A PROPOSAL FOR THE STRUCTURE OF PRODUCTION DRAWINGS OF "DESIGN / BUILD" CONSTRUCTION PROJECTS IN COMPUTER ENVIRONMENT

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Nazlı Naz Çal

ABSTRACT

A PROPOSAL FOR THE STRUCTURE OF PRODUCTION DRAWINGS OF "DESIGN / BUILD" CONSTRUCTION PROJECTS IN COMPUTER ENVIRONMENT

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Documentation is an important aspect in the construction industry since there are many types and number of documents that have to be controlled for the success of a given project. In design/build projects, site technical groups of the contractor upgrade the tender drawings by preparing shop drawings to be sent to the consultant for checking purpose. Especially in large projects a great many shop drawings are produced, causing a need of a system to keep track of and to understand the status of the drawings. These all can be achieved with a proper documentation system to be used within the company.

The main aim of this study was to make a proposal for the structure of production drawings of "design/build" construction projects in computer environment to maintain control of the drawings in the construction sites while documenting them for project completion. This system should base on CADD Standards. In this, first, the architectural production drawings were identified. These were then arranged according to the model file-naming convention of the selected CADD Standard. Following, the main folders of the proposed documentation structure were created and, finally, the working principles of the structure were introduced. The system was applied to a real construction project for a period of two weeks and tested by usability evaluation.

The results of the usability evaluations revealed that the system provides advantages in terms of the control of shop drawings and documentation for project completion. Conversely, the system did not maintain ease of communication.

Keywords: drawing control; documentation; communication; CADD Standards; architectural production drawings.

ÖZ

"TASARLA - İNŞAA ET" TARZI İNŞAAT PROJELERİ UYGULAMA ÇİZİMLERİNİN BİLGİSAYAR ORTAMINDA DÜZENLENMESİ İÇİN BİR ÖNERİ

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İnşaat sektöründe dosyalama önemli bir yer teşkil etmektedir çünkü çok sayıda ve çeşitli belgeler vardır ve de verilen projenin başarıya ulaşabilmesi adına, bunların kontrol edilmesi gerekir. Tasarla-inşaa et tarz projelerde, müteahhidin teknik grupları orijinal çizimlerin üzerinde çalışırken, üretim çizimleri hazırlayarak kontrol edilmesi için kontrolöre gönderirler. Özellikle büyük projelerde, birçok sayıda üretim çizimi hazırlanır ki dolayısıyla çizimlerin aşamasını anlayabilmek ve takip edebilmek için bir sisteme ihtiyaç duyulur. Tüm bunlar şirket bünyesinde kullanılacak uygun bir dosyalama sistemiyle sağlanabilir.

Bu çalışmanın ana amacı, "tasarla - inşaa et" tarzı inşaat projeleri uygulama çizimlerinin bilgisayar ortamında düzenlenmesi için bir öneri sunmaktır ki bu şekilde şantiyelerdeki çizimlerin kontrolünün ve takibinin yapılabilmesi sağlanacaktır. Bu sistem CADD Standardlarını temel almalıdır. Bunun için, ilk öncelikle mimari projede olması gerekli olan çizimler saptanır, sonra seçilen CADD Standardındaki model dosya isimlendirmesi kurallarına göre çizim adları düzenlenir. Takiben, önerilen dosyalama sisteminin ana dosyaları oluşturulur ve son olarak da sistemin çalışma prensipleri tanıtılır. Sistem, gerçek bir inşaat projesinde, 2 haftalık bir süreç için uygulanır ve kullanılabilirlik değerlendirmesi yoluyla test edilir.

Kullanılabilirlik değerlendirmesinin sonuçlarına göre bu sistemin, üretim çizimlerinin kontrolü ve dosyalanması bakımından projenin tamamlanma evresinde birçok avantajı bulunmaktadır. Zıt olarak, sistem iletişim açısından kolaylık sağlamamaktadır.

Anahtar sözcükler: çizimlerin kontrolü; dosyalama; iletişim; CADD Standardları; mimari çizimler.

To,

My Mother and Father

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LIST OF ABBREVIATIONS

AAA	American Arbitration Association
AEC	Architecture, Engineering and Construction
AIA	American Institute of Architects
CAD	Computer Aided Design
CADD	Computer Aided Design and Drafting
CI/SfB	Construction Index/Samarbetskommitten for Byggnadsfragor
CICSs	Construction Information Classification Systems
CPIC	Construction Project Information Committee
EDMS	Electronic Document Management Systems
ISO	International Organization for Standardization
NCS	National CAD Standards
PM-ASP	Project Management System-Application Service Provider
PMIS	Project Management Information Systems
RFI	Requests for Information
RFQ	Requests for Quotation
TSE	Turkish Standards Institution
WPMS	Web-based Project Management System

CHAPTER 1

INTRODUCTION

In this chapter; first, the argument, the problem and the necessity of the study is underlined, followed by a statement of objectives defining specific end results intended to be found at the conclusion of the study. It continues with a sub-section procedure, the stages taken through the investigation process are introduced. The chapter concludes with a section titled disposition, where a summary of material presented in the thesis is given.

1.1. Argument

Construction projects include many types and number of documents. Due to the importance of documentation that affects the success of a given project in the construction industry, the documents used throughout the construction process should have to be controlled by the project team orderly. Since the construction project is a living mechanism documents such as drawings, reports, schedules, *etc*. must be followed up with a useful system which at the end requires the usage of a proper documentation system. Failing to use a proper documentation system may have adverse consequences that sometimes result in claims between the parties. Without a systematic documentation control system, communication within group members and also with the client will be poor. The problems arising due to unsatisfactory communication may result in failure of work on the job site. To avoid such failure, coordination among site staff and the technical office is very important. These all can be achieved by using a proper documentation system in the company.

In design/build projects, site technical groups of the contractor upgrade the tender drawings by preparing shop drawings to be sent to the consultant for checking purpose. Especially in large projects a great many of shop drawings are produced, causing a need of a system to keep track of and to understand the status of the drawings. Tracking up the status of each drawing needs a clear and understandable documentation system. The confusion that may arise due to unsatisfactory tracking system, poor site works can occur which may lead to time and money loss to contractor besides loosing its reputation. To abstain from such confusion, companies should use proper documentation system.

Documentation systems should also maintain a basis for information search and data ownership. Since there are many different documents in construction projects that include huge amount of information, the information search has large importance in the construction industry. In technical group, a person looking for information such as the status of the document, data ownership, computer, folder location, *etc.* should know the entire process well to save time and to obtain correct information. Since there is an information flow between the different parties in construction projects, Computer Aided Design and Drafting (CADD) Standards could be used in the documentation systems to make the communication process easier.

The data should be produced and exchanged according to predefined guidelines that are the CADD Standards which bring consistency to the appearance of CAD drawings and efficiently communicate construction information within the parties of a construction project. A system that is based on CADD Standard may facilitate the documentation and information flow in the construction projects. The challenge is the absence of a current CADD Standard used in the Turkish construction industry.

1.2. Objectives

The main aim of this study was to make a proposal for the structure of production drawings of "design / build" construction projects in computer environment that bases on CADD Standards to maintain control of the drawings in the construction sites while documenting them for project completion. The system was intended for companies that were not using electronic document management systems (EDMS).

In this study the social aspects such as the adaptation process of the users to the proposed documentation structure and the psychology of the participants to accept using a new system were disregarded as an assumption. Proposing a system was a positive attribute of this study but it is not expected to solve the problems directly.

The points set forth below summarize of the objectives intended to be reached at the conclusion of this research;

- To explore current standardization systems in construction sector in respect of drawings.
- To propose a documentation structure for the architectural group of a construction project based on CADD Standards.
- To propose forms that manages the approval of the shop drawing submissions.
- To evaluate the applicability of the proposed system according to usability guidelines.
- To comment on the advantages/ disadvantages of the system based on the views of the Turkish construction industry.

1.3. Procedure

The investigation progresses through several stages which can be followed in Figure 1.1.

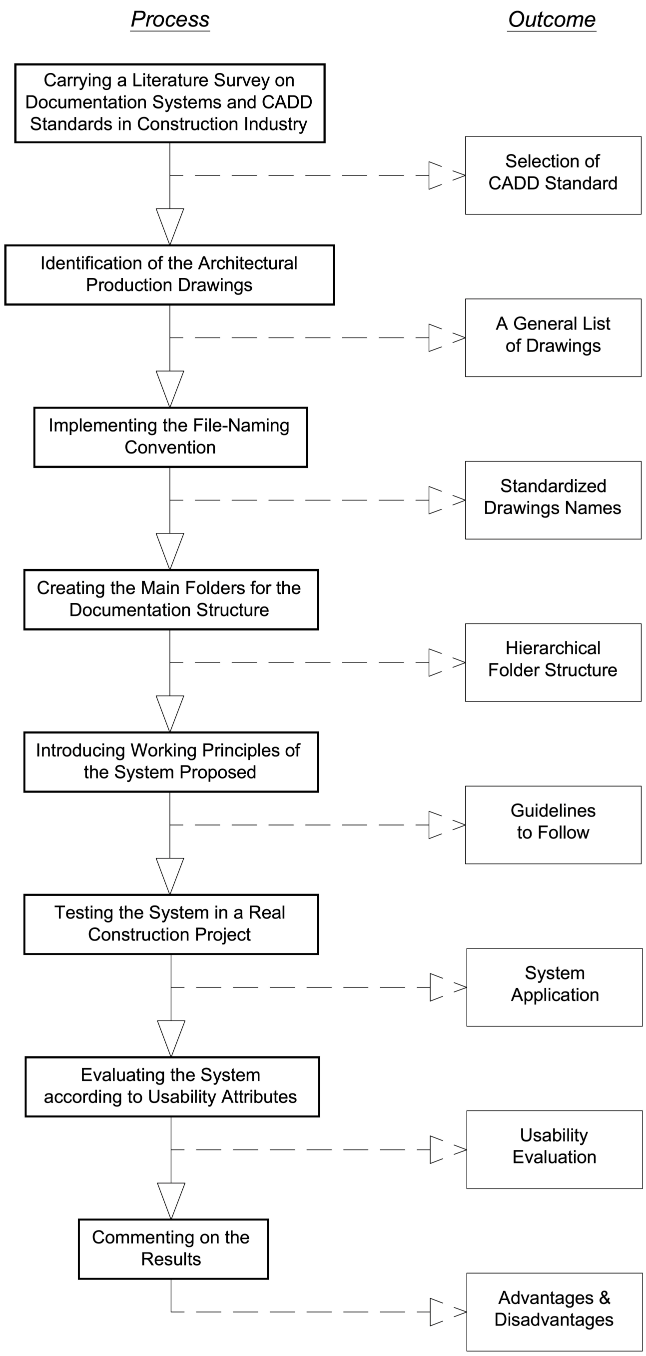

Figure 1.1. The Stages of the Study

As a starting point, a literature survey was carried out to explore the topics related with the documentation systems and CADD Standards in the construction industry. In the light of the findings, as being an ISO compatible standard using the Uniclass, AEC (UK) CAD Standard selected to be used. First, as the architectural group selected to be worked on, the architectural production drawings were identified. Second, the selected standard's model file-naming convention was implemented to the drawings identified. The documentation structure proposed depends on hierarchical folders arranged according to their functions. As a following step, the main folders of the proposed documentation structure were created in the server of the company. It was continued with distributing the working principles of the proposed documentation structure. The proposed system was tested in a real construction project. Usability evaluation was used for the system testing. A semi structured interview was carried out and the results were analyzed according to the comments they gave and the possible advantages and the disadvantages of the system were listed.

