hits “Save” button, the user is redirected to the “Roles” screen where the provided “Roles” list updated through addition of the newly added role. “Authorization” screen provides search of the intended “operation” through “free-text” keyword search within the “Operations” group box provided on the left side of the screen. Once the user selects the related “operation”, it is automatically listed on the “Authorized

Roles” group box on the right side of the screen together with the information of “assigned/authorized roles” and “total number of the authorized roles” where further button are provided for “removing” or “adding” an authorization through the buttons of “Remove” and “Authorize”. “Authorization” screen provides selection of the intended “Menu Item” through “drop-down” list provided on top of the screen. Once the user selects the related “item”, the “Associated Roles” are automatically listed below within the right box, where the left box is already listing the overall roles and the associated roles are transferred to the right box through the use of “arrow” buttons pointing the box as direction of the transfer.

c) Projects

Through this menu the user can add projects, perform project operations and display projects with different search and sorting methods. Sub-menus of “project addition” and “project operations” are presented in terms of further three sub-menus based on project statuses. Through the “project operations” section, all the functions related to the project are gathered together where the user is directed to processes specific to the project status. Content provided below constitutes the menu links and their explanations under the main menu heading of “Projects” in COPPMAN.

“Add Project Screen” opens through selection of the related menu link according to the “status” of the project to be entered. Under “Add Project” main menu link, “Add Completed Project” opens the entry screen for “completed projects”. Therefore, user can access to entry screens of “on-going” and “potential” projects through the menu links “Add On-going Project” and “Add Potential Projects” respectively. Once the screen is opened for entry of a project, the related form may be changed through selection of the “project status” provided on top of the page through a “drop-down” list of the project statuses. The information is entered through group boxes provided as “general project information”, “critical resource information”, “partnership information”, “duration information”, “financial information”, “dependent projects”, and “technologies”. Entry of the information is provided through:

- “free-text entries” (e.g. project name, short code, project scope),
- “free-text entries for numerical value” (e.g. planned project duration, contract price, expected cost, dependent project relation rate),
- “drop-down lists” (e.g. project type, contract type, contract payment type, currency, country, project delivery system, resource type, partnership type, dependent projects, technologies),
- “entry through keyword search where filtered results are provided in a drop-down list” (e.g. client, resource name (also identifiable through direct entry in its row), partner company),
- “selectable entries” (e.g. start date, end date) and also through,
- “mandatory” (e.g. project name, project type, country, etc.) or “optional” (e.g. critical resource, partnership information, dependent projects, technologies) fields where
- “single” (e.g. project name, project type, country, etc.) or “multiple” (e.g. critical resource, partnership information, dependent projects, technologies through “Add” button) entry is provided.

Entry of completion percentage is not provided for “completed” and “potential projects” since they are already opened up entered as “100” and “0” respectively. Entry of dependent project information is to be made with indication of the “relation rate” (a value between [0,100%]) as indication of its importance through magnitude. In case of the user identifies a missing project input in the pre-defined drop-down lists through the “project inputs”, user can open the project inputs on a new window and define the required input. Once the user turn backs to main window and hits the button provided on upper right corner as “Update Project Constants” the related project input would be listed in the related areas.

The required information according to project statuses differs in expression only, whereas the completed project includes a Post Project Appraisal section as a major difference from the others. Required information is provided under group boxes of “evaluation information”, “claim information”, “critical delay causes”, “critical actors”, and “critical work packages”. Most of the information is to be entered through “free-text” provided for numerical entries of “evaluation” and “claim information”, where critical information as “delay cause”, “actor” and “work package” is to be selected from the “drop-down” lists while “effect levels” are to be entered through a numerical value preferred to be ranging between [1,5] or any other interval for entering the effects of different critical figures comparatively. All of the information required at this section is provided as “optional entries” and “multiple” entries are provided for “critical” attributes where “Add” button is provided for “multiple” entry. Therefore, “Save” button at the bottom of the page provides codification of the overall “completed project” information including the PPA section.

Access to “Completed Projects” is provided under “Project Operations” main menu link where the entered project information is summarized together with the “Operations” specific for completed projects and display option through “Project Card”. “Operations” for a completed project further provided through the links of “Edit”, “Lesson Learned Entry”, and “Remove” as grouped under “Operations” button. “Lesson Learned Entry” link opens the same screen with “Lesson Learned Entry” provided under “Corporate Memory” main menu, which will be presented in the following sections, with a small difference of direct entry of the lesson for the selected project. The screen opens up in a version with selected project information.

Access to “On-going Projects” is provided under “Project Operations” main menu link where the entered project information is summarized together with the “Supportive Information” and “Operations” specific for on-going projects together with the “Project Card” for displaying the project information. “Supportive Information” for an on-going project is provided through links for “Display Similar Projects”, “Display Lessons Learned”, “Display Predictions”, and “Display Learning Potential” as grouped under “Supportive Information” button. The overall process also applies and the same for the “Potential Projects”. “Display Lessons Learned” and “Display Predictions” links open the same screen with “Display Lesson Learned” provided under “Corporate Memory” main menu and “Predictions” main menu respectively, which will be presented in the following sections, with small difference of direct selection of the project in question for “similarity-based retrievals”. The screens open up in a version with selected project information. “Display Learning Potential” link directly opens the pop-up screen indicating the overall score and break-down of the score on attribute basis. “Operations” for an on-going project further provided through the links of “Edit”, “Risk Assessment”, “Strategic Fit Assessment”, and “Remove” as grouped under “Operations” button. The overall process also applies and the same for the “Potential Projects”. “Risk Assessment” link opens screen including the factor scoreboard based on the identified “factor set” and “evaluation scale” where “Save” button finalizes the evaluation and “Factor Evaluation History” button presents the previous evaluations for investigation. “Factor Evaluation History” link provided on upper right corner of group box for “Risk Assessment Form” opens the screen including the summary information on previous risk evaluations through “evaluation factor name” (as the name of the “factor set”), “evaluation date”, “overall score”, and status as “active/passive”. “Detail” button provided in the row of related history opens up the details of the evaluation. “Strategic Fit Assessment” link opens screen including the factor scoreboard based on the identified “factor set” and “evaluation scale” where “Save” button finalizes the evaluation and “Factor Evaluation History” button presents the previous evaluations for investigation. “Factor Evaluation History” link provided on upper right corner of group box for “Strategic Fit Assessment Form” opens the screen including the summary information on previous strategic fit evaluations through the “evaluation factor name” (as the name of the “factor set”), “evaluation date”, “overall score”, and status as “active/passive”. “Detail” button provided in the row of related history opens up the details of the evaluation.

“Project Card” for displaying the project information is provided for all type of project statuses. The project symbol differs in the “status color” according to different statuses of the projects and “project card” provided for “completed projects” also lists the information of PPA section. Project cards also presents additional measures as calculated “expected profit” and “adapted profit” where “profitability” is also presented through its calculation on “percentage” bases as provided in the “project symbol”.

Access to “Other Projects” is provided under “Project Operations” main menu link where the entered project information is summarized together with the “Operations” specific for other projects (as “suspended”, “eliminated” and “cancelled” projects) and display option through “Project Card”. “Operations” for the other projects further provided through the links of “Edit” and “Remove” only as grouped under “Operations” button.

“Display Projects” screen opens the display screen for all the entered projects where information of projects is summarized through the identified “short code”, “project name”, “project type”, “country”, “start and end date”, “project status”, and “risk and strategic fit scores”. “Free-text” search is provided as entry of “keyword” for retrieval of the related projects where further filtering on the results may be obtained through the “drop-down” list provided for “project statuses”. Additionally, projects can be sorted by the “project name” and “date” through the small “Arrow” buttons provided next to headings of the related columns. Further display options are provided through “Display” button located at the end of the row of project information. “Display” options opens up further links for display of related “Project Card”, “Lesson Cards”, “Risk Evaluation History” and “Strategic Fit Evaluation History”. “Project Card” is not to be explained again; however, the “Lesson Cards” are retrieved through the listed lessons where only the “approved lessons” of the project are listed in its default. The screen also provides entry of a new lesson through the group box provided on top of the screen where “Save” button is provided for recording the lesson. Further filtering on the retrieved lessons and “Operations” as “Detail/Edit”, “Lesson Learned Card”, “Remove”, and “Rollback Approve” are also provided whose details will be handled in the following sections.

d) Corporate Memory

This area is presented as an alternative method for the lesson entry and display options to be performed independently of the “project operations”. In this way, it is provided that the user can codify the lesson learned information directly without dealing within the processes/operations of portfolio analysis. The user can register the lesson in the same way as it is provided in the project operations by selecting the relevant project under the “Lesson Learned Entry” link provided under “Corporate Memory” main menu link. Through “Display Lessons Learned”, the lesson information can be displayed by different retrieval options as “filtering” and “similarity” or “tag-based” searching. Content provided below constitutes the menu links and their explanations under the main menu heading of “Corporate Memory” in COPPMAN.

“Lesson Learned Entry” screen opens up section where the project that the lesson is to be entered is required to be selected first before entering the lesson related information. The information is to be entered as “free-text” for “lesson learned name”, “event description” and “recommendation”, where option for indication of “Best Practice” or not is provided to be selectable. “Effect on project duration” and “cost” are provided to be selectable through the provided five point scale ranging between “Very Low” and “Very High” where the “Effect Amounts” are to be entered as numerical values by “free-text”. Related “Actors” and the “Tags” are to be assigned through selection from the “drop-down” list and the “tag tree” respectively where multiple entries are provided.

“Display Lesson Learned” screen opens up section where different retrieval mechanism as “filtering”, “similarity” and “tags” are provided on the top of the screen for selection of the way for obtaining the results. Further search on the results is also provided through “tags”, “effect on project duration/cost”, “approval status”, “date”, “best practice or not”, and “actors”. The filtering process together with the obtained results is provided when filtering is made without attribute selection for listing all the entered lessons. The results are presented through further options provided next to lessons retrieved as “Detail” button next to “project name” for opening the “Project

Card”, “Detail” button next to lesson for opening the “Lesson Card”, “Edit” button for editing the lesson, small “Remove” button for removing the lesson, and “Approve/Rollback Approve” button for changing the approval status of the lesson. “Similarity” search is to be done by first selecting the related project from the “drop-down” list provided on top of the screen where additional similarity attributes are to be selected as in a typical “similarity search” already provided in the previous sections. Multiple entry of attribute similarities is provided for “country”, “project type” and “client” attributes through assessment their attribute-based similarity magnitudes. The obtained results based on “similarity” search are provided where further filtering is also possible within the filtered results. Differently from the case with “filtering” based retrieval of the lessons, similarity score breakdown is provided next to projects in addition to the expected “buttons” provided. “Tag” search is to be done by “right clicking” on the “tag tree” for assigning intended “tags” by automatic assignment of their “parent tags” for search within lessons. The obtained results based on “tag” search is provided in a way, whose depiction style is the same with the “filtering” based retrieval. Further “Lesson Card” is to be viewed through the entered information and provision of “Approve/Rollback Approve” button for changing the status of the lesson upon its investigation.

e) Predictions

In this section, as in “Corporate Memory” menu, independent calculation of predictions can be performed separately from the operations provided in “Project Operations”. The collected data from the PPA section of project information, are presented to the user in terms of average values as a result of filtering or similarity-based retrieval methods.. Through “Predictions” menu link, COPPMAN provides access to a screen where filtering and similarity-based prediction calculations can be obtained.

