THE EXTENT OF INFORMATION VISUALISATION IN TURKISH CONSTRUCTION INDUSTRY: A QFD APPROACH

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ABSTRACT

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Distances between dispersed locations may be largely overcome through efficient use of modern data transfer and communication systems. Unfortunately the conclusions drawn from research and surveys carried out in the industry show that companies generally fail in using information technologies properly and that there is a significant communication gap - therefore coordination and cooperation gap - between the site offices and the main office due to data transfer lags and lack

of visualised information. How information is presented has a great bearing on quality of information and visualisation is one of the most important tools used to improve data presentation.

The purpose of this thesis is to evaluate the extent of visualisation as a communication tool in construction industry and to determine potential benefits to be gained through implementation of visualisation. Therefore, available visualisation resources are investigated among Turkish AEC companies. The current status of visualisation use for communication in construction firms is mapped and described. Information flow contents and types are analysed to determine which information in the construction process can be visually represented. Finally, a QFD approach is used for a combined evaluation of the research findings together with the customer needs and requirements expected from visualised information

Keywords: visualisation, communication, QFD, information flow

ÖZ

TÜRK İNŞAAT ENDÜSTRİSİNDE BİLGİ GÖRÜNTÜLENMESİ VE GÖRSELLİĞİNİN KULLANIMI: BİR KALİTE FONKSİYON AÇILIMI YAKLAŞIMI

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Modern data iletim ve iletişim sistemlerinin etkin kullanılmasıyla dağınık yerler arasındaki uzaklıklar yenilebilir. Ne yazık ki sektörde yürütülmüş araştırma ve incelemelerde şirketlerin genellikle bilgi teknolojilerini yerinde ve doğru şekilde kullanmakta başarılı olmadıkları ve şantiyeler ile merkez ofis arasında data iletim gecikmelerine ve görsel bilgilerin eksikliğine bağlı olarak ciddi bir iletişim boşluğu –dolayısıyla işbirliği ve koordinasyon eksikliği- olduğu gözlemlenmiştir. Bilginin

sunuluş şekli bilginin kalitesi üzerinde oldukça kuvvetli bir etkendir ve görüntüleme/görselleştirme bilginin sunumunu geliştirmede kullanılan araçların en önemlilerinden biridir.

Bu tezin amacı görselleştirmenin inşaat sektöründe iletişim amaçlı olarak ne derece kullanıldığını belirlemek ve görüntüleme uygulamalarının getireceği potansiyel kazançları ortaya çıkartmaktır. Bu nedenle Türk tasarım ve inşaat şirketlerindeki mevcut görsellik kaynakları araştırılmış ve inşaat şirketlerindeki görselleştirme kullanımının bugünkü durumu tespit edilmiş ve betimlenmiştir. Şirketlerdeki bilgi akışı içerikleri ve türleri, yapım sürecindeki hangi tip bilginin görsel gösteriminin mümkün olduğunun tespit edilmesi amacıyla incelenmiştir. Son olarak, araştırma sonuçları ile görsel bilgi sistemlerine dair kullanıcı istek ve gereksinimlerinin birleşik değerlendirilmesi için Kalite Fonksiyon Açılımı yaklaşımı kullanılmıştır.

Anahtar kelimeler: görselleştirme, , iletişim, Kalite Fonksiyon Açılımı, bilgi akışı

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LIST OF ABBREVIATIONS

AEC	Architecture, Engineering and Construction
AHP	Analytic Hierarchy Process
BBS	Bulletin Board System
CAD	Computer Aided Design
CAVE	Computer Assisted Virtual Environment
D	Dimension
DIVERCITY	Distributed Virtual Workspace for Enhancing Communication within the Construction Industry
DSS	Decision Support System
DXF	Drawing Exchange Format
GIS	Geographical Information Systems
GPRS	General Packet Radio Services
GSM	Global System for Mobile Communications

ICT	Information and Communication Technology
IFC	Industry Foundation Classes
IS	Information System
IT	Information Technology
LAN	Local Area Network
LEWIS	Lean Enterprise Web Information System
OSCON	Open Systems for Construction
PC	Personal Computer
PDA	Personal Digital Assistance
QFD	Quality Function Deployment
SWOT	Strengths &Weaknesses - Opportunities & Threats
UMTS	Universal Mobile Telecommunications Systems
VIRCON	Virtual Construction Site
VR	Virtual Reality
VRML	Virtual Reality Modelling Language
WLAN	Wireless Local Area Network
XML	Extensive Mark up Language

CHAPTER 1

INTRODUCTION

1.1 General

Construction activities are carried out by many parties collaborating to successful completion of a project creating value to all involved. The traditional approach is similar to a relay race with the assumption that the project life cycle is divided into a series of sequential and separate operations undertaken by individual parties (Egan 1998). In this approach it is considered that each party is responsible for the assigned stage and does not have to pay attention to the previous or the following stages. This system seldom works out well due to the nature of the construction industry with unique, information-intensive projects requiring extensive co-ordination and communication between parties involved including all designers, engineers, constructors, suppliers, client etc.

How this co-ordination and communication will be provided depends on many items; the characteristics of the company, the type of job undertaken, type and format of data required, etc. The strength of the link between the main office

and the site office in a contracting company is determined according to centralisation-decentralisation level of that company. If the centralisation level is high, meaning that the decisions are made in the main office, then the data provided from sites will be in higher amount than a company with a lower centralisation level. No matter how the type and characteristics of the communication differs, the fact that the success of the projects is mainly dependent on quality of communication between construction parties is valid for all. The problems arising from the misunderstanding or incomprehension of the data transferred from one to another can be reduced or eliminated if the quality of communication media and quality of communication data are improved

1.1.1 Quality of communication

The capability of accessing or transferring the right information at the right time can be designated as communication quality. Therefore communication quality includes concepts such as type of communication media, speed of data transfer, amount of time lags, format of data, type of data, amount of data, data accessibility, amount of collaboration and cooperation between parties, organisation type, mobility, efficiency, effectiveness etc. The quality is not hard to establish provided that the communication structure rests on two rigid foundations one of which is the communication data and the other one is work organisation characteristics. No optimum generic solution or communication type can be suggested since each company has its own characteristics and business system.

However each company has to establish its communication structure based on the above foundations stated above in order to provide quality of communication.

The staggering advances in information technology now allow construction industry to hold data in electronic format and to transfer through an electronic environment. According to the centralisation level, the type of job and the data format, the means of data transfer may change from fax or e-mails to well structured network systems. Put simplistically, a simplistic method chosen by the company is acceptable as long as it supplies the right information at the right time. On the other hand the construction sector has rarely succeeded in choosing and applying the optimum methods of keeping, transferring and transmitting data.

1.1.2 Quality of information

Construction sector is a multi party-sector requiring cooperation and collaboration between the parties. General view of the sector provides a picture of sequential and separate operations assigned to individual parties. Conversely some firms have attempted themselves from this method of operation established improved cooperation of the parties in each operation through exploitation of IT (Information Technology) technologies supporting a higher level of integration. Whatever does the construction company choose as a way of business, the information exchange between the parties and operations are inevitable and improving the quality of communication and quality of data will improve the company's competitive status.

In this research, the ability of the comprehension and ease of capturing the idea is referred as one of the most important quality characteristics of information. The communication between the parties and offices are generally established by traditional methods, by exchange of drawings and sketches which have often been found inadequate to provide sufficient information to builders regarding design ideas, methods, procedures or details.

Many problems on site that reportedly occur due to unclear design information are generally caused by the misunderstanding or incomprehension of the design data, complete but presented in old-fashioned form. The presentation of data affects the comprehension time and correctness. It is observed that sometimes even a chart can shorten the comprehension time. Therefore how information is presented has a great bearing on quality of information. One of the most important tools used to improve the presentation of data is visualisation.

1.1.3 Visualisation

Vision is the most highly developed human sense. Visualisation is therefore a means of communication in which comprehension is instant, but also with considerable depth of the information delivered. It may typically be used for clarification of a subject that is difficult to explain in any other notation. Visualisation is directly related with the quality of the information, enhancing faster and easier human comprehension.

Visualisation is the visual representation of information to maximise human comprehension. It has throughout history been a ‘soft’ discipline restricted to the areas of art and architecture. The term visualisation often denotes a mechanism of the mind; to ‘visualise’ something is to make a picture in one’s head of a complicated situation for the purpose of understanding or design development. Computerized visualisation is generally the task of rendering a 3D model into a 2D picture or animation. This is accomplished by rendering appearance of objects (colour, reflections, texture mapping, light sources) in the 3-dimensional model. Simple 3D visualisation or functionality characteristics (like simulation) may in many cases be the purpose of a visualisation, but if required photo-realistic images and animations can be produced by means of sophisticated render algorithms. With real-time human interface with artificial 3D environments created from computer-based data, we enter the realm of virtual reality (VR).

1.2 Objective and Scope

The purpose of this research is to evaluate the extent of visualisation as a communication tool in construction industry and to determine potential benefits to be gained through implementation of visualisation.

In 1990’s there was a Canon camera commercial on television in which after a long, flashy series of tennis forehands, backhands, and other shots, Andre Agassi turns to the screen and says, "Image is everything." This phrase is accepted as the fundamental principle of many organisations in design, advertising,

computer and art industry nowadays. In the commercials, since the time is limited, the visual objects are crucial to bring about sudden flashes in the viewers mind and provide immediate comprehension. In construction, time is extremely limited too. This research is built upon the question "Why would not the construction companies benefit from the same principle in order to decrease the time spent for understanding the information transferred between the parties?"

1.3 Brief Explanation of the Research Methodology

Firstly the current status of visualisation use for communication in construction firms is mapped to determine what has to be done in order that the construction companies obtain optimum benefit from visualisation. Whether construction sector has seized the opportunities offered by visualisation tools are examined.

The general characteristics of the Turkish construction sector -IT in general and visualisation in particular- are derived through a survey composed of both open ended and closed ended questions directed to top level managers of the construction companies during interviews conducted. The IT tools used in order to provide communication between the parties involved in construction processes, the format used to keep and transfer data are investigated. The appropriateness of the IT tools used and IT decisions made to the IT and corporate strategies of the companies are studied. Which data are transferred in which format and from which construction nodes to which construction node are explored.

The current visualisation level of the companies and the level of visualisation required for the construction firms are also derived. The visualisation tools used for visualisation of each data flow are determined. Some examples and past experience stories are provided by the companies enlightening the complexities and possible problems to be faced through the visualisation applications. The survey also aimed to determine the level of visualisation which will balance time, effort and cost of the visualisation process versus the time, effort and cost spent for the advantages brought by visualisation.

Findings of this survey are explained in a detailed manner in the third chapter, “General View of IT& Visualisation in Construction Industry” and the fourth chapter of this thesis study, “Expanding the envelope of visualisation for communication in construction”

Under the light of the survey, whether the tools used currently in the construction sector satisfy the requirements of the construction companies are investigated and possible visualisation enhancements are discussed. The advantages and disadvantages of the visualisation tools are revealed and possible implementation hesitations, pressures, and restraints are questioned. These analyses are carried out through a number of matrix evaluations which are explained in detail in the chapter “Expanding the envelope of visualisation for communication in construction”. In this chapter the use of visualisation is evaluated, computerized or otherwise, in Turkish construction in order to determine an optimum level of visualisation implementation for each data flow.

In this research, it is fully realised that there will be cases where graphical or visual means are unnecessary, such as in cases where the necessary information can be presented in one sentence of text. Similarly, some data are considered to be hard to visualise and it would be fruitless to deal with visualisation for some data if it is not that complex to prevent fast comprehension. However, there is general consensus among construction management researchers that visualisation is a key technological theme with great potential to improve the construction process.

CHAPTER 2

VISUALISATION IN CONSTRUCTION INDUSTRY AND PREVIOUS RESEARCH

2.1 IT Approach in Construction

New technological advances are arising each day and most sectors gain advantage of the technologies directly applicable to them or convertible into new forms to be applied to their particular sector. IT has provided these sectors with great advantages in speed of operation, consistency of data generation, accessibility and exchange of information. [Mohamed and Stewart 2003] With the emergence of technological innovations, the distance and spatial boundaries have been blurred to the point where any organization can theoretically participate in a design or construction project in any location. [Chinowsky 2000]

Mohamed and Stewart (2003) state that the scope and boundaries of the use and performance of IT in construction are defined in different ways as follows:

- use of all electronic means of information transfer (computer networks, LANs (Local Area Network), Internet, mobile phones, faxes, etc)

- use of the latest technology, such as, knowledge-based systems, computer-based decision support systems and object orientated CAD

- part of management strategies and concepts of concurrent engineering, just-in-time production and process reengineering

All these definitions are valid and gain varying importance under certain circumstances. The construction companies are driven to adopt new information technologies by four forces; competitive advantage, process problems, technological opportunities and external requirements. [Mitropoulos and Tatum 2000] Despite all these four forces are active, construction sector is still slow in following the technological developments. Stewart et. al. (2002) proposes a strategic IT/IS (Information System) implementation framework, using strategic management principles and tools such as SWOT (Strengths &Weaknesses - Opportunities & Threats), AHP(Analytic Hierarchy Process), story telling, risk mitigation etc to accelerate the rate at which changes in people, tasks and organisational structure take place in order to keep up with or at least reduce the distance between the rate at which the technology changes.

New technological advances are arising each day and construction sector can either adapt these as they are or redesign the technical systems into the forms appropriate for the sector. Apart from the appropriate design of technical systems, the success of implementing a new ICT (Information and Communication Technology) system requires complete understanding of end users and organizational requirements. [Soetanto et. al.2003] Dasgupta (1997) argued that organization size, the degree of centralization in decision making, formalization of work and organizational culture all influence ICT adoption.

The new technologies, adapted properly to construction sector, may reduce distances between geographically dispersed offices and form a continuous collaboration and cooperation link between the parties but it is observed in the industry that the firms generally fail in implementing the information technologies properly. The problem in construction sector is not a lack of technology but more a lack of awareness of how to exploit it and of how important major process and culture change is in order to allow this to happen. [Betts and Ofori 1999] A technology will be appropriate if and only if the trinity of right technology, at the right place and in the right time is achieved. [Nielsen and Erdogan 2003]. How the firms can achieve this trinity of is one of the main targets of this study.

2.2 Communication in Construction

Construction projects are generally carried out by many parties consisting of people with various skills, knowledge and disciplines. The sector is full of

problems and complexities resulting from the multi party character and geographically dispersed offices, which have to maintain continuous communication. The importance of effective communication for project success is unquestionable. In a study carried out by Thamhain (1992), in which the top thirty potential problems contributing to poor project performance are classified into five categories, communication problems are listed as the third category. Nevertheless, all the other categories -problems with organizing the project team, weak project leadership, conflict-confusion and insufficient upper-management involvement- are directly related to or involve communications which makes quality of communication critical for project success.

2.2.1 Integration

The traditional approach in construction sector is that the project is divided into a series of sequential and separate operations undertaken by individual parties (Egan 1998). The traditional separation of design from execution, the uniqueness of each project, and the temporary teams set up for each project are but some of the aspects causing a complicated construction process. On the other hand for the success of the projects better integration is required since collaboration and cooperation between the parties are inevitable. The integration problems are therefore closely linked to the problem of communication.