1.4. Disposition

Second chapter of this study entails a literature survey regarding the clarification of the related subjects. First, the life cycle of a project, their types and parties involved were described to give a general view about the construction projects. Next, as a starting point for communication and information flow, the main building stones of the documents were mentioned that are data and information, following the importance of information ownership and information systems. As a step forward, document management was explained from the traditional document management to electronic document management systems (EDMS) and then web-based project management system (WPMS) that is one step further of EDMS. As documentation systems should include standards, construction information classification systems (CICS) were mentioned and two of them were introduced briefly; CI/SfB and Uniclass. After introducing the CICS, the CADD Standards that mainly base on them mentioned including the AIA CAD Layer Guidelines, ISO CAD layering (13567), BS 1192 Part-5 and AEC (UK) CAD Standards. Finally, usability evaluation used for the system testing, was introduced by giving the basic usability attributes.

In chapter three, the material and method applied to create the proposed documentation structure were explained briefly. After the creation of the system, the working principles were mentioned. The system was tested in a real construction project for a period of two weeks. The purpose of the case study was to test applicability of the system.

Chapter four includes the results and discussions of the system. The system was evaluated according to usability attributes. The comments of the two participants were given according to a semi structured interview.

In the conclusion chapter according to the results of the usability evaluation, comments were made revealing the possible advantages and disadvantages of the system by referring to the further studies.

CHAPTER 2

SURVEY OF LITERATURE

This chapter entails a literature survey that covers a total of thirty nine references considering the clarification of the related topics about the subject domain. These are mainly grouped under five sub-sections that are;

- Construction projects; to give a general opinion about the sector.
- Communication and information flow; to understand the importance of information in the construction industry.
- Document management; to investigate the current document management systems in the construction industry.
- CADD Standards; to investigate the current drafting standards in the construction industry.
- Usability evaluation; for the system testing used in the methodology.

2.1. Construction Projects

Before stating the main subjects, some general information was given about the construction projects briefly. First, the life cycle of a project was introduced that maintains the understanding of the steps taken in a project. Next, major types of constructions were described to understand the extent of the sector and finally parties involved in a given construction project were introduced to underline the need of communication between them.

2.1.1. Life-Cycle of a Project

As mentioned by Hendrickson and Au (2003) the project life cycle is a continuing process from cradle to grave of a project. The life cycle of a project is divided into several stages by Hendrickson and Au (2003) as can be seen in Figure 2.1, but these stages of development may not be strictly sequential.

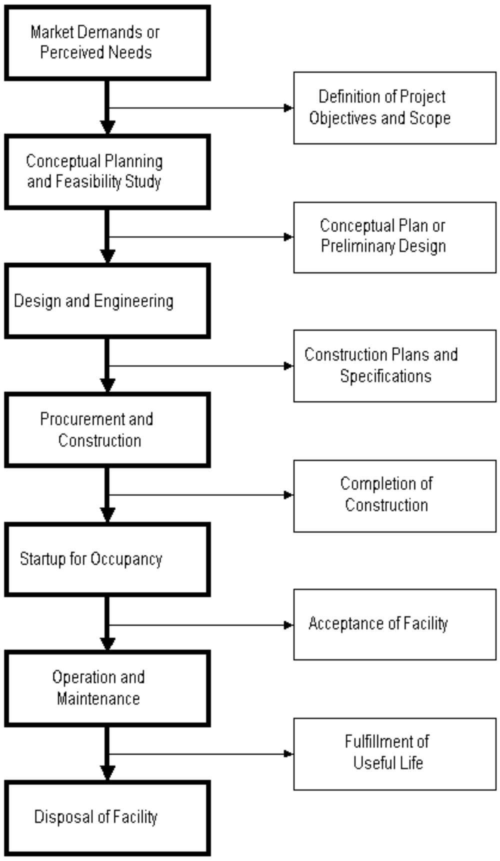

Figure 2.1. The Project Life Cycle of a Constructed Facility
(Source: Hendrickson and Au, 2003)

According to Hendrickson and Au (2003), a project is started to meet the *market demands and needs* in a timely manner. Continued with *the conceptual planning stage* where various alternatives are considered according to their technological and economic feasibilities. It is also mentioned that the completion time and cost is arranged in this stage which constitute the parts of the scope of the project. The next stage pointed out is *detailed engineering design* that creates the basis for construction takes its place. Followed with the delivery of the materials and the erection of the project on site are planned in *the procurement and construction stage*. After the construction completes, s*tart up for occupancy* stage is the time when the completed facility started to be used. It is continued by the stage *operation and maintenance* that includes the management of the facility which is given to the owner until the *disposal of the facility.*

As noted by Hendrickson and Au (2003), there is no single approach for managing projects through their life cycles. The authors continue as, each has advantages and disadvantages and owner must decide to the most appropriate and beneficial approach for a particular project according to his or her knowledge of construction management and also to the type, size and location of the project.

2.1.2. Major Types of Construction

Hendrickson and Au (2003) state that the planning for various types of construction differs from each other in terms of procuring professional services, awarding construction contracts and financing. They classify the constructed facilities into four major categories and described them briefly as can be seen below;

- *Residential Housing Construction;* are single-family houses, multi-family dwellings, and high-rise apartments.
- *Institutional and Commercial Building Construction;* include a great variety of project types and sizes, such as schools and universities,

medical clinics and hospitals, recreational facilities and sport stadiums, retail chain stores and large shopping centers, warehouses and light manufacturing plants, and skyscrapers for offices and hotels.

- *Specialized Industrial Construction;* involve very large scale projects with a high degree of technological complexity, such as oil refineries, steel mills, chemical processing plants and coal-fired or nuclear power plants.
- *Infrastructure and Heavy Construction;* includes projects such as highways, mass transit systems, tunnels, bridges, pipelines, drainage systems and sewage treatment plants.

2.1.3. Parties in a Construction Project

Oberlender (2000) indicates three principal parties in a project; owner, designer and contractor each of which has a role in the various phases of design development and construction. It is also underlined that to complete a project effectively there must be a team work and effective communication between these groups. Oberlender (2000) makes the definitions of these three principle parties as can be seen below;

- *Owner,* which is the ultimate end user of the project, is the party who gives the job and can be public or private. The responsibilities of owner are pointed out as; setting the operational criteria for the completed project, defining special equipment, material, or company standards for the project, identifying their level of involvement to the project and setting parameters on total cost, payment of costs, major milestones, and the project completion date.
- *Designer* produces the design that must fit the federal, state and local codes; standards; and environmental and safety regulations. The responsibilities of the designer are pointed out as; producing design

alternatives, computations, drawings, and specifications, on-site or periodic inspections, review of shop drawings and sometimes acquisition of land and permits, and preparation of a design schedule and budget.

- *Construction Contractor* controls the work done during the construction phase. The responsibilities of the construction contractor are pointed out as; getting the work done in accordance with the contract documents, preparing an accurate estimate of the project, developing a realistic construction schedule and establishing an effective project control system for cost, schedule and quality.

Till now brief information was given about the construction projects. In light of these, it can be understood that construction projects are complex such as the steps taken, their types and the number of the parties involved. In the following sub-section the need of a proper communication between these parties throughout the project life cycle is mentioned by underlining the importance of information flow in terms of information ownership and information systems.

2.2. Communication and Information Flow

Fryer (1990) states there are a lot of people from many different firms in the project team and a lot of information needs to be exchanged among them causing a need of a well-organized network of communication. As also explained by Cleland (1999) a well-developed strategy for understanding and managing the set of procedures and documents establishing information is needed for the management of any project.

2.2.1. Data and Information

Senn (1989) defined data and information as can be seen below;

- *Data* is the facts and records of an event that took place or about to. The facts are independent, unrelated and unlimited in number. He continues as, data must be changed to a useful form and placed in a context to have a value because they are meaningless by themselves.
- *Information* is the input to be acted upon a stimulus results in some action that is taken by managers or others, or the product of some other action.

Cleland (1999) states, unless it is used in the management of the projects the information has no real value and information does not guarantee success, but lack of information can cause to project failure.

2.2.2. Information Ownership

As referred to the Construction Project Information Committee (CPIC), Tanyer (2005) mentioned that when information is shared between the members of construction project teams, it is not always obvious that who generated the information, whether the information is intended to be preliminary or finalized, where explanation can be sought when required, who is responsible for maintaining the information.

Tanyer (2005) underlines that identifying the ownership of information throughout its transfer in the project stages between users is necessary for collaborative working. As mentioned by Tanyer (2005) some standards are used for information ownership within project environments such that; layer, file and directory naming. These will be described in the forthcoming parts.

2.2.3. Information Systems

Fryer (1990) states that for management control, an effective system that passes on information and instructions and receives feedback is essential. This system must work both with in and among the many firms- consultants, contractors, subcontractors, suppliers, and client-who contribute to the design and production of the finished structure.

Radford (1973) analyzes Information systems in three groups:

1. General Information Systems
2. Project Information Systems
3. Management Information Systems

- *General Information Systems:* As stated by Radford (1973) these include the general information of resources such as materials, products, building components, labor, suppliers and technical data, and data from previous projects.

- *Project Information Systems:* Radford (1973) mentioned that these are directly related with the design and construction phases of the building process. It is also mentioned that they include technical drawings, briefs, specifications, schemes, and details and also design information. In this phase designer's and contractor's own data both interrupt on project and general information.

- *Management Information Systems:* Shaheen (1987) point out that this system collects analyzes processes and distributes information relative to project activities, finances, progress, and administration to all parties. It is continued as they vary in form, content, and detail from project to project depending on complexity of the work and the various levels of management requiring information.