“Filtering” is to be used as first option for retrieval of results through selection of the “country”, “project type”, and “contract type” attributes from the “drop-down” list is provided while “client” and “partner company” information are to be selected through “free-text” search of the “keyword”. Once the user selects/enters the data for the attributes to be used for filtering and hits the “Search” button, the results are obtained where numerical data is provided for average “deviation in profit”, “profitability”, “delay duration”, “delay cost”, and “claim success (in duration and payment)”, while critical “actors”, “work packages”, and “delay causes” are presented through sorting in descending order of the cumulative value of their effect levels.

“Similarity” based retrieval is the alternative option for retrieval of results through additional setting of the attribute similarities for by selecting “country”, “project type”, “technology” and “contract type” attributes from the “drop-down” list while “client” information is to be selected through “free-text” search of the “keyword”. Further similarity scores for the “country”, “project type”, and “client” is to be assigned through similarity scores ranging between [0,100]. Once the user selects/enters the data for the additional attribute similarities to be used for calculation of the similarity and hits the “Search” button, the results are obtained where predictions data is provided through numerical values and cumulative effect levels obtained.

f) Portfolio Management

In this section, portfolio analysis can be performed to create portfolios and investigate results through portfolio and project level measures, display the current portfolio of the company and support portfolio selection decision. Contents provided below constitutes the menu links and their explanations under the main menu heading of “Portfolio Management” in COPPMAN. The “Portfolio Analysis” link provides access to the screen where user can perform portfolio analysis and view the analysis results. With the “Current Portfolio” link, the portfolio consisting of only on-going projects resulting from portfolio analysis is to be reached. The “Portfolio Selection” link provides access to a screen where the alternatives resulting from the portfolio analysis can be sorted through “risk based”, “strategic fit based”, “portfolio value based” and “profit based” ranking.

“Portfolio Analysis” screen opens with a blank page of results where “Create Portfolios” button is provided for generating portfolios if there is no current analysis. The screen is to be opened with the results of the latest portfolio analysis results as long as the analysis is not removed. “Create Portfolios” operation requires selection of the “potential projects” (at most four projects), which are to be included in the analysis and also the “common currency” to be used in comparison of alternatives with different currencies. User can re-arrange the selected projects through “Remove” button and can obtain portfolios after hitting “Create” button, where there is an option for withdrawing the process through “Cancel” button. “If no potential project is selected for analysis, COPPMAN establishes the “current portfolio” as the single alternative of the analysis. “Portfolio Analysis Results” are obtained through the charts and graphs at which the properties at the “portfolio level” are presented and therefore portfolios can be compared with each other. The results page includes the “table”, “graphs”, and “warning” on portfolio selection. Table also includes buttons for each portfolio alternative as “Operations” and “Display Portfolio” where portfolio level operations and display of portfolios in terms of included projects are to be performed respectively. Operations for a portfolio alternative are provided as “Edit Portfolio Name” and “Delete Portfolio”, which provides changing of the name of the portfolio that are automatically named as “Alternative n” (where n is integer [1,.., n]) and deleting the specific portfolio alternatives from the analysis respectively. “Display Portfolio” button provides examining a specific portfolio alternative in more detail, where the “tables” and “graphs” at the “project level” (including dependency network map) are presented with various “warnings” as considerations for management of the specific portfolio. The provided “Detail” button next to the projects, opens down the related “Project Card” within the table.

The menu link “Current Portfolio” opens up the details of the fist alternative (Alt 1) as the portfolio alternative consisting of on-going projects only. Apart from the portfolio analysis section, this section provides the user to review the “current portfolio” and obtain specific warnings when there is no “potential project” is available as an option for evaluation.

The other menu link as “Portfolio Selection”, opens up the screen where user can have the opportunity to review and prioritize portfolios based on risk, strategic suitability, portfolio value or profitability to support decision-making in selection of portfolios. In the provided screen, portfolio alternatives are listed with summary of properties through the repeated “table” and their “operations” where sorting is to be made by selection of type through the “dropdown” list provided and “Radio” button for selection of order as “Ascending/Descending Sorting”.

g) Library

Detailed and user-friendly information for the operation principle and usage of COPPMAN is available under the library. It is presented to the user's access through the library links prepared in four main sections as “Tool Process Summary”, “Roadmap”, “Glossary of Terms” (Appendix H) and “Calculation Details”. Once the user selects a heading from the list provided as subjects of the library through the “drop-down” list provided on the upper right corner of the screen, the related section opens up through the PDF file provided where operations through a simple “PDF reader” are also supported within the file.

5. Feedback Messages

The tool can provide feedback on the actions of the user that requires attention. Various information and warning messages are displayed during user operations in COPPMAN. These messages are shown to help the user complete the process by providing feedback through the following matters:

- warning for the incomplete values in the user entries,
- warning for the erroneous values in the user entries,
- informing the user about the result of any operation, and

- directing the user through suggestions for the process.

Combined feedback for both “informing the result of an operation” and “directing through suggestions” can also be provided in single operation.

APPENDIX H

H. COPPMAN LIBRARY GLOSSARY

Table H.1: Left Menu Glossary

Homepage	From this page user can access to quick links for "Add Project", "Project Operations", "Portfolio Management" and "Library" according to user authorization.
Project Inputs	Menu link that enables edit or re-definition of project information provided as dropdown list to the user.
Project Types	Enables the user to edit or re-define the "Project Types" dropdown list provided in the project information entry pages.
Project Delivery Systems	Enables the user to edit or re-define the "Project Delivery Systems" dropdown list provided in the project information entry pages.
Contract Types	Enables the user to edit or re-define the "Contract Types" dropdown list provided in the project information entry pages.
Contract Payment Types	Enables the user to edit or re-define the "Contract Payment Types" dropdown list provided in the project information entry pages.
Resource Types	Enables the user to edit or re-define the "Resource Types" dropdown list provided in the project information entry pages and their coefficients.
Partnership Types	Enables the user to edit or re-define the "Partnership Types" dropdown list provided in the project information entry pages.
Critical Work Packages	Enables the user to edit or re-define the "Critical Work Packages" dropdown list provided in the project information entry pages.
Critical Delay Causes	Enables the user to edit or re-define the "Critical Delay Causes" dropdown list provided in the project information entry pages.
Technologies	Enables the user to edit or re-define the "Technologies" dropdown list provided in the project information entry pages.
Actors	Enables the user to edit or re-define the "Critical Actors" dropdown list in terms of individuals/corporations visible upon keyword search in the project information entry pages.
User Preferences	Menu link that enables the user to design the tool mechanism.
Tag Tree	Enables the user to edit "Tag Tree" to be used with the aim of tagging lessons during "Lesson Learned Entry" process.
Evaluation Factors	Enables the user to edit or define the "Evaluation Factors" that will be used in "Risk" and "Strategic Fit" assessment, to copy the factors, to make factors active or passive, to change factor weights and scores.
Coefficient Constants	Enables the user to edit the "Coefficient Constants" to be used in calculations for "Learning Potential", "Warnings", "Project Similarity" and "Dependencies" between projects. "Learning Coefficients" are used not only in calculation of "Learning Potential" but also in calculation of "Learning Dependency".
Exchange Rate Constants	Enables the user to define the "Exchange Rates" and their "Equivalents in Turkish Liras" to be used in "Project Information Entry" and "Portfolio Analysis" pages.
Edit Library	Enables the user to define sections for "Library" and upload the related documents.
User Management	Enables the user to "Add User", to "Edit User", to "Reset Password" and to identify the extent of "Access and Authorization" by "Assigning a Role to the User".
Access and Authorization	Enables the user to define a "Role" and to identify accessible "Menu Links" and "Operations" for the specific "Role" and to make "Authorization" for the "Role".

Table H.1: Left Menu Glossary (continued)

Projects	The menu link that enables the user to make "Data Entry" and "Operations" on "Project Status" basis, and "Display" the entered projects.
Add Project	The user is enabled to make "Data Entry" on "Project Status" basis. Sub-menu link is provided for "Completed", "On-going" and "Potential" projects; however, user can also change the "Project Status" entry provided at the top of these data entry pages and make entry for other "Project Status" such as "Suspended", "Eliminated" and "Cancelled". The information required for entry based on "Project Status" and the related "Projects Cards" are same with the "Potential" for "Suspended" and "Eliminated" status, whereas same with the "On-going" for "Cancelled" status.
Add Completed Project	Project information for "Completed Projects" can be made through "Data Entry" page including the "Post Project Appraisal" section.
Add On-going Project	Project information for "On-going Projects" can be made through "Data Entry" page.
Add Potential Project	Project information for "Potential Projects" can be made through "Data Entry" page.
Project Operations	The user is enabled to make "Operations" on "Project Status" basis.
Completed Projects	"Lessons Learned Entry" operation is provided for "Completed Projects" in addition to operations valid for all project status as "Edit" and "Remove". The entered project information can be displayed through "Project Card".
On-going Projects	"Risk Assessment" and "Strategic Fit Assessment" operations are provided for "On-going Projects" in addition to operations valid for all project status as "Edit" and "Remove". Investigation of "Supportive Information before the evaluations is provided ("Risk Assessment" and "Strategic Fit Assessment" operations are compulsory for "Portfolio Analysis". Assessments should be done according to the latest "Evaluation Factors" defined and the "Risk Assessments" over 3 months should be renewed). The entered project information can be displayed through "Project Card".
Potential Projects	"Risk Assessment" and "Strategic Fit Assessment" operations are provided for "Potential Projects" in addition to operations valid for all project status as "Edit" and "Remove". Investigation of "Supportive Information before the evaluations is provided ("Risk Assessment" and "Strategic Fit Assessment" operations are compulsory for "Portfolio Analysis". Assessments should be done according to the latest "Evaluation Factors" defined and the "Risk Assessments" over 3 months should be renewed). The entered project information can be displayed through "Project Card".
Other Projects	Operations for "Suspended", "Eliminated" and "Cancelled" project status are done through this menu link. Operations valid for all project status as "Edit" and "Remove" are provided for these projects and the entered project information can be displayed through "Project Card".
Display Projects	The user is enabled to filter and display the projects by "Keyword" search and "Project Type" based filtering. "Project Name" and "Start Date" based sorting between the results is also provided. Project details can be investigated through "Display" option where "Project Card", "Lesson Cards", "Risk Evaluation History" and "Strategic Fit Evaluation History" of the project can be displayed.
Corporate Memory	The menu link that enables the user to enter and display "Lesson Learned" for all project status. "Lesson Learned Entry" for "Completed Projects" is required on top priority and is to be made through "Completed Project Operations". This menu link enables lesson entry apart from "Project Operations" and enables lesson display independently of project display.
Lesson Learned Entry	Upon selection of the related project; the user is enabled to enter the "Lesson Learned Name" for the related lesson, describe the lesson learned in terms of "Event Description" and "Recommendation" separately, make indication of "Best Practice" if it is a best practice example, indication of the effects of the lesson learned to the project in terms of "Duration" and "Cost", attach the related "Actor" and to tag the lesson to make it easily searched through use of "Tag Tree".
Display Lesson Learned	Provides elimination of entered "Lessons Learned" through filtering search based on "Filtering", "Similarity" and "Tags".
Forecasts	"Completed Projects" are eliminated with reference to the project under evaluation through one of the search methods based on "Filtering" or "Similarity" to obtain average values for the relevant attribute data in "Post Project Appraisal" section included in "Data Entry" page for "Completed Projects". Thus, use of past project data as a reference is enabled for investigation of a new project.
Portfolio Management	The menu link that enables the user to create possible "Portfolio Alternatives" by performing "Portfolio Analysis" and to display "Current Portfolio". It also directs the user to selection by prioritizing the portfolios through "Portfolio Selection" menu link.
Portfolio Analysis	The user is enabled to retrieve information on properties of "Portfolio Alternatives" that will be created by addition of combination of selected "Potential Projects" to the "On-going Projects" set.
Current Portfolio	The user is enabled to separately display the "Current Portfolio" that includes only the "On-going" projects.
Portfolio Selection	The user is enabled to display "Portfolio Alternatives" by prioritizing the portfolios according to the "Risk", "Strategic Fit", "Portfolio Value" and "Profitability" criteria.
Library	The user is enabled to gather information about the details of the tool through the sections provided as "Tool Process Summary", "Roadmap", "Glossary" and "Calculation Details".