According to Fischer et. al. (1998) integration is defined as the "continuous interdisciplinary sharing of data, knowledge and goals among project

participants" and is classified as single project, multi-project and industry-wide project integration, social and technical contexts of which are discussed in detail.

In order to achieve continuous interdisciplinary sharing of data two categories of interaction should be achieved [Bennett 1985, Ganah et. al. 2000].

- Communication of information: information should be first translated into text or graphics that the other team is likely to understand. These data need to be communicated to the other team through communication medium.

- Work organisation: clear organisation of work allows the work of teams to fit together. In other words teams should coordinate their actions and decision making should follow management structure.

Communication of information, in this thesis, is handled as the combination of communication medium and communicated information, therefore speaking of their improvement, quality of communication and quality of information are referred respectively.

2.2.2 Quality of communication

The effectiveness of communication can be measured using critical communication variables; accuracy, procedures, barriers, understanding, timelines and completeness. [Thomas et. al. 1998] Luiten and Tolman (1997) state that the quality of communication is dependent firstly on the organisational changes, which

will bridge the gap between design and construction information and between design and construction management stages, and secondly on computer aided communication approach.

The communication between parties is generally carried out through the exchange of drawings, sketches and text documents. If the data are created as written or plotted hard copy documents then the transfer is performed through mail, cargo or courier. Otherwise the electronic environment is used for information transfer. Electronic mail, electronic bulletin board, virtual reality, network applications and web based communication systems are a few examples of electronic transfer. The complexities and problems of construction projects can be reduced by increasing the effectiveness, efficiency and quality of the communication through the introduction of the appropriate IT and visualisation tools offered by the emerging technologies.

2.2.3 Quality of information

Data quality can be a unique source of competitive advantage and construction companies have to treat information as a strategic source for the aims of sustainable competitive advantage. The necessity to improve the quality of data is well explained by Redman (1996) as follows:

Only four types of organizations need to worry about data quality.

- Those that care about their customers
- Those that care about profit and loss

- Those that care about their employees
- Those that care about their futures

Data quality dimensions are defined by Redman (1996) and classified into four main groups: conceptual view, data values, data representation, information technology.

These data quality dimensions groups and their subgroups may be examined in table 2.1.

In this thesis, the data quality in construction sector is the issue of concern, and the focus is mainly on how to present data in order to provide maximum comprehension within minimum time and how to share and transfer those data to the other parties.

2.2.3.1. Quality of information in construction

Many parties coming together on projects have only a casual working relationship because they are from different disciplines and often also from different organisations. [Liston et. al. 2001] Nonetheless each of them needs to access the other's data in order to complete their parts. This information is generally kept in a format according to the creator's discipline neglecting the other parties' disciplines. Many problems arise from unclear presentation of material between the professionals even within the same discipline

Table 2.1 Data quality dimensions

Quality Dimension	Explanation of dimension
CONCEPTUAL VIEW	
CONTENT	
Relevance	The view should provide data needed by the application
Obtainability	Data values should be easily obtainable
Clarity of definition	Each term in the definition of the view should be clearly defined
SCOPE	
Comprehensiveness	Each needed data item should be included
Essentialness	No unneeded data items should be included
LEVEL OF DETAIL	
Attribute granularity	The attributes should be defined at the right level of detail to support applications
Domain precision	The domains of possible values should be just large enough to support applications
COMPOSITION	
Naturalness	Each item in the view should have a “natural” counterpart in the real world
Occurrence identifiability	The view should make identification of individual entities easy
Homogeneity	Entity types should be defined to minimize the occurrence of unnecessary attributes
Minimum redundancy	Redundancy should be kept to a minimum
VIEW CONSISTENCY	
Semantic consistency	The view should be clear and unambiguous and consistent
Structural consistency	Entity types and attributes should have the same basic structure wherever possible

Table 2.1 Data quality dimensions (continued)

Quality Dimension	Explanation of dimension
REACTION TO CHANGE	
Robustness	The view should be wide enough so that it does not require change every time applications change
Flexibility	When necessary, the view can be easily changed
DATA VALUES	
Accuracy	All values must be correct
Completeness	Having all parts, details, values etc. included and with nothing missing
Currency and related dimensions	A measure of degree to which data values are up to date
Value consistency	Two or more values should not conflict with one another
DATA REPRESENTATION	
FORMATS	
Appropriateness	Suit to users' needs
Interpretability	Capable to explain the reasons, results, actions or events
Portability	Applicability to a wide range of situations
Format precision	Provide precision to meet user needs.
Format flexibility	Provide flexibility to accommodate the changes in user needs and recording medium
Ability to represent null values	Capable to provide good formats to represent null values
Efficient use of storage	Includes format, creation of data, storage
PHYSICAL INSTANCES	
Representation consistency	Two or more representations should not conflict with one another

The communication between the design teams and site is generally established by traditional methods, by exchange of drawings and sketches which have often been found inadequate to provide sufficient information to builders regarding design ideas, methods, procedures or details. [Erdogan and Nielsen 2002] The problems on site that reportedly occur due to unclear design information are generally caused by the misunderstanding or incomprehension of the design data, complete but presented in old-fashioned methods. Present computer technologies, such as electronic mail and Internet allow for the electronic exchange of information and can substantially increase the amount and variety of project information communicated as compared to traditional manual methods [Zaneldin et. al. 2001].

2.2.3.2. Visual communication

Visual and written communication can be considered as supports for one another. It is generally accepted that written communication had a pictographic origin, initially as pictorial representation of concrete objects. In most writing systems this simple relationship was later replaced by the concept that a pictographic symbol could be used for its phonetic value. This system – the rebus principle – led to the alphabets [Robinson 1995]. Simplicity of scripts, made possible by the alphabets' phonetic efficiency, has had an importance to human history that cannot be overstated. However, complexity and pace of human endeavours have increased immensely, especially in the last century, and there is a continuous increase in the need for information creation and flow. Meanwhile, technologies have evolved in the last decades that allow for creation and

communication of information, or data, with such ease, that there is an overabundance of information in society, in organisations and in projects. Communication with the written word is no longer the best choice for all cases where there is a need for brief, understandable or particularly complex information. Due to the overwhelming amounts of written communication in a modern project environment, the support brought forward by visual means has become ever more essential.

In our present day, pictographic communication is still highly successful, for example in engineering in the form of drawings or diagrams. Such symbolic or logographic communication, however, is often extremely specific in the type of information it can convey. The effectiveness of symbols is inherently limited, they are most efficient when they represent objects and much less efficient in representing a process or activity.

Vision is the most highly developed human sense. Visualisation is therefore a means of communication in which comprehension is instant, but also with considerable depth of the information delivered. It may typically be used for clarification of a subject that is difficult to explain in any other notation. Visualisation has throughout history been a ‘soft’ discipline restricted to the areas of art and architecture. The term visualisation often denotes a mechanism of the mind; to ‘visualise’ something is to make a picture in one’s head of a complicated situation for the purpose of understanding or design development.

At this point it is important to realize that visualisation is a communication method made accessible to all by the progress in information technology. Computerized visualisation is generally the task of rendering a 3D model into a 2D picture/animation, normally using one of the many software tools available.

2.2.3.3. Visualised communication between design and site teams

The use of computer visualisation tools will improve communication between design offices and site teams, and insure proper and correct implementation of design, and facilitate the collaboration between site and design teams to solve buildability problems [Ganah et. al. 2000].

Design, planning, and scheduling of construction projects requires complicated decision making concerning functional requirements of the project; designs to meet those requirements; plans for the design, construction, start-up and operations processes; budget justification and tracking; scheduling and tracking; and managing the organisation that will do the design, construction and operation. [Kunz et. al. 2002] The plans and designs prepared for these processes and all data transferred between each can be made more effective if visualisation implementations are used.

VR (virtual reality) forms a natural medium for building design as it provides 3D visualisation, which through real-time manipulation can be used collaboratively to explore different stages of the construction process and VR environments can be built from CAD models through data translation approach,

library-based approach or straightforward translation approach. [Whyte et. al. 2000] The DIVERCITY project, Distributed Virtual Workspace for Enhancing Communication within the Construction Industry, using VR technologies, is aiming to develop innovative workspace technologies for the briefing and design phases of the lifecycle that will allow construction companies to conduct client briefing, design reviews, simulate what if scenarios, test constructability of buildings and communicate and coordinate design activities between teams. [Aspin et. al 2001, Aspin et. al. 2002] Another research project focused on solving the problems of design fragmentation and the gap between the design and construction processes is OSCONCAD (Open Systems for Construction CAD), which uses an object-oriented database, model based CAD system and VRML (virtual reality modelling language). [Marir et. al. 1998]

Another application is the multiuser workspace allowing communication between designers and public, between designers and between designers and client through the exchange of text files, images, movies, and 3D objects (CAD or VRML) via Web Robots, BBS [Woo et. al. 2001]

Cory (2002) proposes a database driven web page through which can be accessed 3D renderings and 3D animations created from 2D and 3D data through modelling, rendering, animating and compressing.

2.2.3.4. Visualised communication in scheduling and planning

Visualisation technologies in construction are also used to improve scheduling and planning. The state-of-art in this area is the 2D and 3D animations and simulation, 4D CAD applications used to demonstrate the construction activities. Animation enables the user to visualise on a computer screen the change of status of a construction process and dynamic interactions in the process over simulated time, and provides an opportunity for the user to observe the dynamic interactions between interlinked events. [Zhang et. al. 2002] Besides, visual 4D planning and scheduling technique that combines 3D CAD models with construction activities (i.e. time) has proven benefits over the traditional tools. [Akbas 1998] In 4D models, project participants can effectively visualise and analyse problems regarding sequential, spatial, and temporal aspects of construction schedules [Dawood et. al. 2002].

The vision of 4D-CAD and the functionality of the next generation 3D and 4D tools needed to generate 4D+X models (time, space and additional types of planning information such as cost, productivity and interference) are pictured by McKinney and Fischer (1998).

Another VR based model is proposed by Retik and Shapira (1999) aiming to manage an effective integrated project networking tool for resource planning and scheduling, by means of combining construction scheduling tools, an object oriented database, a visual basic interface and VR tools.

Liston et. al. (2001) demonstrates scenarios, tested in the iRoom, for interactive information workspaces with different visualisation and IT tools, 3D CAD, 4D CAD, CAVE (Computer Assisted Virtual Environment), IFC (Industry Foundation Classes), to support multidisciplinary decision making. The details regarding the iRoom, interactive room, which aims to develop and test new ways to model, visualise, analyse and evaluate the multidisciplinary performance of design-construction projects are explained by Kunz et. al. (2002)

The research DVC, Dynamic Construction Visualiser, proposes visualisation of modelled construction operations and the evolving products in 3D virtual space via several simulations, which allows effectively designed, planned, and scheduled operations without relying solely on the planner's judgement, imagination, intuition, and experience [Kamat and Martinez 2000, 2001].

VIRCON, Virtual Construction Site, and LEWIS, Lean Enterprise Web Information System, are two other research projects in this area. VIRCON is about developing a methodology and DSS (Decision Support System) for evaluation, visualisation and optimisation of construction schedules; and LEWIS is about reengineering workforce information where actual production is being performed on construction sites and provide tools to capture and process construction site information [Christiansson et. al. 2002, Dawood et. al. 2002, Heesom and Mahdjoubi 2002].

PHOTO-NET II is a computer-based monitoring system that uses Internet as a communication medium and links images taken from construction sites via

analog video cameras and standard scheduling tools such as a critical path method engine [Abeid et. al. 2003].

2.3 Why is this research performed?

Visualisation is a significant technological theme that may help in increasing the effectiveness of communication during the construction process. Continuous advances of IT have made it possible for many construction issues to be addressed by use of visualisation at steadily lower cost. Up to now, whether visualisation can be entered to data keeping, transferring and receiving has been investigated for most of these processes and visualisation applications are combined with appropriate IT technologies in order to create effective and efficient communication systems.

Although many researchers have dealt with sophisticated communication tools, none of the papers has considered what information site managers at the workface actually need in order to perform the most important function of construction, the actual building and managing the project [Christtianson et. al. 2002]. The search for improved communication in construction projects is ongoing. Visualisation is a means of improving representation of many types of project information. The question, of which information in the construction process can be visually represented, seems a logical one. What implications follow if the information is not communicated effectively has to be investigated as well.

Retrieving the current situation in Turkish construction industry and the actual need of the construction industry is one of the aims of this thesis. The survey carried out to achieve this goal is explained in the following chapter.

Types of information that can be visualised; information content and quality, problems due to information clarification, are issues considered in this thesis. There will be cases where graphical or visual means are unnecessary or unsuitable, There is an optimum level for implementation of visualisation. This optimum point is project-specific, and furthermore dynamic, as the envelope of visualised information types is expanding, for example due to technological development.

CHAPTER 3

GENERAL VIEW OF IT& VISUALISATION IN CONSTRUCTION INDUSTRY

3.1 General Information on the Survey

The construction sector has long been a key economic factor in Turkey with a history of significant works completed both domestically and worldwide. Turkish construction is a multi-billion dollar industry performing diverse project types: infrastructure, water resources, energy, process and housing. The construction industry's economic 'pull' to the rest of the economy is one of the highest among all economic sectors in Turkey and construction can therefore be considered one of the economic locomotives of the country. With such an economic importance there is plenty of potential to benefit from a well-considered implementation of IT technologies.

To establish the current situation as regards IT in general and visualisation in particular within Turkish construction, a survey has been carried out. The target

groups are 16 AEC companies, most of which are large-scale companies. The survey is composed of both open-ended and close-ended questions. Interviews with the IT managers, project coordinators, project managers and other top-level managers are conducted and open-ended questions are directed to them. Interviewers also filled out the questionnaire composed of close-ended questions prepared in multiple-choice, fill in the blanks and matrix formats. The survey had built-in flexibility so that respondents could include additional comments or real-life stories, for example buildability problems or site construction outside of design intent due to erroneous or insufficient information.

The survey mainly aims at analysing the current situation in Turkish construction industry, understanding what kind of IT applications are used in communication and collaboration, examining how/what visualisation is performed, highlighting the pitfalls met during the planning or implementation stages, identifying what kind of benefits the firm gained by implementing visualisation techniques and detecting what visualisation types the firm requires. The aims are outlined in Table 3.1.

The format used to keep and transfer data are investigated. The appropriateness of the IT tools used and IT decisions made to the IT and corporate strategies of the companies are studied. Which data are transferred in which format and from which construction nodes to which construction node are explored. The visualisation tools used for visualisation of each data flow are also determined. The results of this survey are provided in this chapter in the following sections.

The survey also aimed to determine the level of visualisation which will balance time, effort and cost of the visualisation process versus the time, effort and cost spent for the advantages brought by visualisation. The evaluations and decisions for this level are provided in the following chapter.