As referred to Egan (1998), Björk (2002) indicates the task of managing all the information needed to design and construct any major facility is a real difficulty and it is believed that more efficient information management increase productivity for the construction industry. According to Björk (2002), electronic document management systems (EDMS) and product modeling are the two streams that propose different solutions to the problem of project information management.

Björk (2002) indicates that EDMS has the potential to increase the information management in construction projects considerably, without any need of radical changes to current practice. As continued by Björk (2002) by building the system incrementally on the current documentation practice in the industry, the wide-spread adoption of EDMS is increased within companies and in particular across all the participants in projects. Under the following subsection "document management", the meaning and importance of the EDMS will be mentioned.

2.3. Document Management

Björk (2002) makes the definition of *document* as an information carrier (usually on paper) containing written or drawn information for a particular purpose. As referred to Löwnertz (1998), Björk (2002) indicates that a document can easily be transferred, stored and handled as a unit. As mentioned by Forcada (2005) over the last years the term document has changed in definition, though in today's business world, a large part of the documents are stored as individual computer files. Forcada (2005) continues as documents are processed and stored not longer as physical objects but as digital ones. As referred to Björk(2001), Forcada (2005) states that *electronic document* is an information container in electronic form which includes information from a variety of sources, in a number of formats about a specific topic to meet the needs of a particular individual.

According to Last (2000) basic construction project documents are construction contract and purchase orders, bid documents, schedule data and devices, project diaries, change orders and change order logs, plans, specifications, shop drawings, requests for information and submittals, project correspondence, job cost reports and estimates, financial statements, employee payroll records, photographs and videos and miscellaneous documents.

As stated by Rosenau and Githens (2005), at the completion of a project the customer's acceptance of the result shows us the project success. This is continued as, when closing a contract the delivery of the documentation (deliverables), as well as some other tangible output (results) is very important. Rosenau and Githens (2005) mention, such documentation should include a spare parts list, instruction manuals, and as-built drawings, in addition to a final report. However, as mentioned by them obtaining these final documentation reports may delay the completion date of the project.

According to Rosenau and Githens (2005), completion of the documentation at the end of the project is difficult because of two reasons;

1. Many technical specialists are poor writers and may not want to write.
2. The people who have knowledge may not be still working on that project or may be assigned to another activity.

2.3.1. Traditional Document Management

According to Hjelt and Björk (2006), although construction documents have not changed for decades the technology for producing, managing, duplicating and distributing them has much changed. They state this process of change as; the first step for information duplicating is photocopying in the 60's. During the 80's the second wave of technological innovation occurred that involved the proliferation of personal computing. Towards the late 80's CAD software usage increased the share of CAD produced drawings dramatically. However, the transfer of the information was still done as paper copies in the mail or using couriers. The information can be reused in digital form by diskettes. The fax started to be used as a popular data transfer method during the 80's also, but it was useless for reuse of the data in digital form. In the late 80's and early part of the 90's, by the help of the computer networking the use of document management systems for project documentation was supplied. Since around 1995, the data transfer and management are enhanced by the internet usage in the construction industry.

Hjelt and Björk (2006) indicate that although hardly any documents are produced by hand today, many are still transferred by printing them out and sending them to the other parties by mail or couriers. It is continued as however, there is an improvement that the documents are produced digitally and transferred digitally as e-mail attachments. But according to them this is only a minor improvement since finding a document in another person's PC is a very hard process.

2.3.2. Electronic Document Management Systems (EDMS)

Watson and Davoodi (2002) declare that most of the documents generated for transfer between project team members throughout a given construction project is digital. Rezgui and Cooper (1998) point out that although the production of documents is done using computers, the present document management practices rely to a large extent on manual methods. The later continue their statement as leading construction companies have enforced the use of electronic document management systems (EDMS) to support the effective, consistent management of the entire documentation produced and used in a project in recent years.

As Shipman (2006) indicates, EDMS is a computer-based system which controls the creation/capture and storage of documents; distribution of these documents; user-access to the documents; and process for document updating. It is continued as EDMS also includes control over document check-out, check-in and revisions. As Shipman (2006) points out, in EDMS, there is a database and the system manages the documents containing relevant information through this database. It is underlined that documents are reached by users connected on a network with Windows® based PCs, or by users on an intranet using browser technology.

According to Björk (2002), EDMS maintains the management of documents related with the particular enterprises, projects and work groups in computer networks. It is emphasized that EDMS includes increased features related with the life-cycle and versioning of particular classes of documents, in addition to the basic file management capabilities.

As Björk (2002) indicates, there is primary and secondary information in documents; and they are defined as the primary information is within the documents and the secondary information, which is referred to as metadata, is about the document and it maintains searching, retrieving and opening of the documents.

Hjelt and Björk (2006) list the two ways for document searching in EDMS as using a hierarchical folder structure or using metadata. According to them, using hierarchical folder structure is very easy to understand by the end users since it uses the same way as the folder structure in the Windows® operating system. It is also mentioned by Hjelt and Björk (2006) that the only drawback is the particular view of the total document base. They specify that some systems create the folder structure by themselves meanwhile some allow the users to create their own structures. As said by Hjelt and Björk (2006), in metadata-based systems, the data is placed separately from the documents in a database so that automated searching can be performed. As related by them, the metadata is related to attributes such as type of software with which a document was created, engineering discipline, phase of the construction process, part of the building described, scale (for drawings), revision *etc*. and this type of metadata is in fact already included in traditional documents in the form of drawing headers *etc*. but not in a computer searchable form. According to another study of Björk (2002), simple hierarchical folder structures are popular with end users instead of the more advanced features which can be offered by metadata-based search mechanisms.

Björk (2002) studied EDMS in the construction industry. Within the context of this research, a typology of research questions and methods is used to position the individual research efforts that are surveyed. As a consequence, some of the findings according to the literature search are; the systems used in house and commercially have some features that answer to the needs of the end users and most of the commercial products have the common features, but some not. As referred to Hartvig's (2000) study related with user requirements in the Danish construction industry, Björk (2002) mentioned that, when the number of features in a system increases, it becomes more complex to learn and this creates a barrier to usage. According to him, simplicity to learn and use of the system is a major factor to be considered. Preliminary results of an ongoing study of Björk's group show that the size of the project determines whether or not to use a project web. Björk (2002) concludes that according to the case studies investigated, it can be reported that technical problems or the cost of using systems are no longer barriers to wide-spread adoption and the things now in focus are the organizational issues surrounding the use (who is in control) as well as the psychology involved in getting all participants in projects to accept using new technology.

In the study by Hjelt and Björk (2006), a questionnaire was sent out to companies proposing document management solutions in both the Nordic countries and the USA to learn about the features found in the systems used.

The common features of the systems can be seen below;

- A main retrieval mechanism based on either hierarchical folders or metadata.
- Handling of revisions and change management.
- Viewing of CAD-files using special purpose software.

Features found in only a few systems were, for example:

- Electronic authentication of user identity (*e.g.* smart cards).
- Full text search capability.

Rezgui and Cooper (1998) emphasize that many leading construction organizations with an advanced IT department have undertaken the development of their own tools and solutions to support the production and maintenance of project documents because the various solutions proposed by some software vendors have proven to be unsatisfactory. It is continued as, although these tools include many helpful facilities such as support for document storage, retrieval, versioning and approval, they don't handle any semantics of the information being processed and this causes limited support for the end-user.

In the light of these, it can be said that, EDMS should also include standardization of primary and the secondary information (content and metadata) of the documents. (*e.g.* CADD Standards should be applied) *a. Advantages of EDMS;*

According to Hjelt and Björk (2006), many companies want to standardize information access within their organization by using an EDMS, by means of which it becomes easier for users to access information, to complete their work and to provide the company with security, reliability of data and work process management. It is concluded by Hjelt and Björk (2006) that many of these features eventually save time, simplify work, protect the investment made in creating these documents, enforce quality standards, enable an audit trail and ensure accountability.

b. Limitations of EDMS;

Rezgui and Cooper (1998) analyzed current document management practices of three construction companies and listed the following limitations:

- Every partner within the project must use the same EDMS on a project to be able to access and share documents.
- The semantics of document and it's internal structuring is not controlled by the EDMS. Documents are handled as black-boxes.
- The EDMS does not support document cross-referencing or semantic linking.
- Security is always an issue. It is not easy to implement as for printed documents. EDMS require improved user authentication and document protection.
- The EDMS is not integrated with proprietary and commercial applications used within the company (*e.g.* CAD applications and word processors).
- Most end-users in the construction industry are not computer literate. EDMS lacking user friendliness, or used in a maladapted environment

(*e.g.* network communication problems) discourage the user from using the EDMS.

As mentioned by Forcada (2005), electronic document management systems (EDMS) are applications that can be linked to web-based project management systems (WPMS) to improve communication among partners.

2.3.3. Web-based Project Management Systems (WPMS)

Nitithamyong and Skibniewski (2004) define WPMS as a concept of using the World Wide Web and its associated technologies to manage construction projects. The authors also note that WPMS is used to maintain documentation and control of construction projects and to improve the working of project team. They continue as, WPMS, which is an electronic project management system conducted through *"Extranet"*, that is a private network transmitting information by using internet protocols, increases the speed of communication between project participants.

According to Mead (1997), there are four categories of construction project information that are carried through WPMS:

- *Project information*; details about the project such as project participants, project e-mail directory, project description, and a photo archive of the project's progress.
- *Design information*; any information generated by the design team, such as CAD drawings, specifications, clarifications and changes, and punch lists.
- *Management information*; developed by the project manager and includes meeting minutes, submittals and shop drawings, change order status logs, as-built drawings, requests for information (RFIs), requests

for quotation (RFQs), contract status logs, safety information, daily logs, and project schedules.

- *Financial information*; developed by the accounting staff responsible for the project and includes cash flow, projections, requisition status, general ledger and contract status reports.

As Nitithamyong and Skibniewski (2004) mention, WPMS is a closed network, which means everyone entering the system needs a digital ID and password. As a consequence it is stated that if anyone makes a change in a document, it is possible to determine who did what and when, who looked at what and when which means there is a control. As continued by Nitithamyong and Skibniewski (2004), the system also proposes a hierarchical order that restricts some documents to some people at certain levels of responsibility.

It is underlined by Nitithamyong and Skibniewski (2004) that although they change from product to product "Project Management System-Application Service Provider (PM-ASP)" has a list of current features: document management, project workflow, project directory, central logs and revision control, advanced searching, conferencing and white-boarding, on-line threaded discussions, schedule and calendar, project camera, file conversion, printing service, web-site customization, off-line access, messaging outside the system, wireless integration, achieving of project information, information service, financial service, and e-bidding and procurement.