Table H.2: Project Information Glossary

Project Status	Project status identified for flexibility in use as "Suspended", "Eliminated" and "Cancelled" in addition to status required for tool process as "Completed", "On-going" and "Potential".
Project Status: Completed	It is the project status that the company can use for all of the projects completed during its life time. Information of these projects will be used as an insight for the "On-going" and "Potential" projects. It is represented in "blue" color in the "Project Symbol".
Project Status: On-going	It is the project status for the projects that the company has signed a contract or the construction process is still on-going. Information of these projects will be used in analysis of the current situation and also in analysis of the "Portfolio Alternatives" that will be formed by addition of "Potential Projects" through scenario analysis. It is represented in "green" color in the "Project Symbol".
Project Status: Potential	It is the project status for the project alternatives that the company has an interest in. Information of these projects will be used in analysis with "On-going" projects. It is represented in "yellow" color in the "Project Symbol".
Project Status: Suspended	It is the project status that would be used in excluding projects from the analysis with no requirement for entry of obligatory project information required for analysis. It is represented in "purple" color in the "Project Symbol".
Project Status: Eliminated	It is the project status that would be used for the projects left off and to exclude the projects from the analysis with no requirement for entry of obligatory project information required for analysis. It is represented in "light gray" in the "Project Symbol".
Project Status: Cancelled	It is the project status that would be used for the projects of cancelled contracts and to exclude the projects from the analysis with no requirement for entry of obligatory project information required for analysis. It is represented in "gray" in the "Project Symbol".
General Project Information	It is the fundamental project information required for entry of information for all project status and most of them are designed as compulsory information.
Project Name	"Project Name" is to be entered in text and it is compulsory.
Short Code	The user is enabled to define a "Short Code" for the project to meet the requirement where it is not possible to represent the project in full name and it is compulsory.
Project Type	It is the compulsory project information that is provided as dropdown list and provides grouping of projects according to their contents. It can be edited through "Project Inputs" menu link.
Project Scope	It is the compulsory project information that is to be entered in text and provides to summarize the project content within a sentence.
Client	It is the compulsory project information that is provided as a dropdown list visible upon keyword search and includes the project client information. It can be defined through "Actors" menu link and it is compulsory.
Country	It is the compulsory project information that is provided as dropdown list and represents the country information of the projects as where they are (being) executed.
Project Delivery System	It is the compulsory project information that is provided as dropdown list and represents the construction organizations of the projects. It can be edited through "Project Inputs" menu link.
Contract Type	It is the project information that is provided as dropdown list and represents the standard types of contracts. It can be edited through "Project Inputs" menu link and it is not compulsory.
Contract Payment Type	It is the compulsory project information that is provided as dropdown list and represents the types of contract payments. It can be edited through "Project Inputs" menu link.
Currency	It is the compulsory project information that is provided as dropdown list and represents the "Currency" which the contract is signed. It can be edited through "User Preferences" menu link.
(Planned) Start Date	It is the compulsory project information that is provided in selectable and writeable form and represents the start date of the project contract.
(Planned) End Date	It is the compulsory project information that is provided in selectable and writeable form and represents the end date of the project contract.
Critical Resource Information	"Critical Resource Information" is used in assignment of resources that would be scarce in the project and calculation of "Resource Dependencies" between projects by matching of the assigned critical resources. "Critical Resource Information" may not be assigned or can be assigned more than once.
Resource Type	It is the project information that is provided as dropdown list and represents the resource types according to their use. Resource types and their weights to be used in calculations can be edited through "Project Inputs" menu link.
Resource Name	It is the project information that is provided as a dropdown list visible upon keyword search and represents the critical resource information together with the supplier information. It can be defined by immediate typing as a text with the supplier information over the list and once it is saved it will be defined.
Partnership Information	"Partnership Information" is recorded together with "Partnership Type" and "Partner Company" information. "Partnership Information" may not be assigned or can be assigned more than once.
Partnership Type	It is the project information that is provided as dropdown list and represents the partnership types according to contracts. It can be edited through "Project Inputs" menu link.
Partner Company	It is the project information that is provided as a dropdown list visible upon keyword search and represents partner information of projects. It can be edited through "Actors" menu link.

Table H.2: Project Information Glossary (continued)

Duration Information	"Duration Information" is specified as "Planned Project Duration" and "Completion Percentage".
Planned Project Duration	It is the compulsory project information that is to be entered as numerical text in "Workday" and corresponds to the project duration stated in the contract.
Completion Percentage	It is the project information that is to be entered as percentage and corresponds to project stage on the basis of construction progress. It is compulsory for "On-going Projects" and automatically represented for other projects.
Financial Information	"Financial Information" is specified as "Contract Price" and "Expected Cost".
Contract Price	It is the compulsory project information that is to be entered as numerical text in "Currency" stated in the project information and corresponds to the price stated in contract.
Expected Cost	It is the compulsory project information that is to be entered as numerical text in "Currency" stated in the project information and corresponds to only expected cost of the project excluding profit.
Dependent Projects	"Dependent Project" corresponds to the "Outcome Dependency" identified in the tool and assigned to meet the dependencies where success of a project is dependent of another project due to any reason excluding the situations that meet any of the "Financial Dependency", "Resource Dependency" and "Learning Dependency". Assignment of "Dependent Project" while entry of information of one of the projects automatically sends the information to the dependency information of the other project thus "Outcome Dependency" between projects has been assigned. "Dependent Project Information" may not be assigned or can be assigned more than once.
Technologies	It is the project information that is provided as dropdown list and corresponds to the special technology to be used in the project. It can be edited through "Project Inputs" menu link. "Technology Information" may not be assigned or can be assigned more than once.
Post Project Appraisal	It is the "Completed Project Information" that is to be used as a reference for the projects under evaluation and to be presented in averages on attribute basis according to the selected "Filtering Criteria". It is compulsory only for "Completed Projects".
Evaluation Information	"Duration", "Delay" and "Cost" information of "Completed Projects" that are to be represented in average attribute values on the basis of selected "Filtering Criteria".
Actual Project Duration	It is the project information that is to be entered as numerical text in "Workday" and corresponds to "Actual Duration" of the project including delays.
Extension of Time	It is the project information that is to be entered as numerical text in "Workday" and corresponds to total "Delay Duration" of the project.
Delay	It is the project information that is to be entered as numerical text in "Workday" and corresponds to total "Delays" of the project.
Actual Cost	It is the project information that is to be entered as numerical text in "Currency" stated in the project information and corresponds to the "Actual Cost" of the project.
Change in Contract Price	It is the project information that is to be entered as numerical text in "Currency" stated in the project information and corresponds to "Additional Cost" due to changes in contract.
Delay Cost	It is the project information that is to be entered as numerical text in "Currency" stated in the project information and corresponds to total cost of "Delays" due to contractor.
Delay Penalty	It is the project information that is to be entered as numerical text in "Currency" stated in the project information and corresponds to the "Delay Penalty" portion of the total cost of "Delays".
Early Completion Incentive	It is the project information that is to be entered as numerical text in "Currency" stated in the project information and corresponds to the total "Premium" taken in case of "Early Completion".
Claim Information	It is the project information that is required for indication of success of the claim process in case of it is occurrence in terms of average attribute values on the basis of selected "Filtering Criteria".
Claimed Duration	It is the project information that is to be entered as numerical text in "Workday" and corresponds to the total "Claim" on "Duration" basis encountered in the project.
Duration Awarded	It is the project information that is to be entered as numerical text in "Workday" and corresponds to the total "Awarded Claim Duration".
Claimed Payment	It is the project information that is to be entered as numerical text in "Currency" stated in the project information and corresponds to the total "Claim" on "Payment" basis encountered in the project.
Payment Awarded	It is the project information that is to be entered as numerical text in "Currency" stated in the project information and corresponds to the total "Awarded Claim Payment".

Table H.2: Project Information Glossary (continued)

Critical Delay Causes		It is the project information that is required for indication of "Delay Causes" encountered in projects as "Critical Delay Causes" on the basis of selected "Filtering Criteria" for the projects.
	Critical Delay Cause	It is the project information that is provided as dropdown list and corresponds to "Delay Causes" encountered in projects. It can be edited through "Project Inputs" menu link. "Critical Delay Cause" may not be assigned or can be assigned more than once.
	Effect Level	It is the information that is to be entered as numerical text and corresponds to the level of effect by the entered "Critical Delay Causes" to the project (by indication of the effect in terms of 1 to 10 scale or any other scale identified by the user). "Critical Delay Causes" obtained by the filtering process will be sorted from the least critical one to the most critical one according to total of their effect levels.
Critical Work Packages		It is the project information that is required for indication of "Work Packages" in projects that any problem or delay is encountered as "Critical Work Packages" on the basis of selected "Filtering Criteria" for the projects.
	Critical Work Package	It is the project information that is provided as dropdown list and corresponds to "Work Packages" in projects that any problem or delay is encountered. It can be edited through "Project Inputs" menu link. "Critical Work Package" may not be assigned or can be assigned more than once.
	Effect Level	It is the information that is to be entered as numerical text and corresponds to the level of effect by the entered "Critical Work Packages" to the project (by indication of the effect in terms of 1 to 10 scale or any other scale identified by the user). "Critical Work Packages" obtained by the filtering process will be sorted from the least critical one to the most critical one according to total of their effect levels.
Critical Actors		It is the project information that is required for indication of "Actors" that are the cause of any problem or delay encountered in projects as "Critical Actors" on the basis of selected "Filtering Criteria" for the projects.
	Critical Actor	It is the project information that is provided as a dropdown list visible upon keyword search and corresponds to "Actors" that are the cause of any problem or delay encountered in projects. It can be identified through "Actors" menu link. "Critical Actors" may not be assigned or can be assigned more than once.
	Effect Level	It is the information that is to be entered as numerical text and corresponds to the level of effect by the entered "Critical Actors" to the project (by indication of the effect in terms of 1 to 10 scale or any other scale identified by the user). "Critical Actors" obtained by the filtering process will be sorted from the least critical one to the most critical one according to total of their effect levels.

Table H.3: Corporate Memory Glossary

Lesson Learned Information		It is the information that is provided to enable the "Lesson Learned Information" entry and direct the lesson search process.
	Lesson Learned Name	It is the compulsory lesson information that is to be entered in text and provides "Lesson Learned" content to be summarized in one sentence.
	Best Practice	It is the lesson information that is provided in selectable form to indicate the lessons that are to be entered as a "Best Practice".
	Event Description	It is the lesson information that is to be entered in text and requires detailed description of the "Lesson Learned" content.
	Recommendatio n	It is the lesson information that is to be entered in text and requires detailed description of the "Recommendations" about the "Lesson Learned".
	Effect on Project Duration	It is the lesson information that is provided in selectable form in the "Very Low - Very High" scale and also to be entered in (positive/negative) "Workday" if its "Effect Amount" is known. It corresponds to the "Effect on Project Duration" due to the experienced lesson.
	Effect on Project Cost	It is the lesson information that is provided in selectable form in the "Very Low - Very High" scale and also to be entered in (positive/negative) "Currency" stated in the project information if its "Effect Amount" is known. It corresponds to the "Effect on Project Cost" due to the experienced lesson.
	Actor	It is the lesson information that is selectable and is provided as a dropdown list visible upon keyword search and requires the assignment of the related "Actor" with the "Lesson Learned".