3.2 Strategy & IT Strategy

In construction worldwide there is a mind shift from viewing IT as a set of tools for internal efficiency to strategic technology redefining the boundaries of industries and application areas. It is realised that IT, properly implemented, reaches beyond improving discrete processes. Rather IT is evaluated strategically, as has been done in other economic sectors where IT strategy and business strategy are inseparable. A strategic perspective must justify an implementation of visualisation, as for any other information technology. Therefore, the alignment between the company (business) strategy and IT strategy of the interviewed companies are also investigated and the effects of this relation on the efficiency of the IT applications are examined.

Figure 3.1 and Figure 3.2 are examples of how the company's business strategies are closely linked to its Information System strategy.

Table 3.1 The outline of the survey aims

IT STRATEGY • Vision and strategy • Nature of IT support • Centralisation-decentralisation approach of the company
ARCHITECTURE & VISUALISATION • Goal-setting • Information transfer • Head office – site office information transfer • Which information – in which format • Web use • Visualisation use • Visualisation and communication tools available • Examining how/what visualisation is performed • Visualisation needs • Virtual reality use • Buildability areas with potential problems during construction • Collaboration between site team and design team in solving design problems • Communicating the problems on site with the design team • Shared database use • Highlighting the pitfalls met during the planning or implementation stages • Identifying what kind of benefits the firm gained by implementing visualisation techniques • Assessment of visualisation and communication tools and methods. • Wish-list • Mobile applications
EMERGING TECHNOLOGIES • Company's approach to emerging/new technologies • Any investigation into emerging technologies in general • Any investigation into new telecommunication and wireless technologies

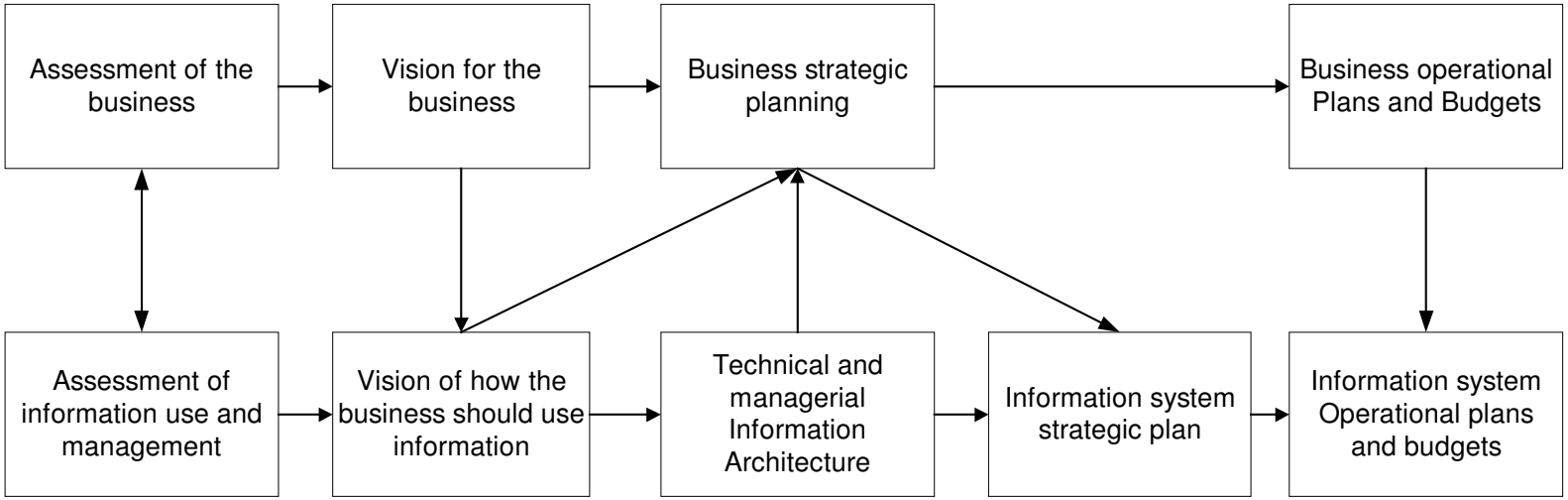

Figure 3.1 The relationship of IS, IT and business strategies

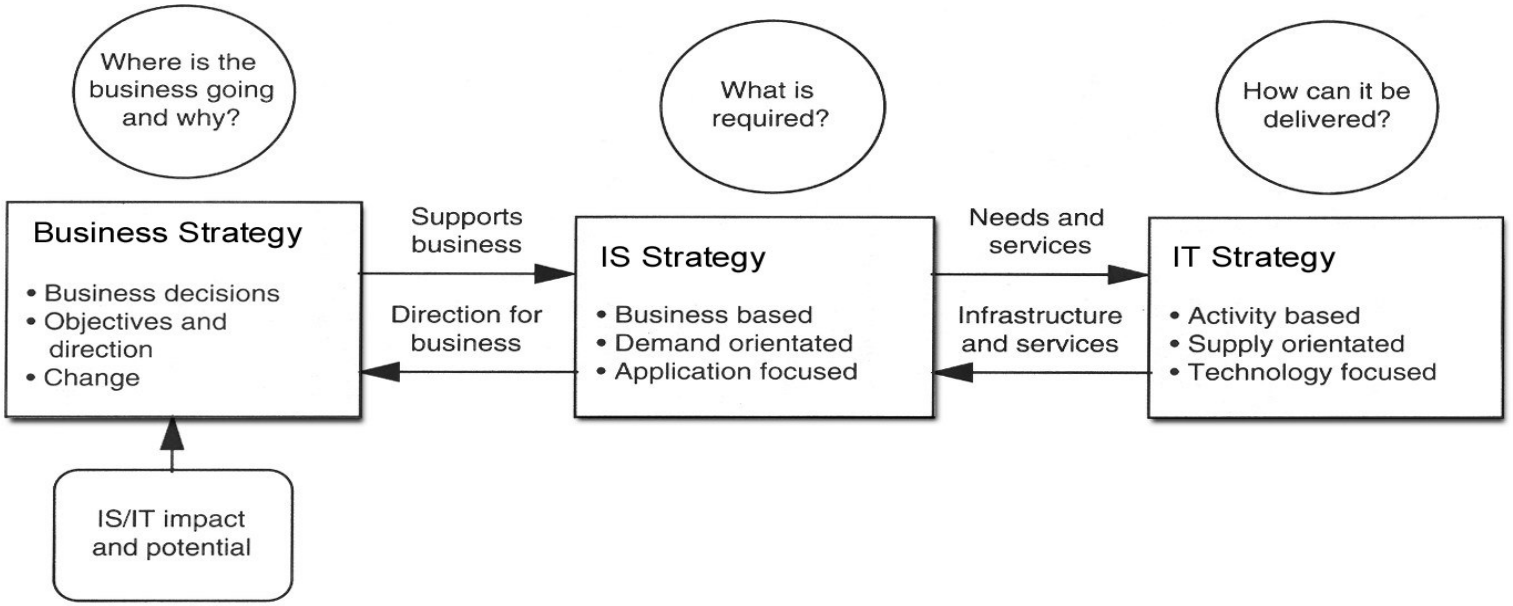

Figure 3.2 The IS/IT business strategies and relationships [Ward and Griffiths 1996]

3.2.1 Vision

Information vision is a written expression of the desired future for information use and management in the organisation. All of the companies stated that they have a vision for implementation despite the general observation that the vision concept is new in Turkish construction companies. Even though there had been a vision in the minds of the shareholders and owners, it started to be expressed literally after the rebuilding of the management system in order to obtain quality certification and awards. All companies that won quality awards assume that the employees do their jobs in accordance with the company vision. Semi annual process control reports are prepared in order to check this accordance. Some traditional companies fail in giving the vision to all levels of the company resulting in unpredicted and erroneous decisions on strategic or tactical levels.

3.2.2 Strategy versus IT strategy

The information technology architecture depicts the way information resources should be deployed to deliver the information vision. The results obtained through the interviews with top-level management revealed that all companies are aware of the fact that having a well-defined business strategy fitting the company expectations is the initial step for sustainable success. On the other hand, most of the companies' strategies are built upon intuitions of the shareholders or top-level managers. Even if they use some strategic management techniques such as SWOT, risk analysis & management, benchmarking, growth- share matrix,

industry attractiveness- business strength matrix, scenario analysis etc. the techniques are not applied properly or formally. In other words the application of the techniques are mostly carried out by the combination of little computational evaluation with high amount of gut feeling.

There are at least 30 current available evaluation methods for IT benefits [Andreasen 1999]. They can be split into objective methods, which quantify inputs and output, and subjective methods, relying on attitudes and opinions of users and system builders. The IT strategies observed in this survey are based on gut feeling. None of the large-scale companies interviewed lack IT strategy, their IT strategies are either completely or partially defined. The completely defined IT strategies are parallel to the corporate strategy of the company. But the partially defined IT strategies, mostly observed in medium size companies, sometimes include elements inappropriate to the corporate strategy. Realizing the importance and necessity of IT in success of the company, large scale companies spend time and money for defining an IT strategy parallel to the company strategy. They also conceive that major IT investments, which generally require substantial investment, effort and attention, are very risky without a well-defined IT strategy and action plans to realise that strategy.

The large-scale companies either have well-established IT departments or an IT company under the umbrella of the corporate firm providing the IT service to the company. The companies interviewed state that all IT applications are managed by the IT department and top-level management commitment exists in most of the

IT actions. The technical support for the IT applications is provided by the technical service groups in the IT department. In the circumstances that the technical service groups can not solve the problems, required service is outsourced to an agreed technical support company.

The external forces' effect on IT investment is very high. The most effective driving force is to gain competitive advantage in the market. The other driving forces are the demands from the client or requirements for developing strategic alliance in some of the projects. The other stated factors driving the construction companies to initiate IT investment and applications are following the advances in IT sector and keeping up with the enhancements in construction sector. A small minority of interviewed companies state that they choose to establish and support their own IT structures since the IT sector has not developed solutions directly applicable to construction.

3.2.3 Centralisation-decentralisation level

Since the centralisation and decentralisation level of the company changes the amount, type and format of information sharing and thus the IT and visualisation approach, the companies' centralisation tendencies are also investigated in the survey.

The interviewed companies have two different approaches in their centralisation-decentralisation level. Some of them consider construction sites as independent company entities, thus sites have right to decide on many subjects

except the decisions requiring high financial amounts. These kinds of decisions are made or approved by the main offices. As one company put it, the firm empowers the sites to cure their headaches themselves but ask for approval for expensive medicine expenditures.

On the other hand some companies choose to provide the control and management of the sites from the main office. These companies are generally either centralized or in a process of centralization, having many large sites geographically dispersed to many locations. These companies intend to control the processes from the main office. Unlike in medium size construction companies where generally the sites and the jobs are also minor, in the case of large scaled companies, the cumulative of the minor losses from all sites will surely cause a problem. Another reason is resource planning, i.e. the company has to make a balance between the sites in using equipment, money and labour. The status of the sites is constantly examined and the construction plan is modified dynamically to obtain the optimum resource distribution with minimum losses. Therefore the firm establishes a structured IT system and thus an IT investment including visualisation, to decrease the distances between offices in case of centralised approach. Ideally this system must be formed according to the IT strategy of the company prepared in parallel to the company strategy but during the observations in the companies it is realised that the companies sometimes fail in acting in accordance with the IT strategy when they are trying to find a short term solution.

3.3 Architecture

3.3.1 Data format

Medium and large scaled companies are storing data both in electronic format and as hard copies. The data format used varies according to the data flow types and according to the field of the projects. Notwithstanding that design and consultancy companies are working with information only, they are observed to work in electronic environment more efficiently than contracting companies and their visualisation skills are also better than contracting companies. Electronic data are preferred to hard copies whenever possible since the electronic data losses are generally recoverable; storing and archiving are easy; and transfer in the electronic medium is faster. Filing and archiving hard copies is considered a time consuming process. Furthermore finding a document in those files is another time consuming process regardless of how well the filing system is.

3.3.2 Communication media

E-mail is the preferred communication media among all companies interviewed. Document transfers over e-mail include DXF (Drawing Exchange Format) files, text files, charts, CAD drawings, digital photographs, virtual models and simulation models as e-mail attachments between the offices. Files of large size are written on CDs (compact disk) and transferred via cargo or post. The hard copies of drawings and text files are also transferred via cargo, courier or post.

All have network system and multi user databases in their main offices and LAN's at the sites. The authorization allowance and restrictions are defined for each user or user group according to their departments or projects they are involved in.

Some of the large-scale companies provide inter-organisational communication via lease lines, ISDN or Intranet. These companies are large scale companies having strong centralisation strategies and their communication system is designed in order that any information recorded on site, generally material, labour and equipment data, can be accessed from each office right after the record. Companies communicating through the web-based medium also have electronic bulletin board applications but they are not used efficiently. Even if bulletin board applications are set, the use is limited to top-level management posting general announcements to inform the employee about company wide subjects.

Electronic communication is preferred for data transfer mostly between the offices of the company for the high speed, immediate response and data recovery characteristics. On the other hand most companies suffer from the senior engineers and project coordinators, highly experienced but failing to follow many technological advances, since they can not use the electronic opportunities at maximum efficiency themselves.

Electronic communication is also preferred between design offices and construction offices but the communication with the client is mainly on hard copies. Even if exchange of electronic copies takes place, the legally accepted

copies remain hard copies. This is due to the fact that many clients are public organisations with relatively traditional or old-fashioned business processes.

3.3.3 Website

All large-scale companies interviewed have websites but only half of the companies included possibility for future intranet and extranet applications in the servers' planning and design. The websites' primary aim is presenting the company for possible strategic partnerships and clients, therefore only general information on company and its short history are published on the website. The completed projects and under construction projects are listed and contact information is given.

3.3.4 Archiving systems

The data are kept in electronic format but they are not archived well for the future. Moreover the current archiving systems are hard copy format in most of the companies. However, some firms are either planning or currently starting a new system. Some firms use web based archiving systems that can be accessed from each node of the construction company but these are archiving systems built for accounting data.

Most of the firms do not treat information as a strategic resource; they feel the importance of it but have been unable to structure a system transferring a person's experience, gained through projects, to a database to be used in future decisions.

3.4 Visualisation

Construction sector has adopted visualisation slower and at different levels of intensity compared to other industries, even though substantial academic efforts have been applied in the construction phase of the building process. All of the companies examined in this survey use visualisation to varying extent defined by the company itself. They consider visualisation as a means of communication in which comprehension is simpler compared to other methods, however project design and contracting companies use visualisation in different ways. Design companies make use of it in showing the final project where contracting companies make use in following the progresses on site from the main office.

There is only one 'very traditional' contracting firm in the survey targets in spite of its large scale. Here, not all of the data are in electronic format and there is still some paperwork in many processes including communication. However, despite resorting to conventional methods this company also benefits from visualisation, although not in sophisticated configurations but in simple and advantageous formats. The methods and tools are 2D and 3D CAD drawings saved and transferred in DXF format. Digital pictures and videos are captured on site and are sent to main office to show the current views of site. It caught attention that the firm has a database in an electronic environment (Paradox based), and is planning to convert it to a database on a web-based environment and improve searching and retrieval functions. This idea may be considered as an intention to use modern methods and tools.