Chinowsky and Rojas (2003) point out that the WPMS provides a centralized, accessible and reliable means of transmitting and storing project information, but that still being new, its optimal styles and extensions have not yet been thoroughly investigated. The authors continue as, there is still debate among architecture, engineering and construction (AEC) firms regarding whether or not to move over to WPMS permanently.

2.3.4. Construction Information Classification Systems (CICSs)

As Caldas and Soibelman (2003) indicate, usage of communications and information technologies in the construction industry creates new opportunities for collaboration, coordination and information exchange among organizations working on a given construction project. The authors continue as the inter-organizational construction management information systems collect, retrieve, process, store, and distribute data to support planning, control, and decision-making among project organizations. Furthermore, it is pointed out that these systems support the construction process by exchanging and integrating data from different sources and in different formats.

In continuing, the same authors state that as a result of the increase in the amount and types of information and the construction industry's subsequent reliance on them, classification standards arranged that comprehend the full scope of the construction information. It is also mentioned that these standards maintain the organization of project information and facilitate communication between project organizations throughout the life of the project. Caldas and Soibelman (2003) carry on as construction information classification systems (CICSs) were developed to provide this classification standard and can be defined as a standard representation of construction project information.

Caldas and Soibelman (2003) give examples of CICSs; these are the CSI Masterformat, the CSI Uniformat, CI/SfB, Uniclass and the Overall Construction Classification System. They mention that CICSs, which is an essential component in the integration of construction project information, provide a common framework for information organization and access in construction management information systems.

Kang and Paulson (2000) indicate that a proper CICS should be used for managing construction information because it will be the information center through the life-cycle of a project. They also state that Construction Index/Samarbetskommitten for Byggnadsfragor (CI/SfB) has been used in various countries as one of the best among the earlier CICSs, as well as Masterformat in North America.

a. CI/SfB;

As mentioned by Jay-Jones and Clegg (1976), the CI/SfB Construction Indexing Manual, which is used for the arrangement of project documents, is primarily a classification of buildings and their components. The basis for the arrangement is set by tables as can be seen below in Table 2.1.

Table 2.1. CI/SfB tables

Table 0	Physical Environment	End results, projects, and the physical environment as a whole.
Table 1	Elements	Constructional parts of projects according to their function.
Table 2	Constructions, Forms	Constructional parts of projects, according to their form.
Table 3	Materials	Materials
Table 4	Activity, Requirements	Non-object and object which assist or affect construction but are not incorporated in it.

(Source: Jay-Jones and Clegg, 1976)

According to Jay-Jones and Clegg (1976), CI/SfB is a system of 'levels of aggregation', that is a model of building process having levels and each are adds to the previous until the final result. The example can be seen in Table 2.2

Table 2.2. Examples for CI/SfB 'level of aggregation'

Material Level	Form of Const. Level	Element Level	Physical Environment Level
(Table 3)	**(Table 2)**	**(Table 1)**	**(Table 0)**
Glass	Sheet(glazing)	Roof light	School
Cement	Block (Block work)	External wall	

(Source: Jay-Jones and Clegg, 1976)

According to Jay-Jones and Clegg (1976), CI/SfB provides a common arrangement for Project Documentation (PD) and General Documentation (GD), but gives the needs of PD priority over GD. They continue that in construction a great deal of information is needed according to physical resources needed, actual work of assembly and the end results to be achieved. It is concluded as, CI/SfB maintains subdividing primary groupings of end result, assembly and resource information.

As mentioned by Jay-Jones and Clegg (1976), the drawings in a project are grouped under 3 headings; location (L), assembly (A) and component (C) drawings in CI/SfB. Accordingly, location drawings are general plans, elevations and sections, assembly drawings show how components are brought together and, finally, component drawings show the individual components to be manufactured. Examples are below in Table 2.3.

According to Kang and Paulson (2000), as CI/SfB has not been revised recently, many new construction technologies introduced during the last few decades. As a result, ISO developed a new CICS framework that is the Uniclass system which is developed based on the ISO framework by the Construction Project Information Committee, including the Institution of Civil Engineers.

Table 2.3. CI/SfB Examples

End Results	Floors	Cost planning information, Regulations, Performance standards	Location Drawings (L)
Assembly Information	Floor Construction	Construction planning information, Workmanship specifications, Measured items, Codes of practice	Assembly Drawings (A)
Resource Information	Floor Components	Commodity information, Material specifications, Schedules, British standards	Component Drawings (C)

(Source: Jay-Jones and Clegg, 1976)

b. Uniclass;

According to Kang and Paulson (2000), Uniclass is the first CICS based on the ISO standard. They make the definition of Uniclass as unified classification for the construction industry. They continue as, Uniclass was guided by the Construction Project Information Committee that consists 5 organizations such as; the Royal Institution of Chartered Surveyors, the Institution of Civil Engineers, and the Royal Institute of British Architects. As specified by Kang and Paulson (2000) that Uniclass can also apply to classify information generated during the construction life cycle which means all stages in a project, such as the planning phase, including contract and schedule management; the design phase, including cost estimating and drawings management; and the construction phase, including procurement management and construction operations.

According to Kang and Paulson (2000), Uniclass is structured with a faceted classification system such as CI/SfB rather than a hierarchical classification system such as Master format. Kang and Paulson (2000) list the 15 main subjects of the general structure of Uniclass facets as referred to the figure of the Construction (1997) in the Table 2.4 that can be seen below in the following page and the Uniclass tables can be found in the Appendix A. They describe the facets as A, B, and C facets are for general summaries such as information form or management field. D, E, F, G, H, and K facets include facilities, spaces, elements, and operations for civil and architectural works. L, M, N, P, and Q facets are for to classify information concerning construction products, materials, and attributes.

As mentioned by Kang and Paulson (2000), the tender documents concerning a bridge project or the drawings concerning the bridge slab may be with Uniclass codes as follows:

- C672:E53 [C672 Tender documents], [E53 Cantilever bridges],
- A94:H526 [A94 Drawings], [H526 Decks/Slabs].

2.4. CADD Standards

Björk, Löwnertz and Kiviniemi (1997) mention that, during the last 10 years, the use of CAD techniques in building design has increased rapidly and today is common practice for producing building documentation. The same authors state that as a result, the need for the transfer of CAD information between different participants in a construction project in digital form and not only as plotted paper drawings has become of vital importance. They continue as although in most countries the layout and symbols of paper drawings are more or less standardized, the techniques for managing digital CAD data are still in the beginning process.

Table 2.4. - Structure of Uniclass Facets

Facets (1)	Characteristics of items (2)	Purposes (3)
A Form of information	Features of information	Organizing general reference information
B Subject disciplines	Fields of knowledge	Reference material related to theory
C Management	Processes with purpose of management	Information concerning all aspects of management
D Facilities	Construction complexes	Classification of construction facilities
E Construction entities	Independent constructions	Classification of physical forms or functions in facility (civil engineering projects)
F Spaces	Independent constructions	Classification of physical forms or functions in facility (architectural works)
G Elements for buildings	Main physical parts of independent construction	Classification of elements in space (architectural works)
H Elements for civil engineering works	Main physical parts of independent construction	Classification of elements in construction entity (civil engineering works)
J Work sections for buildings	Physical parts of element	Classification of operations (civil engineering works)
K Work sections for civil engineering works	Physical parts of element	Classification of operations (architectural works)
L Construction products	Products or components for incorporation into operation	Technical information for construction products
M Construction aids	Construction material resources	Itemizing trade literature and information about equipment
N Properties and characteristics	Attributes and other factors concerning physical objects	Classification of subjects relating to properties
P Materials	Substances and materials	Classifying resources from which construction products, elements, or entities may be made
Q UDC	Connection of items with UDC	Classifying subjects of UDC

(Source: Kang and Paulson, 2000)

According to Tanyer (2005), construction parties need to share CADD data with each other throughout the project life cycle. This condition predicates that the data should be produced according to the predefined guidelines; otherwise the receiving party may need to spend too much time just to interpret what he/she has received. Tanyer (2005) continues as CADD data standards maintain coherent CADD data appearance ,which means how CADD entities should look like considering different categories such as layering, text height, line colors, *etc.,* and interoperability among various partners.

According to Wikipedia (2007), most common CADD Standards can be seen in Table 2.5 considering the file-naming conventions.

Table 2.5. – CADD Standards

Standards	**Layer Standards**	**File-Naming Standards**
AIA CAD Layer Guidelines 2nd ed. (1997) (USA)	✓	✓
ISO 13567-1/3 International Standard (Northern Europe)	✓	×
BS 1192 part-5 A simplified adaptation of the ISO standard based on CI/SfB (UK)	✓	✓
AEC (UK) An adaptation of BS 1192 based on Uniclass	✓	✓

(Source: Wikipedia, 2007)

2.4.1. AIA CAD Layer Guidelines

According to research done by Howard and Björk (2007) in the USA, the AIA CAD Layer Guidelines were incorporated into the US National CAD Standard in 1999. This includes all the fields in ISO 13567 but the NCS is not formally linked to it and only mandatory fields are widely used.

As described by Hall and Green (2006), the layer-naming format is organized as a hierarchy of data fields that include the discipline designator, the major group, two minor groups, and the status that is shown below in Figure 2.2.

Figure 2.2. - The structure of AIA CAD Layer Guidelines
(Source: NCS 3.1 Presentation, 2005)

Discipline designator (mandatory); (**AA**-AAAA-AAAA-A)
Hall and Green (2006) mention that, these are the first components and composed of one or two alphabetic characters; Level 1 and Level 2 discipline designators.

Major Group (mandatory); (AA-**AAAA**-AAAA-A)
According to the same authors, this group includes four character designations for a major facility element: system or assembly, drawing view or annotation and is not user-defined.

Minor Group (optional); (AA-AAAA-**AAAA-AAAA**-A)
Continuing, this group includes four characters that further define the major group. Two minor groups can be used and this group may include user defined minor groups.

Status (Phase) (optional); (AA-AAAA-AAAA-**A**)
Hall and Green (2006) state the status field as a single character that indicates the status of the work or construction phase.

The selected standard used for the proposed documentation structure wanted to be an ISO compatible standard. In the light of the literature survey about the AIA CAD Layer Guidelines, it was investigated that they did not too much depend on ISO 13567. As a consequence, they were not selected and the model file-naming convention was not mentioned.