Table H.3: Corporate Memory Glossary (continued)

Tags	Tagging for "Lesson Learned Information" is used for making search process more efficient by providing grouping on the "Tags" basis. When the user assigns a tag by selecting from the lower level terms of the "Tag Tree" the upper level terms provided in the "Tag Tree" are automatically assigned to the lesson. Thus, the user is enabled to make search at different detail levels. "Tag Tree" allows the user to search for "Tags" within the tree body, once the user writes down for search, the related "Tags" appear in italic form and presented to the user. Content of the tree can be edited through "User Preferences" menu link.
Assigned Tags	It is the lesson information that is to display the "Assigned Tags" all together while entering the "Lesson Learned Information".
Lesson Learned Display Methods	These are the methods that enable "Lessons Learned" to be displayed by filtering through selection of the user.
Filtering	The projects filtered according to the single or multiple attribute selection of the user for "Country", "Project Type", "Contract Type", "Client" and "Partner Company" attributes together with the related lessons learned are presented. Additionally, filtering according to the existing "Tags", "Effect on Project Duration", "Effect on Project Cost", "Approval Status", "Date", "Best Practice" indication and "Actor" within the filtered lessons is provided. Through use of the "Detail" button project information can be displayed by the "Project Card" and the lesson information can be displayed by the "Lesson Card". Moreover, user can modify a lesson through "Edit" and "Delete" buttons and assign an approval status to the lesson through "Approve" and "Rollback Approve" buttons provided.
Similarity	The projects are filtered according to their similarity by using single or multiple attribute selection of the user for "Country", "Project Type", "Contract Type", "Technology" and "Client" attributes and sorted from the most similar to the least similar with indication of the similarity scores and presented together with the related lessons learned. During "Similarity" search "Similarity Percentage" can be assigned to take into consideration the effect of similarity at the attribute level where attribute may be different but be similar for "Country", "Project Type" and "Client" attributes. Additionally, filtering according to the existing "Tags", "Effect on Project Duration", "Effect on Project Cost", "Approval Status", "Date", "Best Practice" indication and "Actor" within the filtered lessons is provided. Through use of the "Detail" button project information can be displayed by the "Project Card" and the lesson information can be displayed by the "Lesson Card". Moreover, user can modify a lesson through "Edit" and "Delete" buttons and assign an approval status to the lesson through "Approve" and "Rollback Approve" buttons provided.
Tags	The projects filtered according to the single or multiple "Tag" selection of the user from "Tag Tree" together with the related lessons learned are presented. Additionally, filtering according to the existing "Tags", "Effect on Project Duration", "Effect on Project Cost", "Approval Status", "Date", "Best Practice" indication and "Actor" within the filtered lessons is provided. Through use of the "Detail" button project information can be displayed by the "Project Card" and the lesson information can be displayed by the "Lesson Card". Moreover, user can modify a lesson through "Edit" and "Delete" buttons and assign an approval status to the lesson through "Approve" and "Rollback Approve" buttons provided.

Table H.4: Predictions Glossary

Prediction Methods	These are the methods that enable "Predictions" to be displayed by filtering through selection of the user.
Filtering	Prediction calculations are based on the projects filtered according to the single or multiple attribute selection of the user for "Country", "Project Type", "Contract Type", "Client" and "Partner Company" attributes.
Similarity	Following the selection of the related project by the user the prediction calculations are based on the projects filtered according to their similarity by using single or multiple attribute selection of the user for "Country", "Project Type", "Contract Type", "Technology" and "Client" attributes and taking into consideration only the 50% or more similar projects. During "Similarity" search "Similarity Percentage" can be assigned to take into consideration the effect of similarity at the attribute level where attribute may be different but be similar for "Country", "Project Type" and "Client" attributes.
Displayed Predictions	It is the information presented by calculation through "Post Project Appraisal Information" entered for "Completed Projects" after selection of the "Prediction Method".
Average Deviation in Profit	It is the "Average Deviation in Profit" calculated in percentage for the filtered projects. It can be deemed as a warning for "Profit" assessment of the project under evaluation.

Table H.4: Predictions Glossary (continued)

Average Profitability	It is the "Average Profitability" calculated in percentage for the filtered projects. It can be deemed as a warning for "Profit" assessment of the project under evaluation.
Average Delay Duration	It is the "Average Delay Duration" calculated in percentage for the filtered projects. It can be deemed as a warning for "Delay Risk" of the project under evaluation.
Average Delay Cost	It is the "Average Delay Cost" calculated in percentage for the filtered projects. It can be deemed as a warning for "Delay Risk" of the project under evaluation.
Average Claim Success (Duration)	It is the "Average Duration Based Claim Success" calculated in percentage for the filtered projects. It can be deemed as a warning for "Risk" of the project under evaluation.
Average Claim Success (Cost)	It is the "Average Cost Based Claim Success" calculated in percentage for the filtered projects. It can be deemed as a warning for "Risk" of the project under evaluation.
Critical Actors	It is the presented information for "Critical Actors" within the filtered projects sorted from most critical actor to the least critical actor according to the total of their "Effect Levels". These "Actors" can be deemed as a warning for the project under evaluation.
Critical Work Packages	It is the presented information for "Critical Work Packages" within the filtered projects sorted from most critical work package to the least critical work package according to the total of their "Effect Levels". These "Work Packages" can be deemed as a warning for the project under evaluation.
Critical Delay Causes	It is the presented information for "Critical Delay Causes" within the filtered projects sorted from most critical delay cause to the least critical delay cause according to the total of their "Effect Levels". These "Delay Causes" can be deemed as a warning for the project under evaluation.

Table H.5: Portfolio Management Glossary

Portfolio Analysis	It is the analysis information calculated automatically and provided upon selection of "Potential Projects" and "Common Currency" by the user. Properties of "Portfolio Alternatives", which are automatically obtained by addition of combination of "Potential Projects" selected by the user to the "On-going Projects" set, are presented to the user.
Common Currency	It is the information to be selected to enable comparison of "Profitability" information of projects in different "Currency". The existing "Profit" information of the projects will be automatically converted into the selected "Currency".
Add Potential Projects	The user can add at most four "Potential Project" alternatives to the "Portfolio Analysis" at once to enable the analysis results to be comparable.
Portfolio Alternatives	They are the "Portfolio Alternatives" that are obtained as a result of "Portfolio Analysis" where "Potential Projects" combinations are automatically added to the "On-going Projects".
Current Portfolio	It is the original portfolio of the user that consists of only the "On-going Projects" at the time of analysis.
Alternatives	These are all "Portfolio Alternatives" in addition to the "Current Portfolio" obtained in single "Portfolio Analysis"
Portfolio Properties	These are the "Portfolio Properties" automatically obtained as a result of "Portfolio Analysis".
Portfolio Name	It is automatically named as "Alternative" with indication of the number; however, it can be edited through the "Operations" menu link.
Average Risk Score	It is the "Average Risk Score" calculated considering the projects of the "Portfolio Alternative" and it represents the "Risk" of the portfolio excluding the "Project Dependencies" of the portfolio.
Average Strategic Fit Score	It is the "Average Strategic Fit Score" calculated considering the projects of the "Portfolio Alternative" and it represents the "Strategic Fit" of the portfolio.
Network Density	It is a value that increases the "Risk" level of the portfolio and calculated according to the "Dependencies" between the projects in the portfolio and depicted with "Dependency Map".
Portfolio Risk	It is the score calculated by "Average Risk Score" calculated with the projects of the "Portfolio Alternative" and the "Network Density" value that represents the "Dependencies" between projects. It represents the actual "Risk" of the portfolio considering the "Project Dependencies" in the portfolio.
Portfolio Success	It is the value created to add negative of the "Portfolio Risk" to the "Portfolio Value", as long as the "Portfolio Risk" increases the "Portfolio Success" decreases. It represents the reliability of the portfolio.
Portfolio Value	It is the value obtained by summation of "Strategic Fit Score" and "Portfolio Success". It constitutes one of the "Portfolio Selection" criteria.
Portfolio Profit	It is the "Average Portfolio Profit" that is calculated by the projects in the "Portfolio Alternative" and presented in the selected "Common Currency". It represents the return of the portfolio.

Table H.5: Portfolio Management Glossary (continued)

Portfolio Graphs	These are the graphs presented for comparing the properties of "Portfolio Alternatives" that are automatically obtained as a result of "Portfolio Analysis".
(Portfolio) Strategic Fit vs. Risk Graph	Bubbles, which indicate the "Portfolio Alternatives", are placed according to "Strategic Fit" and "Risk" values of the portfolios. Bubble diameters are relatively drawn according to the "Portfolio Profitability". When the bubbles are clicked a new page opens as a tab that displays the selected portfolio, this function works as the same with "Display Portfolio" button.
Portfolio Value Graph	"Portfolio Value" is depicted by a "Bar Chart" where "Portfolio Success" and "Strategic Fit" values are represented in different colors.
Portfolio Change Graph (Bubble)	Bubbles, which indicate the "Portfolio Alternatives", are placed according to the "Change" in "Portfolio Value" and "Portfolio Profitability" created by "Portfolio Alternatives" with respect to the "Current Portfolio". Bubble diameters are relatively drawn according to the "Portfolio Profitability". When the bubbles are clicked a new page opens as a tab that displays the selected portfolio, this function works as the same with "Display Portfolio" button.
Portfolio Change Graph (Bar)	"Change" in "Portfolio Value" and "Portfolio Profitability" created by "Portfolio Alternatives" with respect to the "Current Portfolio" are depicted in bar chart with two different colors.
Portfolio Project Properties	These are the properties presented for projects in the "Portfolio Alternatives" that are automatically obtained as a result of "Portfolio Analysis".
Project Risk Score	It is the "Risk Score" of the project in the "Portfolio Alternative" obtained following the assessment process. It is represented for "Risk" comparison of the projects in the portfolio.
Project Strategic Fit Score	It is the "Strategic Fit Score" of the project in the "Portfolio Alternative" obtained following the assessment process. It is represented for "Strategic Fit" comparison of the projects in the portfolio.
Project Centrality	It is the "Centrality Value" of the project within the "Dependency Map" that is obtained as a result of the "Dependencies" between the projects in the "Portfolio Alternative" obtained following the assessment process. It is represented for evaluation of critical projects in the portfolio.
Portfolio Project Graphs	These are the graphs presented for comparison of properties of the projects in the "Portfolio Alternatives" that are automatically obtained as a result of "Portfolio Analysis".
(Project) Strategic Fit vs. Risk Graph	Bubbles, which indicate the projects in the "Portfolio Alternatives", are placed according to "Strategic Fit" and "Risk" values of the projects. Bubble diameters are relatively drawn according to the "Project Profitability".
Dependency Network Map	"Dependencies" between the projects in the "Portfolio Alternative" are depicted by "Dependency Map". Each node and dependency in the "Dependency Map" has appearing information with click. When project node gets double click the "Project Card" can be displayed. The "Dependencies" are depicted in different colors according to their dependency type and depicted in different thicknesses according to their calculated values. Project nodes are drawn relatively according to their "Project Centralities".
Financial Dependency	It represents the dependencies due to project pairs being dependent on the same "Financial Attributes" and it is depicted in "green" in the "Dependency Map". It is automatically calculated through the project attributes and the weights used in dependency calculation and normalization of dependencies can be edited from the "User Preferences" menu link.
Resource Dependency	It represents the dependencies due to project pairs using the same "Resources" and it is depicted in "red" in the "Dependency Map". It is automatically calculated through the project attributes and the weights used in dependency calculation and normalization of dependencies can be edited from the "User Preferences" menu link.
Learning Dependency	It represents the dependencies due to project pairs having the same "Content/Extent" and it is depicted in "blue" in the "Dependency Map". It is automatically calculated through the project attributes and the weights used in dependency calculation and normalization of dependencies can be edited from the "User Preferences" menu link.
Outcome Dependency	It represents the dependencies due to project pairs requiring a "Result/Success" for each other and also any dependency type other than the specified dependencies. It is depicted in "gray" in the "Dependency Map". Its existence is directly asked to the user with its degree under "Dependent Projects" title in the project information entry process. The weights used in normalization of dependencies can be edited from the "User Preferences" menu link.
Project Card	It is the information card that represents the information of the project and some additional "Profitability" calculations and in which general situation of the project is depicted by a "Project Symbol".
Project Symbol	It is the figure in "Project Card" where information of projects as "Name", "Status", "Profitability", "Risk Score" and "Strategic Fit Score" are depicted in summarized form through a colored circular figure and fullness of the partitions of this figure.
Profitability	"Profitability" information of the project is calculated in percentage and depicted with "light blue" fullness ratio in the "Project Symbol".
Risk Score	"Risk Score" of the project is calculated in percentage and depicted with "light pink" fullness ratio in the "Project Symbol".
Strategic Fit Score	"Strategic Fit Score" of the project is calculated in percentage and depicted with "light purple" fullness ratio in the "Project Symbol".