The remaining companies can be accepted as information age companies when their management techniques, methods and tools are examined. As far as visualisation is concerned, the extent changes from one company to another. The general visualisation approach in the companies interviewed is given below. The details of visual communication in companies are provided in the chapter 4.

3.4.1 Visualisation in design companies

Design companies generally use visualisation tools in rather more sophisticated ways. The reason of project design companies to implement visualisation techniques can be:

- Enabling multidisciplinary communication
- Illustration of the completed look of the design
- Solving buildability problems

3.4.1.1. Enabling multidisciplinary communication

Construction projects are multi-disciplinary. The professionals from disciplines other than engineering or architecture will surely have problems in acquiring insight of the project or details in the design when only 2D design drawings are provided. If 3D drawings are provided together with some virtual images or videos, then they will be able to picture the design, which is closer to the original design in their minds. Since they are able to visualise better their decisions will be much more reasonable and to the purpose. A bridge designed for Haliç

(Golden Horn) Istanbul can be given as an example. The project had to be designed in a way that the bridge would not damage the historical characteristics of the environment but provide harmony with them. During the project stage, many alternatives are created and presented as virtual images prepared by combination of CAD and 3D Studio works. The virtual images were photo-realistic and were presented to the board consisting of professionals specialised on history, art history, art and archaeology. The board examined the virtual images and discussed some topics with the design team and after several meetings and modifications a final design alternative was selected. . It must be realized that there are many stakeholders in a construction project from outside architecture and engineering, and the requirements of these stakeholders can more easily be evaluated using visualisation techniques. In the vast majority of construction projects, the final customer is not an architect or engineer. Using visualisation as a communication medium is a method to better meeting customer needs and eventually providing customer satisfaction.

3.4.1.2. Illustration of the completed look of the design

The visualisation may be a part of a project or is prepared for either presentation purposes, or on demand of the client. In highway design projects, the client generally asks for a 3D simulation of the final project. These simulations are presented on a video animation showing the highway from the focus of a camera either on a plane flying over or on a car travelling on the highway designed. The geographical characteristics of the surroundings, the existing structures are shown

and the structures designed in the project – highway, viaducts and tunnels on the route, crossroads, bridges, and expropriation etc. – are demonstrated by using CAD tools and 3D modules of CAD.

Another example can be given from water supply or sewerage system projects. The pipelines designed are shown on the ortho-photographs obtained from satellites and presented to the client for approval.

3.4.1.3. Solving buildability problems

Finding space for heating and ventilation installations is a frequently occurring problem in building design. During actual site works it has often been observed that structural and mechanical designs collide, unnoticed by the designers. A very typical example is a missing block-out in a concrete element where the mechanical design prescribes a heating duct. Such collisions are time-consuming and delay the construction progress. Lighting, acoustic, heating and thermal installations and facilities management designs are built on top of the architectural design. However, electrical and mechanical installations have often considerable space requirements and advanced geometry. In order that the installers understand the design details better, designers provide 3D CAD drawings or rendered images of the buildings to the installers. Outside the housing sector the extent of advanced geometry is even higher; bridges, tunnels and dams are all multi-disciplinary project types with many interfaces between civil and mechanical works. For a dam project, the designer may want to visualise the functioning of a gate..

3.4.2 Visualisation in contracting companies

The contracting companies' approach visualisation from another perspective since the aim of a contracting company is rarely illustrating the final stage of a construction. However, contracting companies are required to show progress – completed jobs/total jobs – and also clarify method of construction. There is an intensive information flow between the contracting companies and the site during construction, where visualisation may play a very important role.

The site office has to provide site information to the main office continuously. Some of the companies send photographs or videos from the site upon request by the client. Contractors maintaining communication between site and main office by e-mail take the photographs themselves and send these via e-mail. Some companies having lease lines, ISDN or intranets, in other words the companies maintaining continuous communication and data transfer, place local cameras on the site. The cameras generally do not send continuous views, since this is not considered a requirement for observing construction activity. Furthermore, it is undesirable to keep data transfer lines busy continuously. The cameras take steady images in 30 or 60 second intervals and send it to the system making up-to-date photographs available whenever a manager at the main office wants to check what is happening on site.

When an unexpected situation is observed at the site, the contracting company uses photographs and videos for design problems communication.

The contracting companies dealing with housing also offer virtual reality applications like walkthrough animations. Typically in walkthrough animations, structural and environmental objects such as walls, columns, buildings, and trees remain stationary while the camera moves through the scene. Walkthrough animations are used to sell houses before construction is complete, giving the buyer possibility to evaluate the house in its completed state.

3.5 Emerging Technologies and Mobility

IT and telecommunications have been converging for many years. Wireless LANs and 3G telecommunications are vital components in IT-Telecoms convergence but they are only two of several technologies are contributing to the mobile revolution: Mobile telecoms through 3G, portable/handheld computing as well as the Internet, notably through XML (Extensive Markup Language) and e-business protocols.

New developments in portable PC (Personal Computer) types support the needs of an increasingly mobile economy. PocketPCs, PDAs (or tablet PC's have reached remarkable levels of performance and functionality and handwritten input is now nearly fully developed.

Already the fastest growing method of Web browsing is through wireless devices. The Internet has a robust data container in XML, which can be considered as an option to transfer of highly structured data, especially over the Web. XML

enables business to be conducted over the Internet, which in turn is spreading to mobile devices through new generations of mobile networks. The mobile revolution is not driven by one industry group, but by an enormous momentum from hardware, software and telecom sectors together.

The new paradigm of IT is therefore the technology's adoption to the way we work rather than docking us to the desktop, even when staying continuously on-line. For construction, with its core processes geographically dispersed outside the main office, there are wide possibilities for integration of IT in our primary functions and therefore in all corners of the construction process. Control of a project depends totally on visibility and communication. By extending digital project data to any location where it is needed in real time, the construction process can be simplified and matured.

3.5.1 Wireless possibilities

Given the unquestionable progress of mobile IT, one of the first questions to be asked is: Who might benefit from real-time, mobile access to project data?

Software vendors to the AEC industry have already identified obvious areas where handheld IT solutions can help improve efficiency.

Construction/engineering professionals normally take large paper drawings into the field. These drawings are familiar and easy to navigate. Conversely, they're costly to print out, cumbersome to carry, and often slightly out-

of-date. Quite regularly, these professionals get to the job site only to realize they don't have all the required drawings. So they're forced to drive back to the office or work on-site without all the information at hand.

Another example is the completion of a quality control check-sheet, which is traditionally filling out blanks on a pre-printed form. In case an online project tool is used (like a project website) the information from the paper sheet will have to be re-entered into the tool.

Mobile access to project data would allow architects, designers, surveyors, and field engineers of all kinds to:

- Enter on-site progress data avoiding much of the 'paper chase'; quality control, check of design, entry of as-built, material ordering, etc.
- Leave bulky design drawings at the office
- Review, mark up, and measure the most up-to-date digital design data at the point of activity - using handheld computers
- Remotely access design and mapping data on an organization's central servers, review it, and mark it up digitally.
- Exchange data between handheld devices and project tool or corporate server.
- Embed digital photos in GIS (Geographical Information Systems) systems.
- Gain freedom from their desktop PC's. More time can be spent on site with the job and field workers.

- Less ‘painfully’ to update of project tool / project website through entering data only once – in the portable PC.

In the longer term mobile IT may in general improve the way construction projects are run. Construction is thinking ‘process’ but handover points in the construction process are often geographically dispersed. Mobile solutions can bridge geographical distance and allow for centralized process control and decision-making. Mobile IT is not the solution to constructions’ problems, but it is a tool helping the solution to the lacking integration in construction. It is obvious that the case for mobile access to real-time project data is strong.

The upcoming 3G networks will play a vital role in enabling mobile solutions. While the highly successful GSM (Global System for Mobile Communications) standard allows for international roaming due to standardization, the implications of 3G are much wider. GSM is a voice (phone) communication standard only. UMTS (Universal Mobile Telecommunications Systems) is a packet-switching protocol from the unset foreseen to be able to offer mobile, high-speed data (like Internet) wherever a network is available. UMTS networks will eventually cover areas to the same extent as GSM networks today. This means minimal investment in hardware for the individual construction project. For Turkey, there are no immediate plans by the operators to roll out 3G networks, but this will change once the business case of 3G has been proven elsewhere.

GPRS (‘2.5G’) (General Packet Radio Services) is an overlay to GSM offering always-on data capabilities. The importance of GPRS is that it is expected

to have a complementary role, using the same wireless devices (dual-mode), in locations where UMTS is not available, although with lower transfer speeds. Turkey has countrywide coverage of GPRS and some contractors have been seen to use it in simplistic ways. The main problems is price: 1 MB transfer over GPRS is approximately 1,5 million TL, one CD-full of information would therefore cost far in excess of 1 billion TL, which must be considered too expensive.

WLAN (Wireless Local Area Network) networks may also have a main or complementary role, where available. The 3GPP organisation is currently discussing degree of integration (roaming) between 3G and WLAN. WLAN access is limited to capacity spots for certain areas, but transfer speeds exceed those possible with UMTS/3G. In some areas it may be beneficial to create internal WLAN coverage on the entire building site, although this may limit the possibility of working off the site area (for example if a handheld computer is used to log on to corporate server outside the building site).

CHAPTER 4

EXPANDING THE ENVELOPE OF VISUALISATION FOR COMMUNICATION IN CONSTRUCTION

4.1 Visual Communication in Turkish Construction

4.1.1 Data Flows in construction

This research is based on the premises that visual information must be augmented in construction projects, an attempt must be made to expand the envelope of visual communication, and that there is an optimum level for implementation of visual communication. In order to suggest an optimum level of visual communication, as a first step all data flows between design and build teams, and data flows between site offices and main office of the contracting company are determined. The context diagram given in Figure 4.1 shows the data flows in the information system of design and construction teams. Secondly, the revealed data

flows are investigated for visualisation areas where visualisation techniques may be plausibly implemented, with likely advantages. The data flows that already include or that may include visual presentations or visual data are determined and explained in Table 4.1

Table 4.1 Data flows that (may) include visualisation

Data Flow	**Explanation**
Detail reports (contracting period)	The details stated in the contract
Design documents	Design documents provided to the contractor. These include the clarification of design details and overcoming buildability problems
Method statements	Explanation of the work procedures and construction methods ie. concreting, excavation or a complex steel connection welding method
What if scenarios	Scenario analysis probable deviations from the planned/ estimated cases during construction Precautions for just in case situations
Schedule-work programme	Planning the activities' logic and durations Timing, restraints, contingencies etc.

Table 4.1 Data flows that (may) include visualisation (continued)

Data Flow	**Explanation**
Resource planning	Labour, Materials, Equipment
Progress reports	Work done vs. planned % work completed
Design problems communication	How is the design office notified if a problem occurs due to misleading or missing design information?
Daily site records	Daily site records kept on site about • Site environment conditions, weather, ground • Work-force and plant parameters • Description of the work task completed that day • Minutes of site meetings
RFI Request for Information	The requests of contractors from the client or design office
Change Order	When client requests changes to project scope or specs and how these are transferred

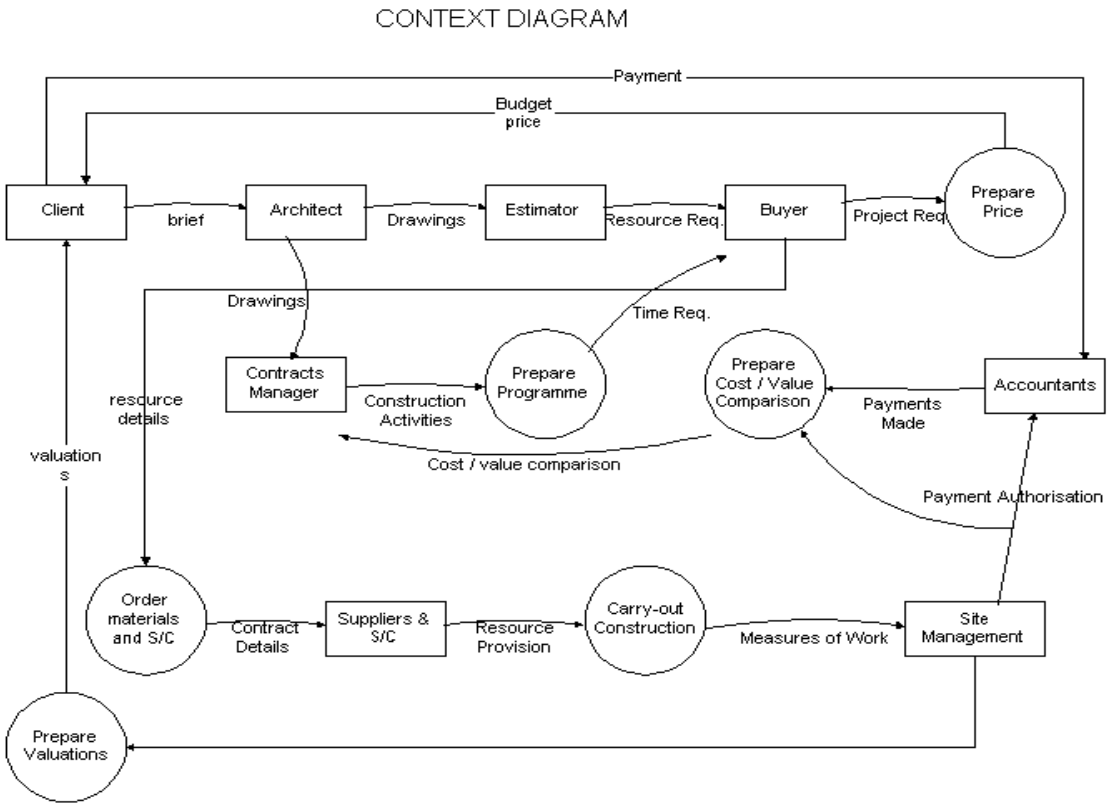

Figure 4.1 Context Diagram [Sayar 2000]

4.1.2 Current visualisation level of the data flows

The visualisation tools that may be used in visualising the construction data flows are determined as: 2D CAD drawings, 3D CAD drawings, 2D Graphics, Charts, 3D Graphics, Charts, Tables, Photographs, Virtual Photographs (3D Studio, studio max), Virtual Reality, Walkthrough, Video, Animation, Simulation, Steady images, Text Documents, Daily/Weekly/ Monthly Reports, 3D Models

It is also observed that the data are transferred via: e-mail, facsimile, telephone, CD, mail- cargo- courier, ISDN, leased lines, cable networks (e.g Cablonet), LAN/ WAN, Electronic bulletin board, intranet, extranet, www, video conference, virtual reality, instant messaging programs (i.e. msn, icq), mobile technologies (i.e. PDA, blue tooth, handheld comp..), Wireless LAN, Face-to-face meetings.

4.1.2.1. Data flow versus visualisation and IT tools matrix

In order to determine where and which visual elements are used in the data flows, and via which common tool, “Current visualisation and communication tools used versus Data flows matrix” is prepared (Table 4.2).