2.4.2. ISO CAD Layering

According to Howard and Björk (2007), one technology which enables data sharing is CAD layering, which requires the definition of standards. They continue that the layer structures and names proposed by ISO were more specific and allowed for building elements to be classified by national systems. The authors state that in ISO 13567 Parts-1 and 2 there is a faceted code for each layer with some mandatory fields and some optional ones to incorporate all the requirements of the different countries represented.

Howard and Björk (2007) show the structure of the ISO 13567 standard with three mandatory fields and some optional ones, leaving the values of fields for national- and company-specific definition as in Figure 2.3:

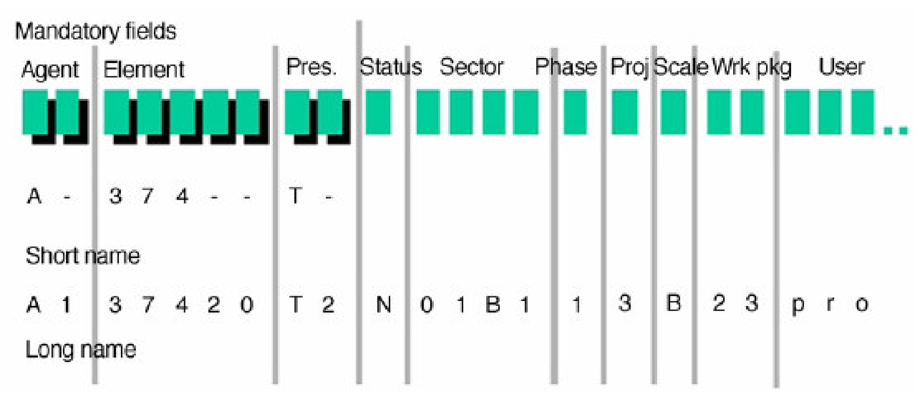

Figure 2.3. Structure of ISO 13567
(Source: Howard and Björk, 2007)

Björk, Löwnertz and Kiviniemi (1997) define fields of ISO 13567 briefly as:

- *Agent Responsible*; is the party responsible for the information in a construction project. No classification is given in ISO because there are classifications in national standards or project-specific agreements.

- *Elements;* as classification tables for the functional parts of a building have been defined in many countries, no mandatory element breakdown is stipulated in the ISO standard, instead ISO allowed nationally defined or project-specific element breakdown, provided that it is well documented.

- *Presentation;* ISO standard contains a mandatory classification in Table 2.6. This is an open-ended classification maintaining the second character for further sub classifications.

Table 2.6. - The first character of the presentation field of ISO 13567

Content	Code
Whole model and drawing page	--(two hyphens)
Model	M
Element graphics	E
Annotation	A
Text	T
Hatching	H
Dimensions	D
Section/detail marks	J
Revision marks	K
Grid	G
Graphic	Y
Dimension	Z
User	U
Redlines	R
Construction lines	C
Page/paper	P
Border	B
Border lines (Frame)	F
Other graphics	O
Text	V
Title	W
Notes	N
Tabular Information	I
Legends	L
Schedules	S
Tables (Query)	Q

(Source: Björk, Löwnertz and Kiviniemi, 1997)

- *Status;* the ISO standard status classification is seen in Table 2.7. as:

Table 2.7. - The status field of the ISO 13567

Content	Code
(no subdivision)	-
New part	N
Existing to remain	E
To be removed	R
Temporary	T
To be moved, Original position	O
To be moved, Final position	F

(Source: Björk, Löwnertz and Kiviniemi, 1997)

- *Sector;* the storey and part of the building. No mandatory classification is proposed.

- *Phase;* A project specific classification depending on phases such as in project management.

- *Projection;* The three main projections are plan, section, and elevation that can be put in independent models or in the same model.

- *Scale;* The scales used in construction documentation which are standardized by ISO are used in layer standards.

- *Work Package;* The subdivision according to the type of activities needed to produce the parts. They can be arranged by national tables in some countries or project specific.

- *User Defined;* A separate information category.

According to Björk, Löwnertz and Kiviniemi (1997), from the above categories, only the first three (agent responsible, element and presentation) are mandatory and the others are optional and the decision whether or not to use a category can be done at the project level.

Howard and Björk (2007) indicate that ISO 13567 has several national implementations and other informal standards make reference to official ones. They continue as most of these used all the mandatory fields in ISO 13567: Agent, Element and Presentation and sometimes extra characters and sub elements had been added for the optional fields.

According to the research of Howard and Björk (2007) the CAD layer standards used in the other countries not mentioned can be summarized as:

- In Germany, ISO 13567 was not adopted since several proprietary standards existed.

- In Sweden, Construction Documentation 90 is not a formal standard but includes ISO 13567 and is widely referenced in project documents.

- In Hong Kong, Layer guidelines based on ISO 13567 have been tested, but this has not lead to any national standard.

- In Finland, a standard was published in 1996 and is about to be revised. The Rakennustieto guideline RT 15-10624 recommends ISO 13567 CAD layers.

In the light of the findings since there is no model file-naming convention proposed by ISO, the country standards adapted according to ISO 13567 and having model file-naming convention investigated to decide on one of them.

To clarify the current CADD Standards used in Turkey, a literature search was carried on. As a consequence, some debates published in Arkitera (2005), which is an information portal for architecture and construction field, had come across that discuss the applicability of CADD Standards within the Turkish construction industry. According to the debates in Arkitera (2005), it was understood that there are not certain CADD Standards used in the Turkish construction industry. It was stated that the architectural offices use their own standards such as the layer naming, model file-naming, *etc*., but some of them use some international standards such as the ISO 13567 directly or with some modifications. It is continued as the layer names in the ISO 13567 are found too long including too many numbers and instead of them abbreviations are preferred. It is also emphasized in the debates that TSE (Turkish Standards Institution) uses the direct translation of ISO 13567. In ISO 13567-2 it was observed that the abbreviations are used directly taking them such as for the presentation field; T is taken that is the abbreviation of “Text”, instead of the M of “Metin” in the Turkish meaning word or D for the “Dimension”, instead of the B for “Boyutlar”, *etc*.

Yalçınkaya (2005) proposed a CAD Standard Model to maintain effective usage of CAD in architecture. In her study, first the scope of the proposal was defined, and then to investigate the current problems and market demands a questionnaire was arranged with the architectural offices in Turkey. According to the results of the questionnaire and after investigating the CAD Standards in other countries, Yalçınkaya (2005) proposed the model and tested by a number of people to take their comments. In the light of these the model was rearranged. The author also investigated the current CAD Standards of the architectural offices in Turkey by this questionnaire. According to the results of the questionnaire, it was mentioned by Yalçınkaya (2005) that there is an absence of a common CAD Standard in the architectural offices which was causing some problems such as different personal model file-names, different layer names, *etc.*

2.4.3. BS 1192 Part - 5

According to Howard and Björk (2007), in UK, BS 1192 part-5 was updated as a subset of ISO 13567 in 1998 and is still widely used. They continue as one of the leading building clients in the UK is BAA, who own and operate the main airports, are well aware of the importance of standards. The authors also indicate that layering is a major element within these standards and BAA has adapted BS 1192 part-5, as a subset of ISO 13567, to use their own categories.

BS 1192 part-5 is defined at Wikipedia as a simplified adaptation of the ISO Standard based on CI/SfB. As described in the "The AEC (UK) CAD Standard For Basic Layer Naming v2.4 (2005)" that there are seven fields in BS 1192 part-5 to classify a layer that can be seen below:

- *Field 1;* Agent Responsible or Discipline (1 Char.)
- *Field 2;* Element (4 Char.)
- *Field 3;* Presentation (1 Char.)
- *Field 4;* Sector
- *Field 5;* Status
- *Field 6;* Scale
- *Field 7;* User Defined.

The fields of the layer naming convention of BS 1192 part-5 are adapted from ISO 13567. The entire mandatory fields are used directly and some of the optional fields are used by changing their places. Although there is file-naming convention of BS 1192 part-5, it was not selected to be used in the proposed documentation structure. This was because as described in the previous parts CI/SfB has not been revised recently. As a consequence, AEC (UK) CAD Standards that uses Uniclass instead of CI/SfB, which is a classification system based on ISO, were selected to be implemented.

2.4.4. AEC (UK) CAD Standards

As mentioned in their web site; AEC (UK) CAD Standards is a unified CAD standard for the architectural, engineering and construction industry in the UK.

a. Layer Naming Convention;

As written in the "The AEC (UK) CAD Standard for Advanced Layer Naming v2.4. (2005)" and "The AEC (UK) CAD Standard For Basic Layer Naming v2.4 (2005)", this standard is based upon the guidelines laid down in BS 1192 part-5 and ISO 13567 using Uniclass.

"The AEC (UK) CAD Standard for Advanced Layer Naming v2.4. (2005)" build their layer naming convention on BS 1192 part-5 with some modifications as seen in Figure 2.4 with a following part including the brief definitions of the fields.

Field 1	Field 2	Field 3	Field 7a	Field 7b
Agent	**Element**	**Presentation**	**User Defined**	**View**

Figure 2.4. The AEC (UK) CAD Standard's Layer naming convention (Source: The AEC (UK) CAD Standard, 2005)

- *Field 1: Agent* (2 char max) this is a simple list of single or double character codes that show the author, or owner, of the data. The list of codes is shown under the discipline field of "The AEC (UK) CAD Standard for Model File Naming v1.1 (2005)".

- *Field 2: Element* this is the field that contains the building components. Uniclass tables F, G, H and an additional table Z for non classifiable elements such as grid, title sheets, etc. are used to define the codes of this field. Two or more codlings may be coupled together from different tables to define a code.

- *Field 3: Presentation:* This is a simple list of codes denoting the type of element stored on the layer.

- *Field 7a: User Description:* This field uses "alias" about the content of the layer rather than relying on Uniclass classification alone. This is the abbreviation of the element codes in the field 2.

- *Field 7b: View:* this defines the view of the CAD element such as where it is shown like elevation, section or hidden.

Some examples of layer names can be seen below:

A-G22-G-Flor-Fwd	An architect's floor outline in plan
S-G22-G-Flor-Fwd	A structural engineer's floor outline in plan
A-G541-G-Lght-Rfl	Architectural ceiling light in a reflected plan

b. Model File Naming Convention;

As written in the "The AEC (UK) CAD Standard for Model File Naming v1.1 (2005)", this standard is based upon the guidelines laid down in BS 1192 part-5 and ISO 13567 using Uniclass. It is mentioned that a naming convention is needed to ensure that all files created on a project can be identified quickly, accurately and without any confusion. It is continued in the "The AEC (UK) CAD Standard for Model File Naming v1.1 (2005)" that an accepted industry standard, BS 1192 part-5, should be used for the classification. It is also mentioned in the standard that project folders are important because they add a level of identification to the files.