Table H.5: Portfolio Management Glossary (continued)

Status	"Status" information of the project is depicted in the "Project Symbol" in "blue" complete fullness for "Completed Projects", in "green" fullness in "Completion Percentage" ratio for "On-going Projects", in "yellow" complete fullness for "Potential Projects", in "purple" complete fullness for "Suspended Projects", in "light gray" fullness for "Eliminated Projects" and in "gray" complete fullness for "Cancelled Projects".
Portfolio Selection	The user is directed in "Portfolio Selection" by sorting of portfolios through prioritization of portfolios according to different criteria.
Risk Based Selection	The user is directed in "Risk Based Selection" by sorting of "Portfolio Alternatives" through prioritization of portfolios according to their "Risks".
Strategic Fit Based Selection	The user is directed in "Strategic Fit Based Selection" by sorting of "Portfolio Alternatives" through prioritization of portfolios according to their "Strategic Fits".
Portfolio Value Based Selection	The user is directed in "Portfolio Value Based Selection" by sorting of "Portfolio Alternatives" through prioritization of portfolios according to their "Values".
Profitability Based Selection	The user is directed in "Profitability Based Selection" by sorting of "Portfolio Alternatives" through prioritization of portfolios according to their "Profitability".
Warnings	"Warnings" are presented to the user regarding the "Portfolio Selection" and the "Portfolio" under evaluation.
Portfolio “Network Density” Warning	"Warning" is made for the portfolio about heavy "Dependencies". It is presented in case of the "Network Density" is over 0.2 and this limit value can be changed through "Warning Coefficients" available under "Coefficient Constants" under "User Preferences".
Project “Centrality” Warning	"Warning" is made for the "Critical Projects" in the portfolio. It is presented in case of the "Project Centrality" is over 0.5 and this limit value can be changed through "Warning Coefficients" available under "Coefficient Constants" under "User Preferences".
Project “Completion Percentage” Warning	"Warning" is made for the projects in the portfolio that are close to completion. It is presented in case of the "Completion Percentage" value of the project is over 80% and this limit value can be changed through "Warning Coefficients" available under "Coefficient Constants" under "User Preferences".
Project “Adapted Profit Percentage” Warning	"Warning" is made for the "Low Profitable" projects in the portfolio. It is presented in case of the "Adapted Profitability" value of the project is below 5% and this limit value can be changed through "Warning Coefficients" available under "Coefficient Constants" under "User Preferences".
Project “Risk Score" Warning	"Warning" is made for the "Risky" projects in the portfolio. It is presented in case of the "Risk Score" of the project is over 70% and this limit value can be changed through "Warning Coefficients" available under "Coefficient Constants" under "User Preferences".
“Client” Warning	"Warning" is made for the "Critical Clients" assigned to the projects in the portfolio.
“Partner Company” Warning	"Warning" is made for the "Critical Partner Companies" assigned to the projects in the portfolio.
“Financial Dependency” Warning	"Warning" is made for "Financial Dependency" when the projects in the portfolio are 45% or more dependent on the same "Client" or the "Currency" and this limit value can be changed through "Warning Coefficients" available under "Coefficient Constants" under "User Preferences".
“Resource Dependency” Warning	"Warning" is made for "Resource Dependency" when the projects in the portfolio use the same "Resource".
“Learning Dependency” Warning	"Warning" is made for "Learning Dependency" when the projects in the portfolio have 40% or more "Learning Dependency" (when the weighted dependency value is used 40%*weight value should be undertaken) and this limit value can be changed through "Warning Coefficients" available under "Coefficient Constants" under "User Preferences".
“Outcome Dependency” Warning	"Warning" is made for "Outcome Dependency" when there exists "Outcome Dependency" between the projects in the portfolio.
Profit-Value Equilibrium Based Selection Warning	"Warning" is made for the "Portfolio Alternative" with the highest "Profitability" according to the unit negative change in the "Portfolio Value" when all "Portfolio Alternatives" has negative "Change in Value".

Table H.6: Buttons Glossary

Settings	It is the button provided at the top right corner of the tool for changing of "Displayed Record Count" and "Displayed Language".
Change Password	It is the button provided at the top right corner of the tool to enable the user to "Change Password".
Logout	It is the button provided at the top right corner of the tool to enable the user to "Logout".
Add	It is the button provided for "Addition" of any kind of information.
Edit	It is the button provided for "Editing" of any kind of information.
Save	It is the button provided for "Saving" of any kind of information.
Remove	It is the button provided for "Removing" of any kind of information.
Search	It is the button provided for "Searching" of any kind of information.
Sort	It is the button provided for "Sorting" of any kind of information.
Cancel	It is the button provided for "Cancelation" of any kind of operation.
Print	It is the button provided for "Printing" of the charts presented in the tool.
Assign a Role to the User	It is the button provided for "Role Assignment" for the defined users.
Reset Password	It is the button provided for "Password Change" for a previously defined password.
Update Project Constants	It is the button provided for definition of "Project Inputs" in case of definition of a new "Project Input" is required while data entry for projects is being undertaken. The button enables the user to define the input by opening the "Project Inputs" identification menu in the new tab and following the definition on this new page updating the inputs in the project "Data Entry" page by clicking "Update Project Constants" button and continuing to the entry.
Operations	It is the button provided for "Operations" to be grouped and easily accessed through one button.
Lesson Learned Entry	It is the button that leads to "Lesson Learned Entry" for "Completed Projects".
Supportive Information	It is the button that leads to "Operations" required to get insight about the projects before "Risk" and "Strategic Fit" assessment for "On-going" and "Potential" projects.
Display Similar Projects	It is the button that leads to "Display Similar Projects" required to get insight about the projects before "Risk" and "Strategic Fit" assessment for "On-going" and "Potential" projects.
Display Lessons Learned	It is the button that leads to "Display Lessons Learned" required to get insight about the projects before "Risk" and "Strategic Fit" assessment for "On-going" and "Potential" projects.
Display Predictions	It is the button that leads to "Display Predictions" required to get insight about the projects before "Risk" and "Strategic Fit" assessment for "On-going" and "Potential" projects.
Display Learning Potential	It is the button that leads to "Display Learning Potential" required to get insight about the projects before "Risk" and "Strategic Fit" assessment for "On-going" and "Potential" projects. "Learning Potential" is presented through sources of the total through this area, the total result can also be observed from the "Project Card" of "On-going" and "Potential" projects.
Risk Assessment	It is the button that leads to "Risk" assessment for "On-going" and "Potential" projects.
Strategic Fit Assessment	It is the button that leads to "Strategic Fit" assessment for "On-going" and "Potential" projects.
Display	It is the button provided in the "Display Projects" page and provides display "Operations" to be grouped and easily accessed through one button.
Project Card	It is the button that leads to the "Project Card" where project information together with some additional "Profit" calculations and "Learning Potential" value for "On-going" and "Potential" projects are presented and general situation of the project is depicted through the "Project Symbol".
Lesson Cards	It is the button that leads to the information card where "Lesson Learned Information" related with project is presented.
Risk Evaluation History	It is the button that leads to the all "Risk" evaluations made for the project.
Strategic Fit Evaluation History	It is the button that leads to the all "Strategic Fit" evaluations made for the project.
Create Portfolios	It is the button that enables formation of "Portfolio Alternatives" through selection of the "Potential Projects" and "Common Currency" by user.
Delete All Portfolio Alternatives	It is the button that is to be used to completely remove the current "Portfolio Analysis".
Edit Portfolio Name	It is the button that is to be used to change the names of "Portfolio Alternatives" that are automatically named.
Delete Portfolio	It is the button that is to be used to remove a single "Portfolio Alternative" within the analysis.
Display Portfolio	It is the button that is to be used to investigate the "Portfolio Alternative" and the projects included.
Detail	It is the button that leads to "Project Card" or "Lesson Card".
Approve/Rollback Approve	It is the radio button that is to be used to assign an approval status to the related "Lesson Learned".

Table H.6: Buttons Glossary (continued)

Changes In Unit Value	It is the button that leads to the summary version of the "Profit-Value Change Bar Chart " in terms of the change in unit value.
Most Crowded Network	It is the button that leads to the "Dependency Network Map" of the biggest portfolio in the analysis for comparison.
Print Matrix Table	It is the button provided for printing of the "Dependencies" within the "Dependency Network" in a "Matrix Table" form.

APPENDIX I

I. SURVEY 7 - USABILITY TESTING

USABILITY TESTING OF COPPMAN

The aim of the study is to evaluate usability of COPPMAN, which is a portfolio management tool generated for construction projects. Within this context sections of the survey are provided as follows:

1. Section 1: Voluntary Participation Form
2. Section 2: Orientation Script
3. Section 3: Pre-Test Questionnaire
4. Section 4: Post-Task Questionnaires (1 to 6)
5. Section 5: Post-Test Questionnaire: Ratings
6. Section 6: Post-Test Questionnaire: Open-Ended Questions

RATING SCALE

1	2	3	4	5	6	7
Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
(DDD)	**(DD)**	**(D)**	**(N)**	**(A)**	**(AA)**	**(AAA)**

For each statement given below sections, circle the number to the right that best fits your level of agreement. Use the rating scale to select the number.

SECTION 1

VOLUNTARY PARTICIPATION FORM

This research has been carried out by Prof. Dr. Irem Dikmen Toker as one of the instructors from the Department of Civil Engineering. This form is designed to inform you about the survey study conditions.