The interviewees are asked to fill in the prepared matrix according to the currently used IT and visualisation applications in their company

Table 4.2 The current visualisation and communication tools used - Data flow matrix

INFORMATION FLOW TYPES	THECURRENT VISUALISATION&COMMUNICATION TOOLS USED FOR DATA FLOWS	TOOLS																		HOW?																VISUALISATION FACILITIES SHOULD BE DEVELOPED
		2D CAD drawings	3D CAD drawings	2D Graphics, Charts	3D Graphics, Charts	Tables	Photographs	Virtual Photographs (3D Studio, studio max)	Virtual Reality	Walkthrough	Video	Animation	Simulation	Steady images	Text Documents	Daily/Weekly/ Monthly Reports	3D Models	e-mail	facsmile	telephone	CD	mail: cargo- courier	ISDN	LAN/ WAN	Elektronic bulletin board	intranet	extranet	www	video konference	virtual reality	web based online messaging programs (msn,icq..)	Mobile teknologies (PDA, bluetooth, handheld comp	WLAN	Face-to-face meetings		
	Detail reports (contracting period)																																			
	Design Documents																																			
	Method statements																																			
	What if scenarios																																			
	Schedule-work Programme																																			
	Resource Planning																																			
	Progress reports																																			
	Design Problems communication																																			
	Daily site records																																			
	RFI Request for info																																			
	Change order																																			

4.1.2.2. Results obtained from the matrices

Currently in the construction industry, information media for the purpose of clarification is limited to 2D drawings, written statements and face-to-face meetings. According to the results of this survey, just a few construction companies are using physical and 3D models, which are limited in use. More than 60% of the design companies interviewed are using simulation tools, but almost none of the contracting companies interviewed use such tools.

The common methods of communication between the design and construction teams are traditional methods and limited to 2D drawings, written statements, face-to-face meetings, telephone, fax and e-mail. Most of the buildability problems are due to insufficient understanding of the drawings and design details, poor communication, and conflicting design information. Construction delays due to buildability problems correspond to about one third of the total project delay.

It is only a few of the interviewed companies who are using a set of visualisation tools, physical and 3D models. Design and construction teams of the companies who are using visualisation tools and physical models have already experienced benefits. They report less communication problems, less project delay time and cost. They have also experienced increase in the quality of information, characterized by more accurate, predictive and clear information.

Less than 5% of the interviewed companies are using videoconferencing,

but this is a tool used not to provide communication between the design and construction teams but for the communication between the top-level managers.

Document transfers over e-mail, which is the most common communication media, include DXF files, text files, digital photographs, virtual models and simulation models as e-mail attachments.

80% of the companies interviewed had an unenthusiastic attitude towards the use of new wireless technologies and integration themes, but they were more interested in visualisation methods.

More than 60% of the design companies interviewed are using simulation tools to exchange information between design and construction teams and for scheduling mainly due to the client's requirement. In contrast, the contracting companies interviewed are not using simulation tools. All contractors communicate through digital photographs taken at site and sent to the main office via e-mail or through images of steady image cameras via ISDN lines.

The simulation of the work progress in a virtual environment enables comparison of the completed work tasks versus a baseline of planned work tasks. A dynamic 3D site can be constructed in the virtual environment, in which the entire construction project can be reflected. Such a visual simulation environment would enable a much more intuitive and simple monitoring of site activities and site-related decision-making will be facilitated.

4.2 QFD Approach

The aim of this research is to determine the optimum level of visualisation in construction data flows. Since visualisation and IT integration are two important themes aiming at increasing quality of information and communication, the evaluation of the optimum level can be achieved through a quality planning perspective. In this thesis, the "optimum level of visualisation" does not refer to optimum visualisation tools but to the optimum combination of the visualisation tools to result in the optimum solution The chosen method for evaluation is the QFD (Quality Function Deployment) approach and the qualitative calculations are computed through matrices inspired from QFD.

QFD is a method for structured product planning and development that enables a development team to specify clearly the customer's wants and needs, and then to evaluate each proposed product or service capability systematically in terms of its impact on meeting those needs [Cohen 1995]. In this research the customer is the construction company desiring to improve the communication and visualisation quality. The QFD product to be produced is the framework of visualisation types and levels for each data flow. The product or service capability is set using the technical characteristics, designated as Substitute Quality Characteristics by some QFD professionals.

QFD process involves constructing one or more matrices through which the subjective customer perspective is converted to technical characteristics. The

most common matrices system is HOQ (House of Quality), taking its name from the shape of the combined matrices. The customer needs and wants are listed along the left of HOQ and the technical characteristics to satisfy those needs are listed along the top. Figure 4.2 shows an example of HOQ.

A customer perception matrix is used for prioritisation of the customer needs and relative importance weights of the needs are determined. The roof of HOQ shows the correlations between the technical characteristics, in other words it shows the impact of one technical characteristic on another one. The 'How Much' matrix lists the rank ordering of the technical responses. The terms used to denote the HOQ elements in literature are shown in Table 4.3.

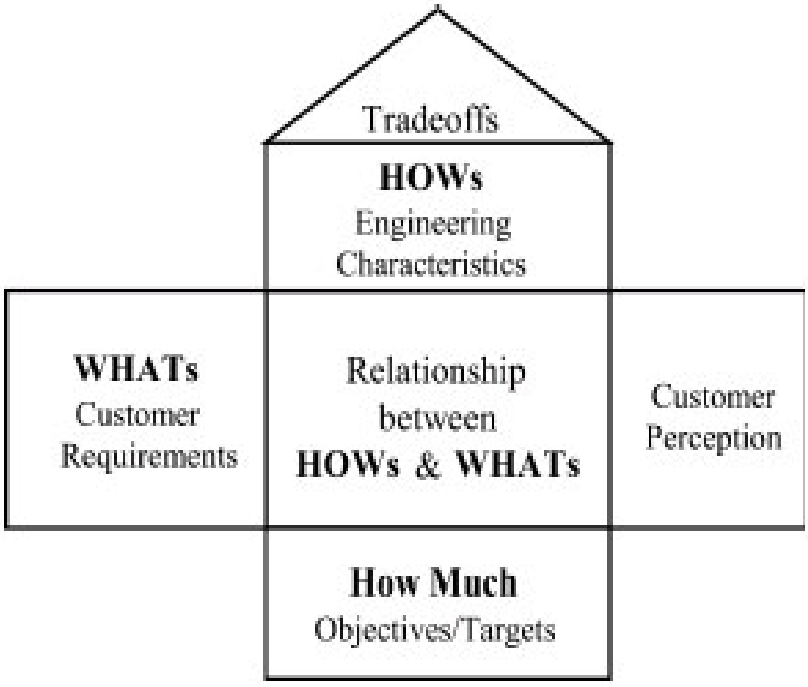

Figure 4.2 The House of Quality

Table 4.3 The QFD terms named in various ways

Customer requirement	Customer needs Customer wants WHATs
Technical characteristic	Technical response Substitute quality characteristic Engineering characteristic Design requirement Technical specification Product requirement HOWs
Customer perception	Importance weight Planning Matrix
Technical Matrix	Objectives Targets HOW MUCHes
Technical correlations	Tradeoffs Impact Matrix

4.2.1 Customer Perception

The general visualisation and IT requirements of companies are determined during interviews and the companies are asked to evaluate the importance of each need for each data flow by using the following notations.

Table 4.4 Notations used in the matrix evaluation

Notation	**Meaning**	**Assigned value**
	Not important	0
L	Low	1
M	Medium	3
H	High	5

It is assumed that the customer needs and requirements' rank of importance would vary for each data flow thus far the interviewers' comments and evaluations proved that the assumption was correct. The procedure of evaluating the customer perception through the matrix evaluations is explained below in a step wise manner.

- Interviewers evaluate the importance of each need for each data flow by entering L, M, H to the cells or leaving them empty or using 0 in order to imply that the need is not important or irrelevant to the data flow. An example of a filled matrix by a company is given in Table 4.5.

- The values of L, M, H are replaced by 1,3 and 5 respectively. The empty spaces have a value equal to 0. The example in Table 4.5is modified according to these replacements and shown in Table 4.6.

- The values entered to the cells by each company are added up and divided by the number of interviewed companies, which is equal to 16 for this research. The values calculated are the average importance values of needs (Table 4.7).

- The average importance values of needs, calculated in the previous step, in the same column are summed up (Table 4.7).

- The average importance values are normalised by dividing the overall importance value of their column. The relative importance total of the needs in the same data flow column becomes equal to 1 after this step (Table 4.8).

The values calculated through these steps provide the customer perception perspective. For example if the values in the Design Documents column are investigated it will be realised that the most important needs to be satisfied are better comprehension, quick comprehension, clarification of design details.

Table 4.5 Customer needs vs Data flow matrix filled by a company (L=1, M=3, H=5)

CUSTOMER NEEDS AND REQUIREMENTS	DATA FLOW TYPES										
Customer Needs- Data Flow Matrix	Detail reports (contracting period)	Design Documents	Method statements	What if scenarios	Schedule-work Programme	Resource Planning	Progress report	Design Problems communication	Daily site records	RFI Request for info	Change order
easy to develop	H	M	H	M	H	M	H	M	M	M	M
electronic data transfer	H	H	M	M	M	M	M	M	L	H	H
fast data transfer (with fast connection availability)	H	H	H	H	H	H	H	H	L	H	H
easy access in remote ares		M	M	H	H	M	M	H	M	H	H
continuous communication (min data transfer lag)	H	M	L	H	M	H	H	H	M	H	H
can clarify design details	H	H	H	M	M	M	H	M	M	H	H
can clarify construction methods	H	M	H	M	L	M	M	H	M	M	M
suitable for conveying gained project experience to future projects	M	M	L	L	M	M	M	M	M	M	M
allow mutidisciplinary communication	M	M	H	H	M	H	H	M	M	M	M
better comprehension	H	H	H	H	M	M	H	H	H	M	M
quick comprehension	H	H	H	H	M	M	H	H	H	H	H
platform mobility		M	M	M	H	M	L	L	L	M	M
check what if scenarios	M	M	L	H	H	H	H	H	H	H	H
help conflict resolution	M	M	M	L	M	M	H	M	M	M	M
possibility for online meeting	M	L	L	L	L	L	L	M	M	M	M

Table 4.6 Customer needs vs Data flow matrix with assigned importance values

CUSTOMER NEEDS AND REQUIREMENTS	DATA FLOW TYPES										
Customer Needs- Data Flow Matrix	Detail reports (contracting period)	Design Documents	Method statements	What if scenarios	Schedule-work Programme	Resource Planning	Progress report	Design Problems communication	Daily site records	RFI Request for info	Change order
easy to develop	5	3	5	3	5	3	5	3	3	3	3
electronic data transfer	5	5	3	3	3	3	3	3	1	5	5
fast data transfer (with fast connection availability)	5	5	5	5	5	5	5	5	1	5	5
easy access in remote ares		3	3	5	5	3	3	5	3	5	5
continuous communication (min data transfer lag)	5	3	1	5	3	5	5	5	3	5	5
can clarify design details	5	5	5	3	3	3	5	3	3	5	5
can clarify construction methods	5	3	5	3	1	3	3	5	3	3	3
suitable for conveying gained project experience to future projects	3	3	1	1	3	3	3	3	3	3	3
allow mutidisciplinary communication	3	3	5	5	3	5	5	3	3	3	3
better comprehension	5	5	5	5	3	3	5	5	5	3	3
quick comprehension	5	5	5	5	3	3	5	5	5	5	5
platform mobility		3	3	3	5	3	1	1	1	3	3
check what if scenarios	3	3	1	5	5	5	5	5	5	5	5
help conflict resolution	3	3	3	1	3	3	5	3	3	3	3
possibility for online meeting	3	1	1	1	1	1	1	3	3	3	3

Table 4.7 Customer needs vs Data flow matrix with average weights

CUSTOMER NEEDS AND REQUIREMENTS	DATA FLOW TYPES										
Customer Needs- Data Flow Matrix	Detail reports (contracting period)	Design Documents	Method statements	What if scenarios	Schedule-work Programme	Resource Planning	Progress report	Design Problems communication	Daily site records	RFI Request for info	Change order
easy to develop	3.17	3.50	3.83	2.33	4.67	4.33	4.67	3.00	2.83	2.33	2.33
electronic data transfer	2.33	3.50	2.00	2.33	2.83	3.17	3.17	2.33	2.00	2.67	2.67
fast data transfer (with fast connection availability)	2.67	3.17	2.33	2.33	3.17	4.33	3.50	2.67	2.17	2.83	2.83
easy access in remote ares	1.17	2.33	2.33	2.67	3.00	3.67	3.00	3.00	2.50	2.33	2.67
continuous communication (min data transfer lag)	2.33	2.00	2.33	2.33	3.50	4.67	3.83	2.67	2.33	2.67	2.33
can clarify design details	2.67	4.33	4.00	2.33	2.67	3.00	2.67	2.83	2.33	2.67	2.67
can clarify construction methods	3.17	3.17	3.83	2.33	2.00	2.33	1.67	3.50	2.33	2.33	2.33
suitable for conveying gained project experience to future projects	2.00	2.00	1.67	1.67	3.33	3.33	3.67	2.00	2.50	2.00	2.00
allow mutidisciplinary communication	1.67	3.50	3.83	2.00	3.83	4.17	2.67	3.83	1.67	1.67	1.67
better comprehension	2.83	4.67	3.83	1.67	3.33	3.50	3.50	2.50	2.17	2.67	2.67
quick comprehension	2.67	4.67	2.67	2.33	2.67	2.83	2.50	3.17	2.33	3.67	3.67
platform mobility	1.17	2.33	2.00	2.00	3.50	2.33	2.00	2.00	2.00	2.00	2.00
check what if scenarios	1.00	1.50	1.17	1.67	2.67	2.67	2.67	2.17	1.33	1.67	1.67
help conflict resolution	2.50	3.67	2.33	2.00	2.17	2.83	2.50	3.17	2.33	2.33	2.33
possibility for online meeting	1.33	1.00	0.67	1.00	0.67	1.00	1.00	1.83	1.33	1.33	1.33
TOTAL	**32.67**	**45.33**	**38.83**	**31.00**	**44.00**	**48.17**	**43.00**	**40.67**	**32.17**	**35.17**	**35.17**

Table 4.8 Customer needs vs Data flow matrix with normalised average importance values

		DATA FLOW TYPES										
CUSTOMER NEEDS AND REQUIREMENTS	Customer Needs- Data Flow Matrix	Detail reports (contracting period)	Design Documents	Method statements	What if scenarios	Schedule-work Programme	Resource Planning	Progress report	Design Problems communication	Daily site records	RFI Request for info	Change order
	easy to develop	0.07	0.05	0.07	0.06	0.07	0.06	0.07	0.05	0.07	0.05	0.05
	electronic data transfer	0.05	0.05	0.04	0.06	0.05	0.04	0.05	0.04	0.05	0.06	0.06
	fast data transfer (with fast connection availability)	0.06	0.05	0.04	0.06	0.05	0.06	0.05	0.05	0.05	0.06	0.06
	easy access in remote ares	0.03	0.04	0.04	0.07	0.05	0.05	0.05	0.05	0.06	0.05	0.06
	continuous communication (min data transfer lag)	0.05	0.03	0.04	0.06	0.06	0.06	0.06	0.05	0.06	0.06	0.05
	can clarify design details	0.06	0.07	0.07	0.06	0.04	0.04	0.04	0.05	0.06	0.06	0.06
	can clarify construction methods	0.07	0.05	0.07	0.06	0.03	0.03	0.03	0.06	0.06	0.05	0.05
	suitable for conveying gained project experience to future projects	0.05	0.03	0.03	0.04	0.05	0.05	0.06	0.03	0.06	0.04	0.04
	allow mutidisciplinary communication	0.04	0.05	0.07	0.05	0.06	0.06	0.04	0.07	0.04	0.04	0.04
	better comprehension	0.07	0.07	0.07	0.04	0.05	0.05	0.05	0.04	0.05	0.06	0.06
	quick comprehension	0.06	0.07	0.05	0.06	0.04	0.04	0.04	0.05	0.06	0.08	0.08
	platform mobility	0.03	0.04	0.04	0.05	0.06	0.03	0.03	0.03	0.05	0.04	0.04
	check what if scenarios	0.02	0.02	0.02	0.04	0.04	0.04	0.04	0.04	0.03	0.04	0.04
	help conflict resolution	0.06	0.06	0.04	0.05	0.03	0.04	0.04	0.05	0.06	0.05	0.05
	possibility for online meeting	0.03	0.02	0.01	0.02	0.01	0.01	0.02	0.03	0.03	0.03	0.03

4.2.2 Visualisation tools satisfying customer needs

The customer needs are revealed through discussions with the interviewees. Likewise, they are asked to prioritise the needs for each data flow. As a result, the average normalised importance weights of needs are determined.