“The AEC (UK) CAD Standard for Model File Naming v1.1 (2005)” separate CAD files into two fields as;

1. *Model Files*; that is a 2D or 3D CAD, drawn at 1:1 scale which contains building elements.
2. *Finished Drawing Files*; that is the paper output including a drawing border and annotations at paper size.

The full model file naming convention in “The AEC (UK) CAD Standard for Model File Naming v1.1 (2005)” is seen in Figure 2.5 with a following part including the brief descriptions of the fields.

Project	Discipline	Zone	View	Level	Content	Seq No.	*.ext*

Figure 2.5. The AEC (UK) CAD Standard’s Full Model File Naming Convention (Source: The AEC (UK) CAD Standard, 2005)

- *Field 1 - Project (unlimited characters-optional field)*: this is a numeric code related to the project or job number. By this every file have a completely unique identifier. This may be either an internal job number or a coordinated reference specified by the client or contractor.

- *Field 2 - Discipline (2 characters max.-Recommended Mandatory):* this is a simple list of single or double character codes identifying the owner of the file. By this various disciplines can use the same file name codes for the same area of a project while maintaining individual accountability. Code descriptions can be seen below in Table 2.8.

Table 2.8. Discipline field Code descriptions

A	Architect
AL	Landscape Architects
B	Building Surveyors
C	Civil Engineers
CB	Bridge Engineers
CD	Drainage, Sewage & Road Engineers
CW	Water/Dam Engineers
D	Spare
E	Electrical Engineers
F	Facilities Managers
G	GIS Engineers & Land Surveyors
H	Heating and Ventilation Engineers
I	Interior Designers
J	Telecommunications
K	Client
L	Lift Engineers
M	Mechanical Engineers
ME	Combined Services
N	Spare
P	Public Health Engineers
Q	Quantity Surveyors
R	Railways
RS	Railways Signaling
RT	Railways Track
S	Structural Engineers
SF	Façade Engineers
SR	Reinforcement Detailers
T	Town & Country Planners
U	Spare
V	Spare
W	Contractors
X	Sub-Contractors
Y	Specialist Designers
YA	Acoustic Engineers
YF	Fire Engineers
YL	Lighting Engineers (Non-Building Services)
Z	General (Non-Disciplinary)

(Source: The AEC (UK) CAD Standard, 2005)

- *Field 3 - Zone (Optional)*: this is the location of the CAD file when a project is split into separate areas, buildings or phases. The subdivision should be agreed by the project professionals and should be explained clearly in the project CAD manual. The examples can be seen below in Table 2.9.

Table 2.9. Zone field example codes

1	Building or zone 1
2	Building or zone 2
A	Building or zone A
B	Building or zone B
B1	Building 1
BA	Building A
Central	Central zone
CP	Car park
Line2	Railway line 2
MP	Master plan
Off	Office building
P1	Phase 1
Ret	Retail
South	Southern zone
Z1	Zone 1
ZA	Zone A
…	…

(Source: The AEC (UK) CAD Standard, 2005)

- *Field 4 - View (1 character-Recommended Mandatory):* this is the direction of view, or type, of information contained within the file. This allows the differentiation of plans, sections, elevations, details, reflected plans, *etc.* Example codes are below in Table 2.10.

Table 2.10. View field example codes

P	Plan
D	Detail
E	Elevation
R	Reflected Plan
S	Section
3	3-Dimensional
…	…

(Source: The AEC (UK) CAD Standard, 2005)

- *Field 5 - Level (2 characters-Recommended Mandatory):* this is used to distinguish the divisions of a project or building such as; horizontal divisions for floor plans and vertical divisions for sections. It should be agreed project professionals. Example codes are below in Table 2.11.

Table 2.11. Level field example codes

B2	Basement 2
B1	Basement 1
PL	Piling
FN	Foundation
00	Ground
01	First
M1	Mezzanine 1
M2	Mezzanine 2
02	Second
03	Third
…	…
RF	Roof*
A	Section A – A
B	Section B – B
01	Section 1 – 1
02	Section 2 – 2
11	Section 11 – 11
N	North Elevation
E	East Elevation
S	South Elevation
W	West Elevation

(Source: The AEC (UK) CAD Standard, 2005)

- *Field 6 - Content (Recommended Mandatory):* this is a simple description or Uniclass code denoting the type of information stored in the file. Uniclass codes (from tables F Spaces, G Elements for Buildings, H Elements for Civil Engineering or J Work Sections for Buildings) is preferred to be used to ensure continuity with the AEC (UK) layer standards.

- *Field 7 - Sequential Number (Optional)* this is used to identify options or versions or sketches of a scheme, or to identify section numbers. This can vary greatly from company to company. Some example codes are Table 2.12.

Table 2.12. Sequential number field example codes

1	Option/Version 01
2	Option/Version 02
11	Option/Version 11
A	Option/Version A
B	Option/Version B
01A	Option 01, Version A
01A	Version 01, Option A
01C	Option 01, Version C
C01	Option C, Version 1
C01	Version C, Option 1
…	…

(Source: The AEC (UK) CAD Standard, 2005)

- *Field 8 - File Extension:* this is the 3-digit code after the period (.) in a file name is used to identify the type of file or the software that is used to create/view/edit the file.

It is continued in “The AEC (UK) CAD Standard for Model File Naming v1.1 (2005)” that all fields should be separated by a hyphen character “-” to distinguish between them and aid comprehension. As is decided that the fields should still be used to maintain identical file name lengths, an “X” should be used if the contents of a file do not refer a single specific View or Level.

Some examples of the model file-names can be seen in Table 2.13.

Table 2.13. Examples of AEC (UK) Model File Naming

Project	**Discipline**	**Zone**	**View**	**Level**	**Content**	**Seq No.**	***.ext***
1838	S	C	P	03	-	-	.dgn
1838	S	x	P	00	-	-	.dwg
1234	A	-	S	01	G22	-	.dgn

(Source: The AEC (UK) CAD Standard, 2005)

In turn in order the meanings of the above model file-names are;
(Project 1838 – Structures – Building C – Plan – Third floor)
(Project 1838 – Structures – Full site – Plan – Ground floor)
(Project 1234 – Architectural – Section – Sec No. 01 – Floor section)

2.5. Usability Evaluation

Tanyer (2006) mentions that usability testing can be applied to different stages of a product development process from the early paper-based stages through fully functional later stages. He also states that a fully working system is not needed to apply the system; prototypes could be evaluated via usability testing.

As Bevan & Macleod (1994) indicate the features and attributes required to make a product usable had to be identified and then measured whether they are present in the implemented product to specify and measure usability. Tanyer (2006) states that there are many researchers who tried to define the features of usability such as Nielsen (1993) listed five usability attributes; namely learnability, efficiency, memorability, error rate and satisfaction.

Tanyer (2006) also points out that the International Organization for Standardization (ISO) defined three usability attributes, such as; *efficiency*, *effectiveness* and *satisfaction* (ISO, 1993) and the brief descriptions are seen below:

- *Efficiency;* compromises the resources expended to achieve the intended goals such as time, money or mental effort. Indicators of efficiency are task completion time and learning time. Tanyer (2006) indicates that Clayton *et al.* (1996) used the principles of usability engineering and evaluated a software prototype by measuring the time required to complete the job and the number of errors by comparing the traditional (before the proposed system, the conventional process) and innovative systems (with the proposed system).

- *Effectiveness;* is the extent to which the intended goals are achieved when using the overall system. It includes the accuracy and completeness when achieving the certain goals. Indicators of effectiveness are quality of solution. Task outputs have to be analyzed.

- *User Satisfaction;* is the extent which the user finds the overall system acceptable. It compromises the user's comfort and the positive attitudes towards the system usage. Indicators are user preferences. As referred to Doll & Torkzadeh's study End User Computing Satisfaction

(EUCS), Tanyer (2006) mentions the indicators of user satisfaction as content, accuracy, format, ease of use, timeliness and global measures.

Tanyer (2006) concluded as according to these three factors ISO 9241-11 (ISO, 1993) made the definition of the usability as the extent to which a product can be used to achieve specified goals (efficiency, effectiveness and satisfaction) in a specified context of use.

Bowden (2005) also used usability evaluation in her study about mobile IT devices in the construction industry. It is stated that the main aim of using usability evaluation was to compare various hand-held computers that were already commercially available and to find out how easy site-based personnel find these devices to use.

According to Bowden (2005) the specific objectives of the usability tests were:

- Obtaining a broad range of site-based personnel to act as participants.
- Increasing awareness about the system investigated.
- Identifying types of tasks that are best suited to the system.
- Identifying functionality that site-based personnel would find useful.
- Identifying the attitudes of site-based personnel to the system usage.
- Determining the preferences of participants and reasons.

CHAPTER 3

MATERIAL AND METHOD

This chapter includes details about the material and method used in this study. The first covers the description of the subject materials used in this research including 3 sub-sections, namely: architectural production drawings, the CADD Standard selected and the selected project for the case study. The second then describes the procedures taken with 3 sub-sections that are the system proposal, system application and finally the system evaluation.

3.1. Material

In this study, the architectural group was taken for the sample to be worked on and the architectural production drawings were listed and described briefly as for one of the subject materials. The documentation structure that is going to be explained in the following sections could be used by each discipline, but the drawing identifications and the application of the standards were arranged according to the architectural group. CADD Standards should be used in the proposed documentation structure. For this purpose after investigating the current standards used in the construction industry, AEC(UK) CAD Standard was selected to be applied which was the second material used in this survey. Finally, the proposed documentation structure was applied to a real construction project for a period of two weeks that was a military complex in Amman / Jordan. This was the application part of the study. The case study project was the third material used in this study.

3.1.1. Architectural Production Drawings

Construction projects include many types of architectural production drawings. These drawings change according to the type and size of a project and the details involved in a project. After making a literature survey and carrying a market search, the architectural production drawings were identified. Although these are the basic architectural production drawings in a construction project, this is a general identification. As a consequence, a project does not have to compromise all of the drawings identified; only the related drawings can be used.

The architectural production drawings may change, but basically they can be categorized under the three headings given below;

1. Main Drawings
2. Typical Details
3. Compartment Details

- *Main Drawings;* these are the main drawings which are needed to construct the main parts of a building like the plans, sections, elevations, application plans, *etc*.

- *Typical Details;* these drawings are the enlargement of the main drawings and show the parts of the constructions much more detailed.

- *Compartment Details;* these drawings are arranged for the production of the unit details that may be done by subcontractors such as the doors, windows, specific walls, *etc*.