What is the Object of the Study? The object of the study is to "conduct a usability analysis of the portfolio management tool developed for construction companies". If you agree to participate in the survey, you are expected to use the tool through different scenarios that will be presented to you. Participation in this survey takes about 30 minutes on average.

What we are Expecting from You? During the test period, you are expected to use the tool through 14 different scenarios that are pre-defined and will be operated in the tool. During your utilization of the tool, your thinking aloud will be an important factor for recording your immediate reactions. During this process, your on-screen displays, camera views, sound recordings, eye movements and mouse use will be recorded. One of the researchers will be in the observation room to intervene the test when required (will act as a technical assistant), while the other will be on your side to record your reactions (will also act as practitioner).

How we will Use the Data Collected from You? Your participation in the study should be based entirely on volunteerism. In the questionnaire, you are not asked for any identifying or institutional information. Your answers will be kept strictly confidential and will only be evaluated by researchers. The information obtained from the participants will be evaluated collectively and used in scientific publications. The data you provided will not be matched with the identity information collected on the voluntary participation forms.

Matters you need to know about your participation: The study does not contain any risks beyond the usual risks encountered in daily life. If you feel uncomfortable due to questions during participation or for any other reason, you are free to leave by interrupting the study. In such a case, it will be sufficient to say to the person who applies the study (practitioner) that you want to leave the study. At the end of the study, your questions about this research will be answered. Your participation in the study may be useful for you as an example of usability analysis applications.

If you want to know more about the research: Thank you in advance for participating in this work. You can contact Gozde Bilgin (E-mail: gbilgin@metu.edu.tr), one of the research assistants of the Department of Civil Engineering, for further information about the research.

I have read the above information and fully agree to participate in this work voluntarily.

(Once you have completed the form and signed, please give it back to the practitioner).

Name Surname: Date: Signature:

SECTION 2
ORIENTATION SCRIPT

Our objective is to observe you while you are using COPPMAN (COnstruction Project Portfolio MANagement) tool to determine design inconsistencies and usability problem areas within the user interface and content areas. Data will be used to access whether usability goals regarding an effective, efficient, and well-received user interface have been achieved. Please keep in mind that the performance of the tool will be tested rather than you.

Test Content: During the test you will use the tool within 14 task scenarios and you will evaluate questionnaires following completion of some of the tasks and a last questionnaire at the end of the test. The whole session may last approximately 30 minutes.

Test Environment: Your face, your voice, and the screen together with your gaze plot, mouse clicks, task completion times, etc. will be recorded by TOBII software which will provide us to obtain some quantitative evaluation data. A moderator will sit next to you to observe and record your reactions as qualitative data. Another moderator will be in the control room and follow the test process and take action regarding with the test in case of need.

Your Responsibility: If you cannot complete a task you can click escape etc. Please do not hesitate to ask questions or a break during the test, they will be provided without violating the test objective. You can check the tool library for help any time. During the session, you should “Think Aloud” to help us keeping your reactions. Please try to behave normal. There is no wrong answer in the tasks, we are only trying to understand the success of the tool.

Your Contribution: Your data will be collected through two main metrics as;

- **Performance Data:** Objective measures of your behaviors during the test such as task completion success, errors, etc.
- **Preference Data:** Subjective measure of your evaluations through questionnaires on your feelings/opinions such as overall ease of use, usefulness of terms and labelling, perceived amount of time and number of steps, etc.

Form Outline: The form consists of three main sections as;

- **Pre-Test Questionnaire:** Short background questionnaire,
- **Post-Task Questionnaire:** Evaluations upon completion of task scenarios,
- **Post-Test Questionnaire:** Evaluation upon overall.

Thank you for your participation!

SECTION 3
PRE-TEST QUESTIONNAIRE
USER BACKGROUND
Title:
Education:
Gender:
Age: ☐ 18-24 ☐ 25-28 ☐ 29-32
Computer Usage: ☐ 0-10 hours per week ☐ 11-25 hours per week ☐ +26 hours per week
Knowledge in Construction Management: ☐ High ☐ Medium ☐ Low
Knowledge in Portfolio Management: ☐ High ☐ Medium ☐ Low
Knowledge in Information Technology: ☐ High ☐ Medium ☐ Low

SECTION 4: POST-TASK QUESTIONNAIRE 1								
SCENARIO 1&2: PROJECT INPUTS MENU								
Statement	**Scale**							
	DDD	**DD**	**D**	**N**	**A**	**AA**	**AAA**
EASE OF USE								
1. It was easy to find my way to relevant information from the homepage.	1	2	3	4	5	6	7
2. As I was searching for the information, I was able to keep track of where I was in the page.	1	2	3	4	5	6	7
3. I was able to accurately find which section of the page contained relevant information.	1	2	3	4	5	6	7
4. It requires the fewest steps possible to accomplish what I want to do with it.	1	2	3	4	5	6	7
5. The terminology was clear and understandable.	1	2	3	4	5	6	7
6. It provides flexibility in identification of actors through detail section.	1	2	3	4	5	6	7
7. It is easy to find and use buttons.	1	2	3	4	5	6	7
8. Utilizing actor type by switch button is useful.	1	2	3	4	5	6	7
9. Searching and refining actors were useful and easy.	1	2	3	4	5	6	7
10. The representation of actors was useful.	1	2	3	4	5	6	7
11. I was satisfied with the ease of completing the task.	1	2	3	4	5	6	7
12. I was satisfied with the amount of time it took to complete the task.	1	2	3	4	5	6	7
SATISFACTION								
1. It works the way I expected.	1	2	3	4	5	6	7
2. The amount of information was sufficient.	1	2	3	4	5	6	7
3. Establishment of an automatic warning system for current portfolios is an important feature	1	2	3	4	5	6	7
4. I am satisfied with performing this task.	1	2	3	4	5	6	7
5. I am satisfied with the visibility of the system.	1	2	3	4	5	6	7
6. I am satisfied with the visual layout.	1	2	3	4	5	6	7
7. I am satisfied with the design.	1	2	3	4	5	6	7

SECTION 4: POST-TASK QUESTIONNAIRE 1							
SCENARIO 1&2: PROJECT INPUTS MENU							
Statement	**Scale**						
	DDD	**DD**	**D**	**N**	**A**	**AA**	**AAA**
CONSISTENCY							
1. The information provided was relevant to the task.	1	2	3	4	5	6	7
2. The terminology was related to the task.	1	2	3	4	5	6	7
3. The ordering of the information was logical.	1	2	3	4	5	6	7
4. The interface was well-suited and consistent with other interfaces.	1	2	3	4	5	6	7
5. I did not observe any inconsistencies.	1	2	3	4	5	6	7
LEARNABILITY							
1. I learnt to perform the task quickly/easily.	1	2	3	4	5	6	7
2. I can easily remember how to carry out the task.	1	2	3	4	5	6	7
3. I can easily remember the names and use of buttons.	1	2	3	4	5	6	7
4. It is easy to remember the interface.	1	2	3	4	5	6	7
5. I can perform the task successfully every time.	1	2	3	4	5	6	7
6. I can perform this task without help.	1	2	3	4	5	6	7
7. The representation makes it easily understandable.	1	2	3	4	5	6	7
USER GUIDANCE							
1. Information/Feedback/Error messages were helpful.	1	2	3	4	5	6	7
2. It provides cancel or back options.	1	2	3	4	5	6	7
3. It is easy to recover from mistakes while performing the task.	1	2	3	4	5	6	7
4. It provides guidance in information entry.	1	2	3	4	5	6	7
5. It provides helpful guidance in performing tasks.	1	2	3	4	5	6	7
6. The help option was useful (applicable if it was used).	1	2	3	4	5	6	7

SECTION 4: POST-TASK QUESTIONNAIRE 2								
SCENARIO 3&4: USER PREFERENCES MENU								
Statement		**Scale**						
		DDD	**DD**	**D**	**N**	**A**	**AA**	**AAA**
EASE OF USE								
1.	It was easy to find my way to relevant information from the homepage.	1	2	3	4	5	6	7
2.	As I was searching for the information, I was able to keep track of where I was in the page.	1	2	3	4	5	6	7
3.	I was able to accurately find which section of the page contained relevant information.	1	2	3	4	5	6	7
4.	It requires the fewest steps possible to accomplish what I want to do with it.	1	2	3	4	5	6	7
5.	The terminology was clear and understandable.	1	2	3	4	5	6	7
6.	It provides flexibility in identification of factors.	1	2	3	4	5	6	7
7.	It is easy to find and use buttons.	1	2	3	4	5	6	7
8.	Utilizing activation by switch button is useful.	1	2	3	4	5	6	7
9.	It is easy to copy and edit a factor set.	1	2	3	4	5	6	7
10.	It is easy to assign weights.	1	2	3	4	5	6	7
11.	Searching and refining were useful and easy.	1	2	3	4	5	6	7
12.	The representation of factors was useful.	1	2	3	4	5	6	7
13.	It is easy to change the order of factors within a factor set.	1	2	3	4	5	6	7
14.	I was satisfied with the ease of completing the task.	1	2	3	4	5	6	7
15.	I was satisfied with the amount of time it took to complete the task.	1	2	3	4	5	6	7
SATISFACTION								
1.	It works the way I expected.	1	2	3	4	5	6	7
2.	The amount of information was sufficient.	1	2	3	4	5	6	7
3.	Establishment of an automatic warning system for current portfolios is an important feature	1	2	3	4	5	6	7
4.	I am satisfied with performing this task.	1	2	3	4	5	6	7
5.	I am satisfied with the visibility of the system.	1	2	3	4	5	6	7
6.	I am satisfied with the visual layout.	1	2	3	4	5	6	7
7.	I am satisfied with the design.	1	2	3	4	5	6	7

SECTION 4: POST-TASK QUESTIONNAIRE 2								
SCENARIO 3&4: USER PREFERENCES MENU								
Statement		**Scale**						
		DDD	**DD**	**D**	**N**	**A**	**AA**	**AAA**
CONSISTENCY								
1.	The information provided was relevant to the task.	1	2	3	4	5	6	7
2.	The terminology was related to the task.	1	2	3	4	5	6	7
3.	The ordering of the information was logical.	1	2	3	4	5	6	7
4.	The interface was well-suited and consistent with other interfaces.	1	2	3	4	5	6	7
5.	I did not observe any inconsistencies.	1	2	3	4	5	6	7
LEARNABILITY								
1.	I learnt to perform the task quickly/easily.	1	2	3	4	5	6	7
2.	I can easily remember how to carry out the task.	1	2	3	4	5	6	7
3.	I can easily remember the names and use of buttons.	1	2	3	4	5	6	7
4.	It is easy to remember the interface.	1	2	3	4	5	6	7
5.	I can perform the task successfully every time.	1	2	3	4	5	6	7
6.	I can perform this task without help.	1	2	3	4	5	6	7
7.	The representation makes it easily understandable.	1	2	3	4	5	6	7
USER GUIDANCE								
1.	Information/Feedback/Error messages were helpful.	1	2	3	4	5	6	7
2.	It provides cancel or back options.	1	2	3	4	5	6	7
3.	It is easy to recover from mistakes while performing the task.	1	2	3	4	5	6	7
4.	It provides guidance in normalization of factor weights.	1	2	3	4	5	6	7
5.	It provides guidance in information entry.	1	2	3	4	5	6	7
6.	It provides helpful guidance in performing tasks.	1	2	3	4	5	6	7
7.	The help option was useful (applicable if it was used).	1	2	3	4	5	6	7