All visualisation tools have different characteristics causing variations in how and to what extent the customer needs are met. Considering the characteristics and capabilities of the visualisation tools, the effectiveness of each tool on the satisfaction of the customer needs are evaluated using L, M, H notations, which are assigned 1, 3 and 9 values, which are the most commonly used values in QFD approach. These values are used in this evaluation process to emphasize the strong relationships in order to determine the parameters to focus on during the design process. If the tool and the need are irrelevant, then 0 is used. The assessments are marked in a matrix where the visualisation tools are listed along the left and customer needs are listed along the top. For example, if the relevance between the need “can clarify design details” and 3D CAD drawings is considered, the impact is assessed as High since 3D CAD drawings have high presentation capabilities which create a 3D picture in the user’s mind quickly and explain all details visually. In contrast, the same need has no relevance with daily/weekly/monthly report which are not unimportant, but typically 1-page paper reports with a different purpose altogether, and therefore the relation is evaluated as 0. The matrix showing the evaluation of the degree of customer need satisfaction is given in Table4.9.

Table 4.9 Tools vs Needs Matrix (L=1, M=3, H=9)

TOOLS	HOW MUCH DOES THE TOOL SATISFY THE CUSTOMER NEEDS?	NEEDS: easy to develop	electronic data transfer	fast data transfer (with fast connection availibility)	easy access in remote ares	continuous communication (min data transfer lag)	can clarify design details	can clarify construction methods	suitable for conveying gained project experience to future projects	allow multidisciplinary communication	better comprehension	quick comprehension	platform mobility	check what if scenarios	help conflict resolution	possibility for online meeting	
	2D CAD drawings	H	H	H	M	H	M	M	H	M	M	M	H	M	M	H	
	3D CAD drawings	M	H	H	M	H	H	H	H	H	H	H	H	H	H	H	
	2D Graphics, Charts	H	0	0	L	0	M	M	H	M	L	L	L	0	M	0	
	3D Graphics, Charts, Virtual photographs (3D Studio, studio max)	M	H	H	M	H	H	H	H	H	H	H	H	H	H	H	
	Tables	H	H	H	M	H	M	0	H	L	L	L	H	M	L	H	
	Photographs	H	0	0	L	0	H	M	H	H	M	M	M	0	M	0	
	Digital photographs	H	L	H	M	H	H	M	H	H	M	M	H	0	M	H	
	Virtual Reality	L	M	M	L	M	H	H	H	H	H	H	M	H	H	M	
	Walkthrough	M	M	M	M	M	M	M	H	H	H	H	M	0	M	M	
	Video	H	L	H	M	M	M	H	H	H	H	H	H	0	H	H	
	Animation	M	L	H	M	M	M	H	H	H	H	H	H	H	H	H	
	Simulation	L	M	H	M	L	L	H	M	H	H	H	H	H	H	H	
	Steady images	H	0	H	M	H	M	M	H	H	H	H	H	0	H	H	
	Text Documents	H	H	H	M	H	M	L	H	H	L	L	H	0	L	H	
	Daily/Weekly/ Monthly Reports (on paper)	H	0	0	0	0	0	0	H	M	L	L	L	0	M	0	
	3D Models	H	0	0	0	0	H	0	H	H	M	M	0	0	0	0	

4.2.3 Constraints in visualisation applications

In all IT implementations, there are constraints as well as benefits. The constraints and factors that cause negative effects on the implementation; i.e. factors that cause hesitation to its implementation and use, are determined during interviews: training need, requirement of user skills, legal constraints due to electronic environment, software and hardware requirement and availability problems, complex or difficult using, user interface, keyboard or operating system inappropriateness and high cost

Taking into account discussions with the companies and also current research in construction IT, it was decided that the constraints will not vary for each data flow. Therefore the interviewed companies are asked to prioritise the determined constraints. All interviewees evaluated the constraints' negative impact using a five-point scale. If the constraint is highly effective the value used is 5, if the effect is medium or low, the grades assessed will be 3 or 1 respectively. As in the prioritisation of needs assessment, 'irrelevance' is rated as 0. The average values of the ratings are calculated and normalised to determine the relative weight of implementation constraints. The average weight of the interviewers and relative weight of constraints are shown in Table 4.10. As seen from the table the highest hesitation is due to the high cost and of second–most importance the interviewees state a training requirement, which is also highly related with cost. The companies are aware, that making a software work in the organisation, i.e. training costs can be comparable or higher, than the cost of the software itself.

Table 4.10 The relative weight calculation of constraints

	Average scale	Relative weight
Needs training	4.00	0.157
User skills required	3.00	0.118
Legal constraints due to electronic environment	3.50	0.137
Software and hardware requirement and availibility problems	3.75	0.147
High cost	4.75	0.186
Complex or difficult to use:	3.50	0.137
User interface, keyboard, running system differences (inc. Language)	3.00	0.118
TOTAL	25.50	

4.2.4 Relationship between visualisation tools and constraints; How are the tools affected by the constraints?

Considering the characteristics and capabilities of the visualisation tools, the negative effects of each tool are evaluated using the same procedures as used for prioritisation of customer needs. Similarly, the constraints are evaluated using L, M, H notations, which are assigned 1, 3 and 9 values and irrelevance is graded as 0. The assessments are marked in a matrix where the visualisation tools are listed along the left and customer hesitations are listed along the top. (Table 4.11)

The effect of the prioritisation of these constraints are reflected on these relationships by multiplying two values. The sum of the products in each row determines the overall constraint affects created by the visualisation tool in that row. The importance weights of the constraints do not vary according to each data flow. Therefore the constraint calculations shown in Table 4.12 for design documents data flow will not change for the other data flows. The calculated constraint affection values for all data flows are shown in Table 4.13

Table 4.11 Tools vs Constraints Matrix (L=1, M=3, H=9)

TOOLS	CONSTRAINTS						
HOW MUCH ARE THE TOOLS AFFECTED BY THE CONSTRAINTS?	Needs training	User skills required	Legal constraints due to electronic environment	Software and hardware requirement and availibility problems	High cost	Complex or difficult to use:	User interface, keyboard, operating system differences (inc. Language)
2D CAD drawings	M	M	M	M	H	M	L
3D CAD drawings	H	H	M	M	H	H	M
2D Graphics, Charts	M	M	L	0	0	0	L
3D Graphics, Charts, Virtual photographs (3D Studio, studio max)	H	H	M	H	H	H	M
Tables	L	M	M	L	L	M	L
Photographs	L	L	0	0	L	0	0
Digital photographs	L	L	H	L	M	L	L
Virtual Reality	H	M	H	H	H	H	H
Walkthrough	H	M	0	H	H	M	M
Video	L	L	L	L	M	0	0
Animation	H	M	0	H	H	L	H
Simulation	H	M	0	H	H	L	H
Steady images	0	L	L	M	M	L	0
Text Documents	L	L	H	L	0	L	H
Daily/Weekly/ Monthly Reports	0	L	0	0	0	0	M
3D Models	L	L	0	0	L	0	0

4.2.5 Satisfaction of needs vs. constraints for each data flow

In the Tools versus Needs matrix the impact of the visualisation tools on satisfying the customer needs are assigned through values of 0, 1, 3, 9. Besides, the interviewers have also determined the importance of the needs. The product of these two values gives the weighted impact of the visualisation tool on satisfying the needs.

The sum of these weighted impacts termed the Need Satisfaction Value. This value shows the capability of the visualisation tool to satisfy the needs defined by the customer according to the prioritisation, reflecting the customer's perspective, of the needs.

In Table 4.12 the need satisfaction value calculations for the Design Documents are shown at the right side of the matrix. When the values are observed, 3D CAD drawings, 3D Graphics, charts, virtual photographs, animations and videos seem to be the most effective media. To draw the boundaries of the visualisation tools this technique can be used effectively. On the other hand although 3D CAD drawings have the highest Need Satisfaction Value for design documents data flow this does not necessarily mean that the optimum visualisation tool to be used in design documents communication is 3D CAD drawings. But it can be stated that 3D CAD drawings usage should be prioritised in the visualisation applications. The calculated need satisfaction values for all data flows are shown in Table4.13.

Table 4.12 Need Satisfaction Value calculation

DATA FLOW: DESIGN DOCUMENTS

Constraint Value	CONSTRAINTS: Needs training	User skills required	Legal constraints due to electronic environment	Software and hardware requirement and availibility problems	High cost	Complex or difficult to use:	User interface, keyboard, operating system differen (inc. Language)	HOW MUCH DOES THE TOOL SATISFY THE CUSTOMER NEEDS? HOW MUCH ARE THE TOOLS AFFECTED BY THE CONSTRAINT?	NEEDS: easy to develop	electronic data transfer	fast data transfer (with fast connection availability)	easy access in remote ares	continuous communication (min. data lag)	can clarify design details	can clarify construction methods	suitable for conveying gained project experience to future projects	allow multidisciplinary communication	better comprehension	quick comprehension	platform mobility	check what if scenarios	help conflict resolution	possibility for online meeting	Need Satisfaction Value
	0.1569	0.1176	0.1373	0.1471	0.1863	0.1373	0.1176	**Relative Weight of constraints and needs**	0.053	0.053	0.048	0.0354	0.0303	0.0657	0.048	0.0303	0.053	0.0707	0.0707	0.0354	0.0227	0.0556	0.0152	
2.88	0.6275	0.3529	0.2745	0.4412	0.5588	0.2745	0.3529	2D CAD drawings	0.48	0.48	0.43	0.11	0.27	0.20	0.14	0.27	0.16	0.21	0.01	0.32	0.07	0.17	0.14	3.45
3.32	0.7843	0.3529	0.2745	0.5882	0.5588	0.4118	0.3529	3D CAD drawings	0.16	0.48	0.43	0.11	0.27	0.59	0.43	0.27	0.48	0.64	0.21	0.32	0.20	0.50	0.14	5.23
1.55	0.4706	0.2353	0.1373	0.1471	0.1863	0.1373	0.2353	2D Graphics, Charts	0.48	0.00	0.00	0.04	0.00	0.20	0.14	0.27	0.16	0.07	0.64	0.04	0.00	0.17	0.00	2.19
3.05	0.7843	0.3529	0.2745	0.5882	0.5588	0.1373	0.3529	3D Graphics, Charts, Virtual photographs	0.16	0.48	0.43	0.11	0.27	0.59	0.43	0.27	0.48	0.64	0.07	0.32	0.20	0.50	0.14	5.09
1.54	0.3137	0.2353	0.1373	0.2941	0.1863	0.1373	0.2353	Tables	0.48	0.48	0.43	0.11	0.27	0.00	0.00	0.27	0.05	0.07	0.64	0.32	0.07	0.06	0.14	3.38
1.00	0.1569	0.1176	0.1373	0.1471	0.1863	0.1373	0.1176	Photographs	0.48	0.00	0.00	0.04	0.00	0.20	0.14	0.27	0.48	0.21	0.07	0.11	0.00	0.17	0.00	2.16
1.62	0.1569	0.1176	0.2745	0.4412	0.3725	0.1373	0.1176	Digital photographs	0.48	0.05	0.43	0.11	0.27	0.20	0.14	0.27	0.48	0.21	0.21	0.32	0.00	0.17	0.14	3.48
4.26	0.7843	0.5882	0.4118	0.7353	0.7451	0.4118	0.5882	Virtual Reality	0.05	0.16	0.14	0.04	0.09	0.59	0.43	0.27	0.48	0.64	0.21	0.11	0.20	0.50	0.05	3.96
4.26	0.7843	0.5882	0.4118	0.7353	0.7451	0.4118	0.5882	Walkthrough	0.16	0.16	0.14	0.11	0.09	0.20	0.14	0.27	0.48	0.64	0.64	0.11	0.00	0.17	0.05	3.34
1.68	0.3137	0.1176	0.1373	0.2941	0.5588	0.1373	0.1176	Video	0.48	0.05	0.43	0.11	0.09	0.59	0.43	0.27	0.48	0.64	0.64	0.32	0.00	0.50	0.14	5.16
4.13	0.7843	0.5882	0.4118	0.7353	0.7451	0.2745	0.5882	Animation	0.16	0.05	0.43	0.11	0.09	0.59	0.43	0.27	0.48	0.64	0.64	0.32	0.20	0.50	0.14	5.05
4.13	0.7843	0.5882	0.4118	0.7353	0.7451	0.2745	0.5882	Simulation	0.05	0.16	0.43	0.11	0.03	0.59	0.43	0.09	0.48	0.64	0.64	0.32	0.20	0.50	0.14	4.80
3.04	0.7843	0.5882	0.4118	0.4412	0.5588	0.1373	0.1176	Steady images	0.48	0.00	0.43	0.11	0.27	0.20	0.14	0.27	0.48	0.64	0.64	0.32	0.00	0.50	0.14	4.61
1.50	0.1569	0.2353	0.1373	0.2941	0.1863	0.1373	0.3529	Text Documents	0.48	0.48	0.43	0.11	0.27	0.07	0.05	0.27	0.48	0.07	0.64	0.32	0.00	0.06	0.14	3.85
1.35	0.1569	0.2353	0.1373	0.1471	0.1863	0.1373	0.3529	Daily/Weekly/ Monthly Reports (on paper)	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.16	0.07	0.07	0.04	0.00	0.17	0.00	1.25
1.43	0.4706	0.2353	0.1373	0.1471	0.1863	0.1373	0.1176	3D Models	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.48	0.21	0.07	0.00	0.00	0.00	0.00	1.51

Table 4.13 Need Satisfaction Values and Constraints of visualisation tools for each data flow