In the below Table 3.1 the list of the architectural production drawings in a construction project is given with a following part that compromises the definitions of the main drawings briefly.

Table 3.1. The List of the Architectural Production Drawings

ARCHITECTURAL PRODUCTION DRAWINGS
MAIN DRAWINGS:
Notation Legend
Drawing List
Site Application Plan
Application Plan
Area List
Working Drawings
Notation Plans
Reflected Ceiling Plan
Tiling Plans
Furnishing Layout
Stair Enlargement
Wet Areas Enlargement
System Details
TYPICAL DETAILS:
System Details Enlargement
Wall Finish Details
Floor Drain Details
Floor Finish Details
Roof Details
Expansion Joint Details
Miscellaneous Details
Stairs & Balustrade Details
Skirting Details
COMPARTMENT DETAILS:
Door Types & Details
Window Types & Details
Wall Types & Details
Façade Cladding Types & Details

Notation Legend; This is the drawing that includes the legend of the notations used in all of the drawings with their brief explanations, in other words identification of the symbols.

Drawing List; Includes lists of all the drawings related with the project; such as the architectural, structural, electrical, mechanical, *etc.* These drawing lists may be organized also in spreadsheet files or any other kind of listing styles under schedules.

Site Application Plan; includes the plan of the whole construction site with a smaller scale, showing the around buildings, roads, accesses, *etc*. Levels of the roads and the main buildings should be given with the coordinates of each.

Application Plan; A general plan of the building indicating all the needed levels (± 0.00 level, finish floor level of the ground floor and the basement, upper most level and the land levels of all around the building of walkways, green areas, pavements, *etc*.), the coordinates and the outer dimensions. The scale is depended on the size of the building and can be 1/100 or 1/200 or more.

Area List; These drawings contain an abstract layout of all the floors specifying the area of each floor one by one. They include the areas of each floor and the total area of the building. The list may also be given as spreadsheet files or any other kind of listing styles under schedules.

Working Drawings; One of the most important drawings which are needed in a construction project is the working drawings. Working drawings include all the floor plans, sections and elevations.

- *Plans;* A horizontal cut from the building is given. Their scale is 1/100 or 1/50 depending on the size of the project. All the dimensions, axes, levels of areas, section lines, elevation numbers, the room names and numbers are shown on the plans. Some notifications with circles and notification numbers are given to be reference for the more detailed drawings.

- *Sections;* A vertical cut from the building is given. All the vertical dimensions, the levels of all slabs and the finish floor levels are shown. The same mentality of notification of the plans can be used and some notes that specify much more detailed drawing numbers may be added.

- *Elevations;* The outer appearance of the building is shown. Each level of each component is displayed such as; slab levels, finish floor levels, upper most levels, the upper and below levels of each door and window, *etc*.

Notation Plan; In these plans an identification symbol, that shows the dimension and the name of each unit, is placed next to each door, window, partition wall, aluminum louver, curtain wall, *etc*. All the needed information about each piece and all the drawing numbers of the related details can be found in schedules.

Reflected Ceiling Plan; In this type of architectural production drawings the distribution and the type of ceiling which is used in each area are drawn. All electrical and mechanical fixtures (*e.g.* lights, fire alarms, smoke detectors, heat detectors, sprinklers, diffusers, transfer grills, loudspeakers, *etc*.) are located to their exact place. In addition, the height of each ceiling is identified in order to know how the mechanical and electrical equipments take place over the suspended ceiling.

Tiling Plans; In tiling plans, the distribution and arrangement of tiles on the floors of the building are shown. These tiles are drawn with the correct dimensions, according to the tile type which is used; a start point with specified location is needed. The notification of floor type of each room that shows the detail drawing numbers may be added to these plans.

Furnishing Layout Plan; A plan for each floor showing all the furniture which is used in each space, marked with a symbol of letter or number. In this type of plans, parts of mechanical and electrical fixtures and equipments which can affect the furnishing of the space such as the radiators, fire hose cabinets, trenches, water cooler, access doors, *etc*. must be shown.

Stair Enlargement; These drawings include stair plans and sections. As mentioned before, in the working drawings, some notifications with numbers are written on each stairs drawn in the plans. The numbers on the stairs are guiding to these stair system details. Each one of the stairs in the project is shown in detailed drawings of plans and sections enlarged to a larger scale such as 1/20, showing all the details needed in the construction site. In these details some more notifications and numbers, that are guiding to some other drawings with more detailed of special parts of the stairs, are included.

Wet Areas Enlargement; As known wet areas need special drawings showing all the details needed to construct these areas. For this reason the drawings of wet areas are arranged in enlarged plans and sections. In these drawings tiling distributions for floors and walls of the wet areas, with a starting point that specifies the exact point where the tiling procedure will start is displayed. Meanwhile in these drawings all the sanitary fixtures are shown in their exact places on plans and sections with all the dimensions needed to fix the sanitary units.

System Details; This type of drawing is an enlargement of important parts to a larger scale. Lots of needed details are drawn and identified. They include some circles and symbols that guide to more detailed drawings of some specific parts.

3.1.2. Selected CADD Standard

As described earlier, CADD Standards should be used in the drawings to make them understandable and usable without any need of extra time for adaptation to their own systems of each discipline and to make the communication process easier between the different disciplines.

CADD standards include many fields related with the drawings such as the layering, line type, text, model file-naming, *etc*. But they should not be taken separately. To gain a common language between the drawings, all of the fields of a CADD Standard should be accomplished. In this study, as it was related with the documentation, the standards based on the ingredients of a drawing such as the layering, line type, text, dimension, *etc.* not described. As the main aim of this study was to propose a documentation structure to maintain control of the drawings in the construction sites while documenting them for project completion, the model file-names of the drawings were important in the first glance, because the drawings were seen under the documentation structure by their names directly so standards should be used while naming these documents. The ingredients of the drawings were the next issue for this study and were assumed to obey the rules in the proposed standard and left for the further studies. As a consequence, the adaptation of a project to the model file-naming standards and the working of the system in the light of this were tested.

Many of the standards had been investigated in order to decide on the one to be implemented. An ISO compatible standard was decided to be selected for the implementation. After the literature search, the document ISO 13567 was found that is related with the CAD layer naming. Unfortunately there was not a model file-naming standard proposed by ISO. The country standards that use ISO CAD layer naming for a base for their CADD Standards were decided to be investigated. Finally "The AEC (UK) CAD Standard" was selected to be used. This standard is based upon the guidelines laid down in BS 1192 part-5 and ISO 13567. BS 1192 part-5 is a standard used in the UK, based on the ISO 13567 using CI/SfB classification system. Since “The AEC (UK) CAD Standard” uses the “Uniclass” instead of CI/SfB, this makes it much more preferable because as mentioned in the literature review part, Uniclass is the classification system of ISO and CI/SfB has not been revised recently.

Consequently, the AEC (UK) CAD Standard was selected because:

- It uses the BS1192 part-5 that also based on the ISO 13567.
- It uses the Uniclass that is a classification system based on ISO.

3.1.3. Selected Project

The selected project for the system application concerns a military complex that is constructed in Amman / Jordan. This project was selected because it is a design / build type of construction including site technical offices of the contractor that work on the incomplete parts of the project, revise drawings and produce shop drawings to be checked by the consultant. It is an international project that maintains viewing the subject in a much more sophisticated environment and as a final statement EDMS is not used. The contractor is a Turkish Construction Company (ABC was used for the company name and XYZ was used for the consultant name). The names of the company and the consultant were not presented due to confidential reasons. The complex has a total site area of 400.000 m^2, and closed gross construction area is 111.866 m^2.The scope of the work is the construction and the maintenance of the military complex that comprises of many buildings with different functions. The furniture of the buildings is also under the scope of the contract. The responsibility of the contractor is defined in the general conditions of the contract as;

> "The Contractor shall, with due care and diligence, design (to the extent provided for by the Contract), execute and complete the Works and remedy any defects therein in accordance with the provisions of the Contract. The Contractor shall provide all superintendence, labour, materials, Plant, Contractor's Equipment and all other things, whether of a temporary or permanent nature, required in and for such design, execution, completion and remedying of any defects, so far as the necessity for providing the same is specified in or is reasonably to be inferred from the Contract"

Since the contractor has the full responsibility of any kind of works in design / build type of projects, the documentation system should work properly. For the success of the projects, the documentation structure to be applied has significant importance throughout the project life cycle because there are plenty of shop drawings and they have to be controlled. If the system does not work efficiently and properly there may appear deficient works (both at site and technical office), which may cause inevitable delays. All these types of problems may also lead contractor to prepare faulty claims during the project life cycle. Besides, company reputation is affected due to unsatisfied customer that affects the future projects which may be signed between the parties.

3.2. Method

The method carried in this study consists of three main sub-sections that are the system proposal, system application and finally the system evaluation. Each includes a procedure of steps to be taken.

The steps taken for the system proposal are described briefly as follows:

- The previously identified architectural production drawings were organized according to the model file-naming convention of the CADD Standard selected that was the AEC (UK) CAD Standard.

- The main folders of the proposed documentation structure were created and previously arranged drawings were moved into the related folders.

- Finally the working principles of the structure were introduced to end users.

In the system application, the proposed system was applied to a real construction project for a period of two weeks following the related sub-sections as the creation of the folders and the implementation of the system.

Finally for the system evaluation, usability testing was decided to be done that compromises identification of the usability attributes. A questionnaire was arranged and in the light of the findings a semi-structured interview was done by the participant to maximum capture the advantages and the disadvantages of the system according to the end user point of view.

3.2.1. System Proposal

The first step to be taken for the system proposal was the implementation of the model file-naming convention of the AEC (UK) CAD Standard to the previously identified architectural production drawings.

a. Implementing the CADD Standards;

In the following parts the previously listed architectural production drawings are arranged according to the "The AEC (UK) CAD Standard for Model File Naming v1.1 (2005)". As mentioned in the literature review part the model file-naming convention of the AEC (UK) CAD Standard consists of these fields; project, discipline, zone, view, level, content, sequence no and extension.

The implementation process of the model file-naming of The AEC (UK) CAD Standard to the previously listed architectural production drawings is explained below briefly and the applied names of the drawings are seen in Table 3.2.