SECTION 4: POST-TASK QUESTIONNAIRE 3								
SCENARIO 5-8: PROJECTS MENU								
Statement		**Scale**						
		DDD	**DD**	**D**	**N**	**A**	**AA**	**AAA**
EASE OF USE								
1.	It was easy to find my way to relevant information from the homepage.	1	2	3	4	5	6	7
2.	As I was searching for the information, I was able to keep track of where I was in the page.	1	2	3	4	5	6	7
3.	I was able to accurately find which section of the page contained relevant information.	1	2	3	4	5	6	7
4.	It requires the fewest steps possible to accomplish what I want to do with it.	1	2	3	4	5	6	7
5.	The terminology was clear and understandable.	1	2	3	4	5	6	7
6.	It provides flexibility in identification of inputs.	1	2	3	4	5	6	7
7.	It provides flexibility in identification of projects through scope section.	1	2	3	4	5	6	7
8.	It is useful to assign a short code for projects to ease their representation.	1	2	3	4	5	6	7
9.	It is easy to find and use buttons.	1	2	3	4	5	6	7
10.	It is easy to assign ratings.	1	2	3	4	5	6	7
11.	It is easy to enter information through drop-down lists.	1	2	3	4	5	6	7
12.	Searching and refining were useful and easy.	1	2	3	4	5	6	7
13.	It is easy to select projects for operation.	1	2	3	4	5	6	7
14.	It is easy to perform project operations.	1	2	3	4	5	6	7
15.	I was satisfied with the ease of completing the task.	1	2	3	4	5	6	7
16.	I was satisfied with the amount of time it took to complete the task.	1	2	3	4	5	6	7
SATISFACTION								
1.	It works the way I expected.	1	2	3	4	5	6	7
2.	The amount of information was sufficient.	1	2	3	4	5	6	7
3.	I am satisfied with performing this task.	1	2	3	4	5	6	7
4.	I am satisfied with the visibility of the system.	1	2	3	4	5	6	7
5.	I am satisfied with the visual layout.	1	2	3	4	5	6	7
6.	I am satisfied with the design.	1	2	3	4	5	6	7
7.	I am satisfied with the loading time.	1	2	3	4	5	6	7

SECTION 4: POST-TASK QUESTIONNAIRE 3								
SCENARIO 5-8: PROJECTS MENU								
Statement		**Scale**						
		DDD	**DD**	**D**	**N**	**A**	**AA**	**AAA**
CONSISTENCY								
1.	The information provided was relevant to the task.	1	2	3	4	5	6	7
2.	The terminology was related to the task.	1	2	3	4	5	6	7
3.	The ordering of the information was logical.	1	2	3	4	5	6	7
4.	The interface was well-suited and consistent with other interfaces.	1	2	3	4	5	6	7
5.	I did not observe any inconsistencies.	1	2	3	4	5	6	7
LEARNABILITY								
1.	I learnt to perform the task quickly/easily.	1	2	3	4	5	6	7
2.	I can easily remember how to carry out the task.	1	2	3	4	5	6	7
3.	I can easily remember the names and use of buttons.	1	2	3	4	5	6	7
4.	It is easy to remember the interface.	1	2	3	4	5	6	7
5.	I can perform the task successfully every time.	1	2	3	4	5	6	7
6.	I can perform this task without help.	1	2	3	4	5	6	7
7.	The representation makes it easily understandable.	1	2	3	4	5	6	7
USER GUIDANCE								
1.	Information/Feedback/Error messages were helpful.	1	2	3	4	5	6	7
2.	It provides cancel or back options.	1	2	3	4	5	6	7
3.	It is easy to recover from mistakes while performing the task.	1	2	3	4	5	6	7
4.	It provides guidance in information entry.	1	2	3	4	5	6	7
5.	It provides helpful guidance in performing tasks.	1	2	3	4	5	6	7
6.	The help option was useful (applicable if it was used).	1	2	3	4	5	6	7

SECTION 4: POST-TASK QUESTIONNAIRE 4							
SCENARIO 9&10: CORPORATE MEMORY MENU							
Statement	**Scale**						
	DDD	**DD**	**D**	**N**	**A**	**AA**	**AAA**
EASE OF USE							
1. It was easy to find my way to relevant information from the homepage.	1	2	3	4	5	6	7
2. As I was searching for the information, I was able to keep track of where I was in the page.	1	2	3	4	5	6	7
3. I was able to accurately find which section of the page contained relevant information.	1	2	3	4	5	6	7
4. It requires the fewest steps possible to accomplish what I want to do with it.	1	2	3	4	5	6	7
5. The terminology was clear and understandable.	1	2	3	4	5	6	7
6. It provides flexibility in identification of inputs.	1	2	3	4	5	6	7
7. It provides flexibility in identification of lessons/recommendations through event description section.	1	2	3	4	5	6	7
8. It provides flexibility and easiness in assignment of tags.	1	2	3	4	5	6	7
9. It is easy to find and use buttons.	1	2	3	4	5	6	7
10. It is easy to assign effect levels.	1	2	3	4	5	6	7
11. Highlighting of the related lessons on the screen simplifies tag assignment.	1	2	3	4	5	6	7
12. Utilizing approve/rollback approve button is useful.	1	2	3	4	5	6	7
13. Searching and refining were useful and easy.	1	2	3	4	5	6	7
14. I was satisfied with the ease of completing the task.	1	2	3	4	5	6	7
15. I was satisfied with the amount of time it took to complete the task.	1	2	3	4	5	6	7
SATISFACTION							
1. It works the way I expected.	1	2	3	4	5	6	7
2. The amount of information was sufficient.	1	2	3	4	5	6	7
3. I am satisfied with performing this task.	1	2	3	4	5	6	7
4. I am satisfied with the visibility of the system.	1	2	3	4	5	6	7
5. I am satisfied with the visual layout.	1	2	3	4	5	6	7
6. I am satisfied with the design.	1	2	3	4	5	6	7
7. I am satisfied with the loading time.	1	2	3	4	5	6	7

SECTION 4: POST-TASK QUESTIONNAIRE 4								
SCENARIO 9&10: CORPORATE MEMORY MENU								
Statement		**Scale**						
		DDD	**DD**	**D**	**N**	**A**	**AA**	**AAA**
CONSISTENCY								
1.	The information provided was relevant to the task.	1	2	3	4	5	6	7
2.	The terminology was related to the task.	1	2	3	4	5	6	7
3.	The ordering of the information was logical.	1	2	3	4	5	6	7
4.	The interface was well-suited and consistent with other interfaces.	1	2	3	4	5	6	7
5.	I did not observe any inconsistencies.	1	2	3	4	5	6	7
LEARNABILITY								
1.	I learnt to perform the task quickly/easily.	1	2	3	4	5	6	7
2.	I can easily remember how to carry out the task.	1	2	3	4	5	6	7
3.	I can easily remember the names and use of buttons.	1	2	3	4	5	6	7
4.	It is easy to remember the interface.	1	2	3	4	5	6	7
5.	I can perform the task successfully every time.	1	2	3	4	5	6	7
6.	I can perform this task without help.	1	2	3	4	5	6	7
7.	The representation makes it easily understandable.	1	2	3	4	5	6	7
USER GUIDANCE								
1.	Information/Feedback/Error messages were helpful.	1	2	3	4	5	6	7
2.	It provides cancel or back options.	1	2	3	4	5	6	7
3.	It is easy to recover from mistakes while performing the task.	1	2	3	4	5	6	7
4.	It provides guidance in information entry.	1	2	3	4	5	6	7
5.	It provides helpful guidance in performing tasks.	1	2	3	4	5	6	7
6.	The help option was useful (applicable if it was used).	1	2	3	4	5	6	7

SECTION 4: POST-TASK QUESTIONNAIRE 5								
SCENARIO 11: PREDICTIONS MENU								
Statement		**Scale**						
		DDD	**DD**	**D**	**N**	**A**	**AA**	**AAA**
EASE OF USE								
1.	It was easy to find my way to relevant information from the homepage.	1	2	3	4	5	6	7
2.	As I was searching for the information, I was able to keep track of where I was in the page.	1	2	3	4	5	6	7
3.	I was able to accurately find which section of the page contained relevant information.	1	2	3	4	5	6	7
4.	It requires the fewest steps possible to accomplish what I want to do with it.	1	2	3	4	5	6	7
5.	The displayed information was clear.	1	2	3	4	5	6	7
6.	The terminology was clear and understandable.	1	2	3	4	5	6	7
7.	It is easy to find and use buttons.	1	2	3	4	5	6	7
8.	Searching and refining were useful and easy.	1	2	3	4	5	6	7
9.	It is easy to examine the results.	1	2	3	4	5	6	7
10.	I was satisfied with the ease of completing the task.	1	2	3	4	5	6	7
11.	I was satisfied with the amount of time it took to complete the task.	1	2	3	4	5	6	7
SATISFACTION								
1.	It works the way I expected.	1	2	3	4	5	6	7
2.	The amount of information was sufficient.	1	2	3	4	5	6	7
3.	I am satisfied with performing this task.	1	2	3	4	5	6	7
4.	I am satisfied with the visibility of the system.	1	2	3	4	5	6	7
5.	I am satisfied with the visual layout.	1	2	3	4	5	6	7
6.	I am satisfied with the design.	1	2	3	4	5	6	7
7.	I am satisfied with the loading time.	1	2	3	4	5	6	7

SECTION 4: POST-TASK QUESTIONNAIRE 5							
SCENARIO 11: PREDICTIONS MENU							
Statement	**Scale**						
	DDD	**DD**	**D**	**N**	**A**	**AA**	**AAA**
CONSISTENCY							
1. The information provided was relevant to the task.	1	2	3	4	5	6	7
2. The terminology was related to the task.	1	2	3	4	5	6	7
3. The ordering of the information was logical.	1	2	3	4	5	6	7
4. The interface was well-suited and consistent with other interfaces.	1	2	3	4	5	6	7
5. I did not observe any inconsistencies.	1	2	3	4	5	6	7
LEARNABILITY							
1. I learnt to perform the task quickly/easily.	1	2	3	4	5	6	7
2. I can easily remember how to carry out the task.	1	2	3	4	5	6	7
3. I can easily remember the names and use of buttons.	1	2	3	4	5	6	7
4. It is easy to remember the interface.	1	2	3	4	5	6	7
5. I can perform the task successfully every time.	1	2	3	4	5	6	7
6. I can perform this task without help.	1	2	3	4	5	6	7
7. The representation makes it easily understandable.	1	2	3	4	5	6	7
USER GUIDANCE							
1. Information/Feedback/Error messages were helpful.	1	2	3	4	5	6	7
2. It provides cancel or back options.	1	2	3	4	5	6	7
3. It is easy to recover from mistakes while performing the task.	1	2	3	4	5	6	7
4. It provides helpful guidance in performing tasks.	1	2	3	4	5	6	7
5. The help option was useful (applicable if it was used).	1	2	3	4	5	6	7