HOW MUCH DOES THE TOOL SATISFY THE CUSTOMER NEEDS? HOW MUCH ARE THE TOOLS AFFECTED BY THE CONSTRAINT?		NEEDS											CONSTRAINTS
		Detail reports (contracting period)	Design Documents	Method statements	What if scenarios	Schedule-work Programme	Resource Planning	Progress report	Design Problems communication	Daily site records	RFI Request for info	Change order	
TOOLS	2D CAD drawings	4.16	3.45	3.52	4.15	4.06	3.81	3.89	3.61	4.29	4.02	3.98	2.88
	3D CAD drawings	**5.82**	**5.23**	**5.28**	**5.73**	**5.33**	**5.11**	**5.02**	**5.30**	**5.77**	**5.65**	**5.61**	3.32
	2D Graphics, Charts	2.44	2.19	2.20	2.18	2.20	1.95	2.07	2.06	2.41	2.25	2.25	1.55
	3D Graphics, Charts, Virtual photographs	**5.69**	**5.09**	**5.18**	**5.62**	**5.24**	**5.03**	**4.94**	**5.19**	**5.66**	**5.49**	**5.45**	3.05
	Tables	3.98	3.38	3.17	4.04	3.91	3.65	3.76	3.44	4.15	4.12	4.07	1.54
	Photographs	2.36	2.16	2.44	2.20	2.44	2.15	2.18	2.18	2.40	2.04	2.04	1.00
	Digital photographs	4.07	3.48	3.72	4.03	4.06	3.81	3.73	3.73	4.21	3.90	3.86	1.62
	Virtual Reality	4.25	3.96	4.06	4.02	3.78	3.60	3.53	3.92	4.12	3.99	3.97	4.26
	Walkthrough	3.46	3.34	3.29	3.27	3.24	3.04	3.00	3.14	3.43	3.40	3.40	4.26
	Video	**5.66**	**5.16**	**5.25**	5.25	4.95	4.63	**4.56**	**5.01**	**5.51**	**5.30**	**5.30**	1.68
	Animation	5.43	5.05	5.03	**5.28**	4.89	4.60	4.50	**5.03**	5.39	**5.32**	**5.32**	4.13
	Simulation	5.01	4.80	4.70	4.92	4.40	4.16	4.00	4.72	4.89	4.97	4.99	4.13
	Steady images	5.12	4.61	4.63	4.85	4.79	4.53	4.47	4.59	5.13	4.95	4.91	3.04
	Text Documents	4.35	3.85	3.79	4.42	4.35	4.08	4.04	3.96	4.49	4.40	4.36	1.50
	Daily/Weekly/ Monthly Reports (on paper)	1.52	1.25	1.36	1.32	1.59	1.37	1.52	1.26	1.58	1.26	1.26	1.35
	3D Models	1.68	1.51	1.75	1.50	1.90	1.66	1.72	1.54	1.70	1.39	1.39	1.43

4.2.6 Discussion of results

In this research quality perspective of visualisation as well as the current situation in construction sector is examined. The customer needs and requirements are explored during the interviews organised with the top level managers of construction companies. The interviewees are asked to set importance weights to their perceived needs they stated. Likewise the constraints for the application of the visualisation tools and their importance weights are determined.

Using the QFD approach and the matrices, the voice of customer is converted into technical specifications, which are applied to visualisation tools in this research. The final outputs of this approach are the need satisfaction values obtained for each visualisation tool for each data flow and the constraint value determined using the same procedures and scale. The final values are shown in Table 4.13 and the visualisation tools in the highest three or four rank are written in bold numbers.

According to the calculations, the general tendency of the optimum is the 3D CAD drawings, 3D Graphics, Charts, Virtual Photographs, videos and animations. This is not surprising since the customers' importance of need evaluations came up as high averages the needs such as; easy to develop, better comprehension, quick comprehension, clarification of methods and design details, relatively higher than the other tools. Since the visualisation tools, 3D CAD, graphics, videos, and animations have these advantages, both the weighted

averages and the rated satisfaction values have yield a high Need Satisfaction Values of these particular tools. Therefore the degree of visualisation tools usage should be in accordance with the rank of need satisfaction values.

Although the qualitative approach yields an optimum level through rating techniques and matrix evaluation, the visualisation tool highlighted as the optimum is not necessarily the optimum solution for that data flow since each visualisation tool has specific characteristics and offers varying solutions to different problems. But it provides the prioritisation of the technical characteristics, visualisation tools, to be used in order to achieve the customer needs ranked according to the customer importance weights. It can not be stated that, for example, since the highest need satisfaction value for the schedule and work programme data flow is 3D CAD drawings, starting to use or increasing the use of 3D CAD drawings in this data flow will solve all the problems and the optimum visualisation level will be achieved. But it can be said that to achieve the needs defined within the rank provided by the customer, the visualisation tools to be used should be ranked according to the need satisfaction values.

Visualisation tools may have totally different characteristics. On the other hand, some of them may have similar characteristics but they may have unique features, which may make them the only solution for a particular task. In some situations a particular tool may be the unique solution for a task. In other situations, there may be tools with similar functions where we may choose the most suitable.

Despite rating techniques of QFD are applied to convert the qualitative

characteristics into quantitative characteristics the subjectivity is still in the matrices. The subjectivity of the companies is natural, since there is no way that precise metrics can be applied in an attempt to re-shape the manner which information is conveyed Oppositely it is defended that the optimum tool selection must be based on the decisions and evaluations of each company on its own Furthermore, projects are unique and level of implementation of visualisation tools must be considered project-specific, for reasons of cost-intensity, type (special engineering or standard construction works), and so on.

In this thesis a general application of the method is provided. An overview is presented of what is entailed in QFD as a background to assessing levels for visualised information in the construction process. In most cases, however, a QFD approach in this area would rather involve one individual company.

In this method constraints are also examined. And a final weighted average constraint value, which is calculated reflecting the prioritisation of the constraint affect of the tools, is determined. On the other hand although the two values, need satisfaction value and the overall constraint value are calculated via the same procedure and with the same scales, comparative results from other evaluation techniques, such as benefit - cost technique or similar are not done. It is believed in this research that all constraints must be evaluated separately, although the overall constraint value reflects the affect of each single constraint.

If the satisfaction/constraint proportion is used in this analysis to find the optimum text documents and daily/weekly/ monthly reports (on paper) would have

the greatest ratios. Although they do not satisfy any visualisation need since the constraints other than the inappropriateness of the keyboard, user interface and operating system would be very low the ratio will be very high. Therefore in this research satisfaction values and overall satisfaction values are calculated separately.

CHAPTER 5

CONCLUSION

Visualisation has been recognized as a significant technological theme that may help in increasing the effectiveness of communication during the construction process. Continuous advances of IT have made it possible for many construction issues to be addressed by use of visualisation at steadily lower cost. In this thesis some of the advantages of visualisation have been presented together with a qualitative approach to evaluate use of visualisation techniques in Turkish construction.

It has been attempted to identify types of information that can be visualised; by considering information content, information quality, and problems due to information clarification. The field study has taken place using interviews and survey questionnaires applied with the top level managers of Turkish construction companies.

There are many ways to help overcome conflicts and resistance in the construction process, but effective communication is maintained as central to

successful project performance. Traditional methods are increasingly incapable of providing fast and effective communication and in most cases modern networking and telecommunications has greatly increased the amount but not the quality of information. In fact, where information technology had long been hailed the enabler of the 'paperless office', it has instead caused an increase in the amount of paper.

In most construction projects the client is not an architect or an engineer. Project stakeholders are not all technically based, meaning that using traditional 2D drawings and sketches is not always effective or efficient when the overall project is considered from decision making, communication and customer requirements perspective.

5.1 Summary of the Survey Results

It is observed that computerized visualisation mainly consists of 2D and 3D drawings, although in project design companies some simulations and animations are also added to these views. In contracting companies visualisation is generally used for following the progress at site from main office. No cases were found where visualisation was implemented during construction stage to specifically circumvent buildability problems, for collaborative design, information exchange with site, clarification of technical details or construction methods, etc. Project decisions are based on visualisation in cases where the purpose of the visualisation is a presentation for the client; but visualisation does not leave the

conceptual design stage.

The question posed was; to what extent should visualisation be used for information and communication in a construction project. There will be cases where graphical or visual means are unnecessary. It follows that there is an optimum level for implementation of visualisation. This optimum point is project-specific, and furthermore dynamic, as the envelope of visualised information types is expanding, for example due to technological development. Nonetheless, the advantages presented in this thesis, compared with the survey result show that use of information visualisation and its tools is very low in construction. Logic dictates that, due to the ever-increasing amount of information needed in projects, we are below such an optimum point.

According to the field observations performed in this study, visualisation has not been fully embraced as a strategic tool for construction. There has been increase in extent of use but no change in the role of visualisation. This can be ascribed to construction not evaluating IT strategically, but rather implementing IT as tools on a project-basis. It is tempting to compare to the development of CAD. Unlike CAD however, which became fully implemented in the AEC industry because it fulfilled an already existing task (manual drawing methods) more cost-efficiently, visualisation represent a way of displaying information which is not rooted in construction tradition. The key, however, to appropriate and industry-changing utilisation of IT is effective strategic thinking, in the case of visualisation thinking about how to communicate efficiently.

5.2 QFD for Setting the Visualisation Levels

"Time was when a man could order a pair of shoes directly from the cobbler. By measuring the foot himself and personally handling all aspects of manufacturing, the cobbler could assure the customer would be satisfied," stated Dr. Yoji Akao, one of the founders of QFD, in his private lectures.

The origin of QFD technique is based on the aim to achieve converting the voice of customer into technical characteristics. In this thesis the customer voice is collected during the interviews conducted with the top level managers of the companies. The technical characteristics are the visualisation tools. The interviewees defined the importance weights for the needs for each data flow, and the relationships between the visualisation tools and the needs are determined. QFD technique implemented in this thesis takes the needs and their prioritisation as input, makes assessments using the relations between the needs and the tools, and gives out a rank of visualisation tools to satisfy the needs according to the prioritisation levels. In this thesis, the "optimum level of visualisation" does not refer to optimum visualisation tools but to the optimum combination of the visualisation tools to result in the optimum solution. Besides, QFD can not be used to find the optimum visualisation tool to achieve the desired needs' satisfaction. The output will always be the rank of visualisation tools to be improved starting from the one having the highest need satisfaction value. In Figure 5.1 are shown these evaluated visualisation tools' ranks for each data flow.

Table 5.1 Rank of visualisation tools for each data flow

RANK OF VISUALISATION TOOLS	DATA FLOWS										
	Detail reports (contracting period)	Design Documents	Method statements	What if scenarios	Schedule-work Programme	Resource Planning	Progress report	Design Problems communication	Daily site records	RFI Request for info	Change order
	3D CAD drawings 5.82	3D CAD drawings 5.23	3D CAD drawings 5.28	3D CAD drawings 5.73	3D CAD drawings 5.33	3D CAD drawings 5.11	3D CAD drawings 5.02	3D CAD drawings 5.30	3D CAD drawings 5.77	3D CAD drawings 5.65	3D CAD drawings 5.61
	3D Graphics, Charts 5.69	Video 5.16	Video 5.25	3D Graphics, Charts 5.62	3D Graphics, Charts 5.24	3D Graphics, Charts 5.03	3D Graphics, Charts 4.94	3D Graphics, Charts 5.19	3D Graphics, Charts 5.66	3D Graphics, Charts 5.49	3D Graphics, Charts 5.45
	Video 5.66	3D Graphics, Charts 5.09	3D Graphics, Charts 5.18	Animation 5.28	Video 4.95	Video 4.63	Video 4.56	Animation 5.03	Video 5.51	Animation 5.32	Animation 5.32
	Animation 5.43	Animation 5.05	Animation 5.03	Video 5.25	Animation 4.89	Animation 4.60	Animation 4.50	Video 5.01	Animation 5.39	Video 5.30	Video 5.30
	Steady images 5.12	Simulation 4.80	Simulation 4.70	Simulation 4.92	Steady images 4.79	Steady images 4.53	Steady images 4.47	Simulation 4.72	Steady images 5.13	Simulation 4.97	Simulation 4.99
	Simulation 5.01	Steady images 4.61	Steady images 4.63	Steady images 4.85	Simulation 4.40	Simulation 4.16	Text Documents 4.04	Steady images 4.59	Simulation 4.89	Steady images 4.95	Steady images 4.91
	Text Documents 4.35	Virtual Reality 3.96	Virtual Reality 4.06	Text Documents 4.42	Text Documents 4.35	Text Documents 4.08	Simulation 4.00	Text Documents 3.96	Text Documents 4.49	Text Documents 4.40	Text Documents 4.36
	Virtual Reality 4.25	Text Documents 3.85	Text Documents 3.79	2D CAD drawings 4.15	Digital photographs 4.06	2D CAD drawings 3.81	2D CAD drawings 3.89	Virtual Reality 3.92	2D CAD drawings 4.29	Tables 4.12	Tables 4.07
	2D CAD drawings 4.16	Digital photographs 3.48	Digital photographs 3.72	Tables 4.04	2D CAD drawings 4.06	Digital photographs 3.81	Tables 3.76	Digital photographs 3.73	Digital photographs 4.21	2D CAD drawings 4.02	2D CAD drawings 3.98
	Digital photographs 4.07	2D CAD drawings 3.45	2D CAD drawings 3.52	Digital photographs 4.03	Tables 3.91	Tables 3.65	Digital photographs 3.73	2D CAD drawings 3.61	Tables 4.15	Virtual Reality 3.99	Virtual Reality 3.97
	Tables 3.98	Tables 3.38	Walkthrough 3.29	Virtual Reality 4.02	Virtual Reality 3.78	Virtual Reality 3.60	Virtual Reality 3.53	Tables 3.44	Virtual Reality 4.12	Digital photographs 3.90	Digital photographs 3.86
	Walkthrough 3.46	Walkthrough 3.34	Tables 3.17	Walkthrough 3.27	Walkthrough 3.24	Walkthrough 3.04	Walkthrough 3.00	Walkthrough 3.14	Walkthrough 3.43	Walkthrough 3.40	Walkthrough 3.40
	2D Graphics, Charts 2.44	2D Graphics, Charts 2.19	Photographs 2.44	Photographs 2.20	Photographs 2.44	Photographs 2.15	Photographs 2.18	Photographs 2.18	2D Graphics, Charts 2.41	2D Graphics, Charts 2.25	2D Graphics, Charts 2.25
	Photographs 2.36	Photographs 2.16	2D Graphics, Charts 2.20	2D Graphics, Charts 2.18	2D Graphics, Charts 2.20	2D Graphics, Charts 1.95	2D Graphics, Charts 2.07	2D Graphics, Charts 2.06	Photographs 2.40	Photographs 2.04	Photographs 2.04
	3D Models 1.68	3D Models 1.51	3D Models 1.75	3D Models 1.50	3D Models 1.90	3D Models 1.66	3D Models 1.72	3D Models 1.54	3D Models 1.70	3D Models 1.39	3D Models 1.39
	Reports (on paper) 1.52	Reports (on paper) 1.25	Reports (on paper) 1.36	Reports (on paper) 1.32	Reports (on paper) 1.59	Reports (on paper) 1.37	Reports (on paper) 1.52	Reports (on paper) 1.26	Reports (on paper) 1.58	Reports (on paper) 1.26	Reports (on paper) 1.26

It is observed that the trends are similar in each data flow. This is not surprising since the highest importance weights of the customer needs were alike. In the results the highest need satisfaction values correspond to 3D CAD drawings, 3D graphics, charts, virtual photographs, animations and videos. As a result, to improve the quality of information used in construction communication these visualisation tools are the first tools that should be used or improved –if it has already been used.