SECTION 4: POST-TASK QUESTIONNAIRE 6								
SCENARIO 12-14: PORTFOLIO MANAGEMENT MENU								
Statement	**Scale**							
	DDD	**DD**	**D**	**N**	**A**	**AA**	**AAA**	
EASE OF USE								
1. It was easy to find my way to relevant information from the homepage.	1	2	3	4	5	6	7	
2. As I was searching for the information, I was able to keep track of where I was in the page.	1	2	3	4	5	6	7	
3. I was able to accurately find which section of the page contained relevant information.	1	2	3	4	5	6	7	
4. It requires the fewest steps possible to accomplish what I want to do with it.	1	2	3	4	5	6	7	
5. The displayed information was clear.	1	2	3	4	5	6	7	
6. The terminology was clear and understandable.	1	2	3	4	5	6	7	
7. Searching and refining were useful and easy.	1	2	3	4	5	6	7	
8. It is easy to find and use buttons.	1	2	3	4	5	6	7	
9. Utilizing create/delete portfolio buttons were useful.	1	2	3	4	5	6	7	
10. It is easy to select the projects and the common currency before analysis.	1	2	3	4	5	6	7	
11. It provides flexibility in identification of projects and the currency required for analysis.	1	2	3	4	5	6	7	
12. It is easy to perform portfolio analysis.	1	2	3	4	5	6	7	
13. It is easy to examine the results of portfolio analysis.	1	2	3	4	5	6	7	
14. The representation of project information through the figure and the card was useful.	1	2	3	4	5	6	7	
15. The dependency map was representative and useful.	1	2	3	4	5	6	7	
16. It is easy to examine the portfolio analysis results through the tables.	1	2	3	4	5	6	7	
17. It is easy to examine the portfolio analysis results through the graphs.	1	2	3	4	5	6	7	
18. It is easy to examine the warnings provided.	1	2	3	4	5	6	7	
19. Changing order of the portfolios for selection by switch button is useful.	1	2	3	4	5	6	7	
20. I was satisfied with the ease of completing the task.	1	2	3	4	5	6	7	
21. I was satisfied with the amount of time it took to complete the task.	1	2	3	4	5	6	7	

SECTION 4: POST-TASK QUESTIONNAIRE 6							
SCENARIO 12-14: PORTFOLIO MANAGEMENT MENU							
Statement	**Scale**						
	DDD	**DD**	**D**	**N**	**A**	**AA**	**AAA**
SATISFACTION							
1. It works the way I expected.	1	2	3	4	5	6	7
2. The amount of information was sufficient.	1	2	3	4	5	6	7
3. I am satisfied with performing this task.	1	2	3	4	5	6	7
4. I am satisfied with the visibility of the system.	1	2	3	4	5	6	7
5. I am satisfied with the visual layout.	1	2	3	4	5	6	7
6. I am satisfied with the design.	1	2	3	4	5	6	7
7. I am satisfied with the loading time.	1	2	3	4	5	6	7
CONSISTENCY							
1. The information provided was relevant to the task.	1	2	3	4	5	6	7
2. The terminology was related to the task.	1	2	3	4	5	6	7
3. The ordering of the information was logical.	1	2	3	4	5	6	7
4. The interface was well-suited and consistent with other interfaces.	1	2	3	4	5	6	7
5. I did not observe any inconsistencies.	1	2	3	4	5	6	7
LEARNABILITY							
1. I learnt to perform the task quickly/easily.	1	2	3	4	5	6	7
2. I can easily remember how to carry out the task.	1	2	3	4	5	6	7
3. I can easily remember the names and use of buttons.	1	2	3	4	5	6	7
4. It is easy to remember the interface.	1	2	3	4	5	6	7
5. I can perform the task successfully every time.	1	2	3	4	5	6	7
6. I can perform this task without help.	1	2	3	4	5	6	7
7. The representation makes it easily understandable.	1	2	3	4	5	6	7

SECTION 4: POST-TASK QUESTIONNAIRE 6								
SCENARIO 12-14: PORTFOLIO MANAGEMENT MENU								
Statement		**Scale**						
		DDD	**DD**	**D**	**N**	**A**	**AA**	**AAA**
USER GUIDANCE								
1.	Information/Feedback/Error messages were helpful.	1	2	3	4	5	6	7
2.	It provides cancel or back options.	1	2	3	4	5	6	7
3.	It is easy to recover from mistakes while performing the task.							
4.	It provides guidance in selection of required information.	1	2	3	4	5	6	7
5.	It provides helpful guidance in performing tasks.	1	2	3	4	5	6	7
6.	The help option was useful (applicable if it was used).	1	2	3	4	5	6	7

SECTION 5: POST-TEST QUESTIONNAIRE: RATINGS							
OVERALL EVALUATION							
Statement	**Scale**						
	D D D	**D D**	**D**	**N**	**A**	**A A**	**A A A**
1. Using the tool was very easy.	1	2	3	4	5	6	7
2. The terminology was easy to understand, clear and consistent.	1	2	3	4	5	6	7
3. The tool interface and the sequence was intuitive.	1	2	3	4	5	6	7
4. Navigating through the tool was very easy.	1	2	3	4	5	6	7
5. Finding desired menu choices was very easy.	1	2	3	4	5	6	7
6. Page design/graphics was useful.	1	2	3	4	5	6	7
7. Locating the information needed in the tool was very easy.	1	2	3	4	5	6	7
8. The speed of the system was appropriate.	1	2	3	4	5	6	7
9. The tool is sufficient in providing visibility of system status and it is able to keep user informed about what is going on through the feedback provided within reasonable time.	1	2	3	4	5	6	7
10. The portfolio analysis results and graphs are adequate to display information regarding a project or portfolio under evaluation.	1	2	3	4	5	6	7
11. The provided system language was familiar and the information provided was appearing in a natural and logical order.	1	2	3	4	5	6	7
12. The tool provides user control and freedom through its cancel and back options.	1	2	3	4	5	6	7
13. The tool provides consistency in usage of words, situations and actions.	1	2	3	4	5	6	7
14. The tool provides suitable error messages for error prevention.	1	2	3	4	5	6	7
15. The tool provides recognition rather than recall through making objects, actions and options visible or easily retrievable when required.	1	2	3	4	5	6	7
16. The tool provides flexibility and efficiency of use through user defined sections.	1	2	3	4	5	6	7
17. The tool has an aesthetic and minimalist design since its dialogues do not contain irrelevant information.	1	2	3	4	5	6	7
18. Error messages provided in plain language in the tool help users to recognize, diagnose, and recover from errors.	1	2	3	4	5	6	7
19. The tool provides easy to search help and documentation through the library.	1	2	3	4	5	6	7
20. Content and communication provided in the tool is adequate in terms of visual and verbal information.	1	2	3	4	5	6	7
21. The tool provides content with appropriate legibility.	1	2	3	4	5	6	7
22. I'm satisfied with my experience using the tool.	1	2	3	4	5	6	7
23. If the tool was available in the market, I would use it.	1	2	3	4	5	6	7

SECTION 6: POST-TEST QUESTIONNAIRE: OPEN-ENDED QUESTIONS

- What did you like most about the tool?

- What did you like least about the tool?

- Was there any task that was difficult for you to do?

- What else should be included in the tool to make it more usable?

- Would you like to make any comments or suggestions about the tool?

- If you are not likely to use the tool, why?

APPENDIX J

J. SESSION AUDIT FORM

PARTICIPANT:

- **Scenario:**

- **Scenario:**

- **Scenario:**

APPENDIX K

K. SURVEY 8 - REAL APPLICATION

Practitioner Information
Title:
Education:
Experience:
Use of Company Specific Tools:
Knowledge in Information Technology: High / Medium / Low
Knowledge in Portfolio Management: High / Medium / Low
Form Outline
Section 1 – Open-Ended Questions
In this section you are asked to evaluate the real application process through open-ended questions.
Section 2 – Ratings
In this section you are asked to evaluate how much COPPMAN meets the expected benefits by indicating the ratings to the provided statements for each section.

SECTION 1 – OPEN-ENDED QUESTIONS

- Please indicate your general comments about COPPMAN. What did you like most?

- Please indicate any limitations/improvements of COPPMAN or item/property that needs to be changed in or be added to COPPMAN.

- What would be the expected benefits of COPPMAN for companies in general?

- Please indicate possible benefits of implementing COPPMAN in your organization.

- Please indicate possible barriers to implementing COPPMAN in your organization.

SECTION 2: RATINGS

EVALUATION OF THE REAL APPLICATION PROCESS

RATING SCALE

1	2	3	4	5	6	7
Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
(DDD)	**(DD)**	**(D)**	**(N)**	**(A)**	**(AA)**	**(AAA)**

For each statement given below (except for the 17th statement), circle the number to the right that best fits your level of agreement. Use the rating scale to select the number.

Statement	Scale						
	DDD	**DD**	**D**	**N**	**A**	**AA**	**AAA**
1. COPPMAN tool provides an effective portfolio management.	1	2	3	4	5	6	7
2. We are satisfied with the COPPMAN implementation.	1	2	3	4	5	6	7
3. We are satisfied with the features/components of COPPMAN tool.	1	2	3	4	5	6	7
4. COPPMAN tool is useful for organizational learning.	1	2	3	4	5	6	7
5. COPPMAN tool is useful for portfolio risk evaluation.	1	2	3	4	5	6	7
6. COPPMAN tool facilitates strategic evaluation of the portfolio.	1	2	3	4	5	6	7
7. COPPMAN tool supports effective reporting and documentation.	1	2	3	4	5	6	7
8. COPPMAN tool facilitates visualization of the portfolios.	1	2	3	4	5	6	7
9. COPPMAN tool provides adequate warnings regarding the portfolios.	1	2	3	4	5	6	7
10. COPPMAN tool eases selection of the right projects.	1	2	3	4	5	6	7
11. COPPMAN tool facilitates decision-making for managers	1	2	3	4	5	6	7
12. COPPMAN tool provides support for short and long term planning.	1	2	3	4	5	6	7
13. COPPMAN tool is user-friendly.	1	2	3	4	5	6	7
14. COPPMAN tool does not require extra burden (additional cost / workload or legal issues) for implementation.	1	2	3	4	5	6	7
15. COPPMAN tool would be implementable in our organization.	1	2	3	4	5	6	7
16. COPPMAN tool would be implementable in similar construction organizations.	1	2	3	4	5	6	7

SECTION 2: RATINGS

EVALUATION OF THE REAL APPLICATION PROCESS

17. Possible benefits with utilization of COPPMAN in your company: *please select*

it may provide:

- ☐ *achievement of strategic objectives*
- ☐ *minimization of risk*
- ☐ *selection of right projects (optimum portfolio)*
- ☐ *better long term profitability*
- ☐ *better knowledge management and organizational learning*
- ☐ *better resource management*
- ☐ *better scheduling*
- ☐ *better strategic planning*
- ☐ *better communication within the company*
- ☐ *better documentation and reporting*
- ☐ *cost savings*
- ☐ *time savings*

CURRICULUM VITAE

PERSONAL INFORMATION

Surname, Name	: Bilgin, Gözde
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EDUCATION

Degree	**Institution**	**Year of Graduation**
MS	METU Civil Engineering	2011
BS	METU Civil Engineering	2008
High School	Ankara Atatürk High School, Ankara	2004

WORK EXPERIENCE

Year	**Place**	**Enrollment**
February-June 2018	METU-NCC Department of Civil Engineering	Part-time Instructor
2012 - 2017	METU Department of Civil Engineering	Research Assistant
2009 - 2012	Merkezi Isıtma Sistemleri Engineering Ltd. Co.	Project Engineer
2007 Summer	Kınacı Engineering Architectural Consultancy Ltd. Co.	Intern Engineering Student
2006 Summer	Uğur Barlık Construction Industry & Trade Ltd. Co.	Intern Engineering Student

FOREIGN LANGUAGES

Advanced English, Beginner German, Beginner Russian

PUBLICATIONS

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HOBBIES

Reading, Movies, Walking, Pilates, Tai-Chi, Qigong