It is also observed that the visualisation tools in the first three rank are the tools that are determined to be used by just a few companies in Turkish construction industry and within limited extents. The reason for this is the high cost of these tools. They also require qualified users and training must be provided at the beginning of the implementation. Generally, the construction companies hesitate to implement visualisation techniques since they find their investment quite costly. However, they ignore the chance of lowering projects costs arising due to less rework of the wrongly built items and improved communication in general in an inherently inefficient construction process. If they can predict the long term benefits to be gained through the implementations other than the satisfaction of the customer needs the visualisation use level of the communication will increase. On the other hand the appropriateness of the visualisation implementations to the IT strategy of the company and the appropriateness of the IT strategy to the business strategy are the important critical success factors that must not be ignored. Otherwise the implementations will serve solutions only for short term periods but return of investment will not be possible in the long term.

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APPENDIX A

INTERVIEW QUESTIONS

Corporate Strategy & IT Strategy

1. Does the firm have any determined strategy?

   a) no b) partially determined c) yes

2. If yes who has determined this strategy?

   a) owners and/or shareholders of the firm

   b) top level management

   c) top and middle level management

   d) employees of the firm

3. Which of the following techniques for analysis has been used in determining the general strategy of the firm?

   a) SWOT
   Strength and weakness opportunities and threat

b) Risk Analysis and Management

c) Benchmarking

d) Growth share matrix

e) Industry Attractiveness-Business strength matrix

f) Experience Curve

g) Scenario Analysis

h) Other :_____

i) No technique for analysis has been used

4. If you have marked the option i in question 3; how and according to which determinants has your firm's strategy been determined?

_____

_____

_____

5. Does your firm have a vision?

a) yes b) no

6. In which way the vision of the firm is described and how is it transferred to your employees?

_____

_____

_____

7. If you have a vision, are all employees acting in accordance with this vision?

   a) yes b) no

8. If you answered the above question as 'yes', how do you control whether they act in accordance with it or not?

   _____

   _____

   _____

   _____

9. If your answer is 'no' what can be the reason? (you can choose more than one option)

   a) The vision is only been known by the general manager and /or the top level management.
   b) The vision of company has not been worded.
   c) The vision has been prepared for the purpose of acquiring a quality certificate.
   d) The vision has been described appropriately but it has not been understood by the employees
   e) The vision has been described appropriately but it has not been adopted by the employees.
   f) Other: _____

10. Is there any determined IT strategy of the firm?

    a) no b) partially determined c) yes

11. If yes, who has described it? (You can mark more than one option)

a) Owners and/or shareholders of the firm

b) Top level management

c) Top and middle level management

d) Employees of the firm

e) IT department

f) Other: _____

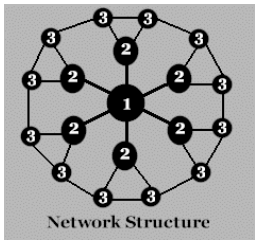
12. How often the following statements are observed in your firm?

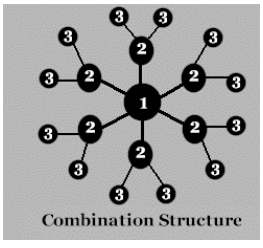
	never	sometimes	always
a) IT applications are determined in accordance with the studies that the IT department has conducted.			
b) Studies in the field of IT start on directions coming from high-level management of the company.			
c) Studies in the field of IT start on the demand of employees			
d) Studies in the field of IT start due to the external forces like rivalry, developments in the sector and/or IT.			
d) IT strategies are developed parallel to the corporate strategy of the firm.			
e) IT investments are developed and implemented within the framework of determined IT strategy of the firm.			
f) The purchase of even a small IT equipment is evaluated with respect to the IT strategy of the company.			
g) IT expenditures are concentrated mainly on the purchase of computers.			

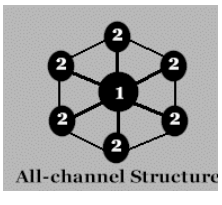
13. If you are conducting your IT studies due to external forces, which of the followings effect you in which level? (If you have some further reasons you can add them into the blanks)

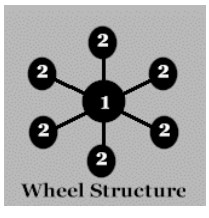
	Never	Rarely	farely	highly
a) Obtaining competitive advantage				
b) Catching up with the developments in the sector				
c) Being benefited from the developments taken place in the IT sector				
d) Pressures coming from other project partners				
e) Pressures coming from clients				
f) Pressures coming from customers (walkthrough, virtual reality)				
g) The obligation of establishing and supporting our own IT structures resulting from the lack of application in IT sector that can be directly used in construction market.				

14. Which of the following data transfer network structures, explained in the diagrams and definitions, resemble to your firm's data transfer structure?









a) *Network structure*: Communication takes place between the ones who directly need knowledge and the ones who have the knowledge

b) *Combination structure*: Sub-group leaders are communicating with principal group leaders. Sub-group members are in communication with the other members of their group.

c) *All-channel structure*: Partially independent group members are communicating with other members of their group and leader of the group. Besides they create products individually and/or as a group.

d) *Wheel structure*: Partially independent group members are only communicating with the group leaders and they produce individual products.

e) *Indefinite hierarchical structure*: Group members take certain roles in their group and there are no limitations in their communication channels.

e) Other: _____

15. Which of the followings are valid for the IT applications of your firm?

	Yes	No
a) There is a specific IT department, whose responsibilities and authority is clearly defined, in the firm.		
b) There is a group of employees supplying technical IT support.		
c) IT applications are conducted only by the IT department.		
d) High level managers are also responsible for IT studies together with the IT department.		

16. How is the necessary technical support for IT applications of firm supplied?

a) By the technical support group functioning bounded to the IT department in the firm.
b) By a contractually agreed technical support firm.
c) By temporarily agreed technical support firm upon a specific need.
d) By a group functioning bounded to IT department of the firm and when it is inefficient, by a contractually agreed technical support firm.
e) By a group functioning bounded to IT department of the firm and when it is inefficient, by temporarily agreed technical support firm.

f) Other _____

Data Architecture

17. Who and at which level, uses IT applications in the firm?

	poor	fare	advance
a) General manager			
b) High level manager			
c) Project manager			
d) Site manager			
e) Engineers			
f) Technicians			
g) Employees in the site (foreman, craftsman...)			
h) Accountants on site			

18. Please evaluate the validity of the following propositions for the data transfer and access in your firm.

	Yes	No
a) All information within the firm is recorded transmitted electronically.		
b) Information is recorded and classified electronically.		
c) Both electronic copies and hard copies are kept.		
d) All electronic data is also recorded and kept as in hardcopies.		
e) Drawings are mostly kept as drafts. And their transmittals are realized as drafts.		
f) In the data transfers, time difference (difference between the sender and the receiver) is usually observed.		
g) Sometimes, because of using hardcopies, loss of data occurs		
h) Data loss also occurs in electronic communication.		
i) Data loss in electronic communication can be remedied.		
j) Electronic communication is preferred due to the increased amount of time saving relative to other methods.		
k) Electronic communication is used if there are external forces making electronic communication an obligation.		
l) It is observed that employees hesitate to use electronic communication.		
m) Especially, senior engineers, who are highly experienced but also are far from the technological developments, are not able to benefit from electronic communication.		
n) Studies are conducted to remove the hesitations of the employees towards the electronic communication.		

19. Are definitions of permissions available for each user and group in the access of electronically kept data?

a) yes b) no

20. If you have answered YES to the question 19, which criteria determine these limitations? (You can mark more than one option)

a) Department based (permission to view for only the data related with their department)
b) Project based (permission to view the data related with the project in which they work)
c) User based.
d) Based on organisational hierarchy
e) Based on division of labours determined for multi-projects

21. Which data are kept electronically in the site? (You can mark several options)

a) Environmental conditions of the site (weather, place etc.)
b) Workforce parameters (number of the workers, qualification levels etc.)
c) Daily reports and head/equipment counts etc...
d) Site meeting minutes.
e) Revisions taken place in planning and programming.
f) Financial data.
e) The data concerning planning and scheduling.
f) Difficulties faced with in the phase of construction.

22. Has the web site of the firm designed considering the possible intranet and extranet applications?

a) yes b) no

23. Does the firm's web site take place in the data transfer and decision making mechanisms?

a) yes b) no

24. Among which locations, your information systems and IT structure elements are satisfactory?

a) Only in head office.
b) In head office and the site offices in other cities without access problem.
c) In head office and the site offices in other countries without access problem.
d) Between head office and the site offices whether there are access problems or not (even valid for the remote areas)
e) Other _____

Common Problems

25. In which degree, your data transfer methods are organised? (standardized data transfer methods, printed forms for these methods…etc.)

a) None b) Very low c) Low d) Medium e) High f) Very high

26. Are there any defined standard rules for the data transmission?

a) None b) Very low c) Low d) Medium e) High f) Very high

27. How often do you face inconsistency and vagueness problems due to various forms of information transfer made by different people?

a) Never b) Rarely c) Sometimes d) Frequently e) Very frequently

28. From the human originated factors given below please state the amount of problems arise during the site record keeping and transfer processes.

a. Insufficient time for record keeping

a) None b) Very low c) Low d) Medium e) High f) Very high

b. Insufficient number of site personnel

a) None b) Very low c) Low d) Medium e) High f) Very high

c. Varying levels of experience among the site personnel

a) None b) Very low c) Low d) Medium e) High f) Very high

d. Insufficient level of knowledge

a) None b) Very low c) Low d) Medium e) High f) Very high

29. How often do you face problems similar to the ones given below in your site.

a. Uneasy reach to the required data

a) Never b) Rarely c) Sometimes d) Frequently e) Very frequently

b. Readability

a) Never b) Rarely c) Sometimes d) Frequently e) Very frequently

c. Missing data

a) Never b) Rarely c) Sometimes d) Frequently e) Very frequently

d. Discrepancy

a) Never b) Rarely c) Sometimes d) Frequently e) Very frequently

30. How often do you face problems during the construction due to undefinite, ambiguous project information?

a) Never b) Rarely c) Sometimes d) Frequently e) Very frequently

31. How often do you use simulation technologies?

a) Never b) Rarely c) Sometimes d) Frequently e) Very frequently

Database

32. Do you have multi user common databases?

    a) yes b) no

33. If your answer is yes to the previous question, please evaluate the proposals given below for your company.

	Yes	No
a) Common databases should be electronic.		
b) Strategic data should be kept in electronic environment.		
c) Decision making tools connected to databases should exist		
d) Data base is web based.		
e) Easy access to the database from all offices and sites.		
f) Only main office may access the database.		
g) Database contains only numerical data.		
h) Database also contains visual information.		

34. What are the decision criteria in the selection of visualisation and information methodologies and tools?

    a) Ease of use

    b) Client requirement

    c) Cost ratio

    d) Market availability

e) Widespread utilization in the sector

f) Competitive advantage

g) Others_____

35. If you had a web based system with visualisation features, where would you use it efficiently?

a) Feasibility study

b) Planning

c) Design

d) Pre-construction stage

e) Construction stage

f) At the end of the job, at the delivery stage

g) Operation stage

h) Others: _____

Mobility

36. Do you use mobile technologies?

a) yes b) no

37. If your answer is yes to the question 36, in which areas do you use?

_____

_____

38. Which type of mobile devices and technologies do you use?

a) Cellular phones

b) Handheld computer

c) PDA (personal digital assistant)

d) Bluetooth

e) GPRS

f) WLAN

g) Others _____

Visualisation Approach

39. Some factors effective during the visualisation use are given below. Please add the factors that you find important but missing to the empty rows at the end of the table below.

Evaluate the degree of effectiveness of the factors below during a visualisation application using a 5-point scale. (0-not important) (5-very important)

Possible difficulties encountered	**Degree of importance**
a) Training and seminars	
b) Education level	
c) Legal constraints due to electronic environment	
d) Level of responsibilities and authorization	

e) Software availability	
f) High costing	
g) Uneasy use	
h) Risks	
i) Language (user interface, running system, keyboard)	
j) Other: _____	
k) Other: _____	

40. In the matrix given below left column indicates the information flow types during the construction stage. Please add the missing flow types in the empty boxes. Please indicate the tools currently used in your company with an X.

INFORMATION FLOW TYPES	THECURRENT VISUALISATION&COMMUNICATION TOOLS USED FOR DATA FLOWS	TOOLS																	HOW?																		VISUALISATION FACILITIES SHOULD BE DEVELOPED
		2D CAD drawings	3D CAD drawings	2D Graphics, Charts	3D Graphics, Charts	Tables	Photographs	Virtual Photographs (3D Studio, studio max)	Virtual Reality	Walkthrough	Video	Animation	Simulation	Steady images	Text Documents	Daily/Weekly/ Monthly Reports	3D Models	e-mail	facsmile	telephone	CD	mail- cargo- courier	ISDN	LAN/ WAN	Elektronic bulletin board	intranet	extranet	www	video konference	virtual reality	web based online messaging programs (msn,icq,)	Mobile teknologies (PDA, bluetooth, handheld comp	WLAN	Face-to-face meetings		
	Detail reports (contracting period)																																			
	Design Documents																																			
	Method statements																																			
	What if scenarios																																			
	Schedule-work Programme																																			
	Resource Planning																																			
	Progress reports																																			
	Design Problems communication																																			
	Daily site records																																			
	RFI Request for info																																			
	Change order																																			

41. General user needs and visualisation requirements are given at the left side of the matrix shown below. Information flow types where visualisation use may be beneficial are indicated at the right side of the matrix. Please add the items you find appropriate into the boxes supplied below.

    Please evaluate the importance level of requirements given for the information flow types mentioned, using the representations below.

Sign	Meaning
	Not important
L	Low importance
M	Medium importance
H	High importance

		DATA FLOW TYPES											
CUSTOMER NEEDS AND REQUIREMENTS	Customer Needs- Data Flow Matrix	Detail reports (contracting period)	Design Documents	Method statements	What if scenarios	Schedule-work Programme	Resource Planning	Progress report	Design Problems communication	Daily site records	RFI Request for info	Change order	
	easy to develop												
	electronic data transfer												
	fast data transfer (with fast connection availability)												
	easy access in remote ares												
	continuous communication (min data transfer lag)												
	can clarify design details												
	can clarify construction methods												
	suitable for conveying gained project experience to future projects												
	allow mutidisciplinary communication												
	better comprehension												
	quick comprehension												
	platform mobility												
	check what if scenarios												
	help conflict resolution												
	possibility for online meeting												