Table 3.2. The Architectural Production Drawings based on the Model File Naming Convention of The AEC (UK) CAD Standard

	project	discipline	zone	view	level	content	seq. No	.ext
Notation Legend	1234	A	B1	X	XX	A12	SD01, 02...	CAD Drawing Specific
Drawing List	1234	A	B1	X	XX	A94	SD01, 02...	
Site Application Plan	1234	A	B1	P	XX	B33	SD01, 02...	
Application Plan	1234	A	B1	P	0 0	B32	SD01, 02...	
Area List	1234	A	B1	X	B2,B1,00,01, M1,M2,02,03	B4	SD01, 02...	
Working Drawings	1234	A	B1	P,E,S	B2,B1,00,01, M1,M2,02, 03,RF,A,B, N,E,S,W	A1:A94	SD01, 02...	
Notation Plans	1234	A	B1	P	B2,B1,00,01, M1,M2,02,03	A12:A94	SD01, 02...	
Reflected Ceiling Plan	1234	A	B1	R	B2,B1,00,01, M1,M2,02,03	JK4	SD01, 02...	
Tiling Plans	1234	A	B1	P	B2,B1,00,01, M1,M2,02,03	G22:JM	SD01, 02...	
Furnishing Layout	1234	A	B1	P	B2,B1,00,01, M1,M2,02,03	G4	SD01, 02...	
Stair Enlargement	1234	A	B1	D	XX	G23	SD01, 02...	
Wet Areas Enlargement	1234	A	B1	D	B2,B1,00,01, M1,M2,02,03	G44	SD01, 02...	
System Details	1234	A	B1	D	XX	A94	SD01, 02...	
System Details Enlargement	1234	A	B1	D	XX	A94:L2	SD01, 02...	CAD Drawing Specific
Wall Finish Details	1234	A	B1	D	XX	G25:JM	SD01, 02...	
Floor Drain Details	1234	A	B1	D	XX	G22:H135	SD01, 02...	
Floor Finish Details	1234	A	B1	D	XX	G22:JM	SD01, 02...	
Roof Details	1234	A	B1	D	XX	G24	SD01, 02...	
Expansion Joint Details	1234	A	B1	D	XX	G73	SD01, 02...	
Miscellaneous Details	1234	A	B1	D	XX	KN	SD01, 02...	
Stairs & Balustrade Details	1234	A	B1	D	XX	G23:G74	SD01, 02...	
Skirting Details	1234	A	B1	D	XX	G22:G74	SD01, 02...	
Door Types & Details	1234	A	B1	D	XX	G32:JL	SD01, 02...	CAD Drawing Specific
Window Types & Details	1234	A	B1	D	XX	G32:JL	SD01, 02...	
Wall Types & Details	1234	A	B1	D	XX	G25	SD01, 02...	
Façade Cladding Types & Details	1234	A	B1	D	XX	F6:JH	SD01, 02...	

- *Project;* An imaginary project was created, and "1234" was supposed to be the project name.

- *Discipline;* As the architectural group was the sample group "A" was used for the discipline field.

- *Zone;* The imaginary project was supposed to be a complex consisting three different buildings as Building 1 (B1), Building 2 (B2) and Building 3 (B3) and the Building 1 was taken for the example. So "B1" was used for the Zone field.

- *View and Level;* The view and level abbreviations were used from the examples given in "The AEC (UK) CAD Standard for Model File Naming v1.1 (2005)". If the drawing did not belong to any certain level or view, "X" was used instead to supply the same length for the model file-names.

- *Content;* The content field was taken from the "Uniclass tables" that was described in the literature review part.

- *Sequence no;* The sequence no field was used for the numbering of the shop drawings and the abbreviation "SD" was used. The shop drawings started with SD01 and continued as SD02, SD03, *etc*. for each drawing. If there was no need for a shop drawing submission for the related drawings, nothing was written in the sequence field.

- *Extension;* The extensions of the CAD drawing specific were written here.

The naming convention of Wall Finish Details of the imaginary project is; 1234-A-B1-D-XX-G25:JM-SD01.dwg which means; Project 1234, Architectural, Building 1, Details, Not Belong to a Certain Level, Walls: Surface Finishes, Shop Drawing 01.

Till now, the previously identified architectural production drawings were arranged according to the model file-naming convention of the AEC (UK) CAD Standard. The next step of the methodology is the creation of the main folders of the proposed documentation structure and in the following part the working principles are mentioned.

b. Creation of Folders;

The proposed documentation structure aimed to control the drawings of a project in the site technical offices throughout the construction life cycle and document them for the project completion. In order to implement the proposed system, the following assumptions were made;

1. Approved tender drawings were on hand.
2. Mobilization concerning site technical office was completed.
3. Construction was commenced.

Before creating the main folders of the documentation structure the size of the project should be taken into consideration since the project was firstly divided into folders according to the function of the buildings if included. Then the documentation structure was applied.

The structure of the documentation system which denotes creation of folders is described below in 6 steps. It should be noted that all of the folders were created in the main server of the company IT system. After the name of the architectural group's server was identified as *Architectural Group*, the following folders were created;

- Original Project Folder
- Project Development Folder
- Personal Folders
- Shop Drawings Folder
- Waiting Approval Folder
- Follow Up Spreadsheet File

The main view of the documentation structure is seen in Figure 3.1, following with the description of the folders.

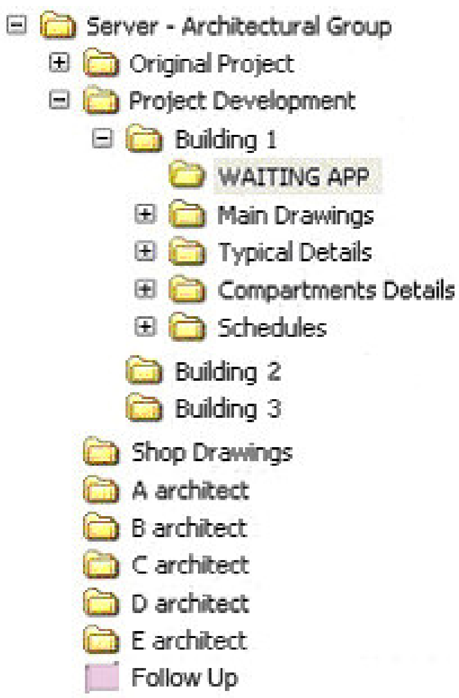

Figure 3.1. The View of the Documentation Structure

1. *Original Project (App. Tender Project) Folder;* this was the first created folder. The architectural production drawings, that were identified and standardized before, copied inside this folder and locked as write protected.

2. *Project Development Folder;* this was the second created folder. In this folder, the tender project was copied again to be used for the revised drawings. Since, this folder was always changing, developing and including the latest situation of the project, it was not write protected. It should be strictly noted that this folder was the highest important one during the project life cycle and should be controlled carefully. For several times the back up of these files should be kept in other parts of the server by the IT team.

3. Personal Folders; these were the folders arranged according to the name of the user architects responsible in various sections of the project such as; -A. architect, -B. architect, -C. architect, -D. architect, -E. architect, *etc*.

4. Shop Drawings Folder; the next step was the forming of the shop drawings folders. This was the one that contains all the shop drawings done throughout the construction process. These were kept in this folder because if there was a need in the future for the previous drawings they could be reached over here.

5. Waiting Approval Folder; this was the final folder in the system. It was located under the project development folder and used to check if the drawings were in the consultant. The drawings were waited in this folder until they come back from the consultant. Once a drawing was required from the site staff, the waiting approval folder should be checked before submitting it to them.

6. *Follow Up Spreadsheet File;* this was the list indicating the status of the shop drawings. It was basically arranged for the purpose of checking the status of the shop drawings given to the consultant according to the submittal reference numbers. Everyone could see and follow the status of the shop drawings by viewing the Follow Up spreadsheet file that is seen in Table 3.3.

Table 3.3. The view of the Follow Up Spreadsheet File

Area for Contractor Logo	**NAME OF THE PROJECT**							
	APPROVED	A, B1						
	RESUBMIT	B2						
	REJECTED&RESUBMIT	C						
	WAITING APPROVAL	W						
Architectural Group							as of	
Submittal Reference Number	**Building NO.**	**Description of Drawing :**	**Submittal Date**	**Number of days passed**	**Status of Approval**	**Return Date**	**Notes Related with Drawings**	**Shop Drawing Names**

The Follow Up spreadsheet file includes the following headings;

- Submittal Reference Number (the number used when presenting the shop drawings to the consultant)
- Building No (which building the given shop drawings belong to)
- Description of Drawing (definition of the shop drawings)
- Submittal Date (date of submission to the consultant)
- Numbers of Days Passed (from the submission date)
- Status of Approval (the status of the shop drawings given by the consultant)
- Return Date (date of the return of the consultant)
- Notes Related with Drawings (what changes are made in the related drawings)
- Shop Drawing Names (the model file-names of the shop drawings)

c. Working Principles;

The proposed documentation structure was originated from simple hierarchical folders going to be used by the site technical personnel according to some rules. The main aim of the system was to control the drawings throughout the construction process while maintaining the documentation. As mentioned before at the sites, the construction is done according to the shop drawings that are produced by the site technical groups of the construction team. The working principles of the documentation structure should also create a basis for the shop drawing approval period. During the construction process, the shop drawings prepared must be submitted to the consultant for checking purpose. Shop drawing approval forms are used for this distribution period. These forms are given to the consultant besides the shop drawings. The shop drawing approval form is seen in Table 3.4.

Table 3.4. Shop Drawing Approval Form

Client Logo		Contractor Logo	
SHOP DRAWING APPROVAL FORM			
Project:		**Submittal Date:**	
		Submittal Ref No:	
Name of Building :			
List of Attachments :	**Description**	**Shop Drawing Name**	**Status**

STATUS OF APPROVAL

- A. Approved with no comments
- B1. Approved with the following comments. Do not resubmit.
- B2. Approved with the following comments. Resubmit.
- C. Not approved. Resubmit in accordance with the following comments

Comments:

Contractor's Name
Submitted by : ____________ Signature: ____________

Client's Name
Returned by: ____________ Signature: ____________

In design/build projects, each company has their own approval procedure with respect to the contract clauses but generally in many projects the approval process is followed like this; Shop drawings are sent to the consultants with shop drawing approval forms to be checked. These are filled both by the consultant and the related party of the contractor. The consultants check the shop drawings submitted, evaluate them, write comments and sent back to the related technical groups of the contractor to be used according to the status of the approval.

The status of approval of these forms can be list below;

a) Approved with No Comment. (A)
b) Approved with the Following Comments. Don’t Resubmit. (B1)
c) Approved with the Following Comments. Resubmit. (B2)
d) Not Approved. (C)

The shop drawing approval form in the Table 3.4 includes the headings below;

- General information; client, contractor and project names.
- Document information; name of building, list of attachments as description and shop drawing name, submittal date and submittal reference number.
- Approval information; status of approval and the comments of the consultant.

The working principles of the documentation structure proposed can be followed from the Figure 3.2 and described in the following part in turn in order.

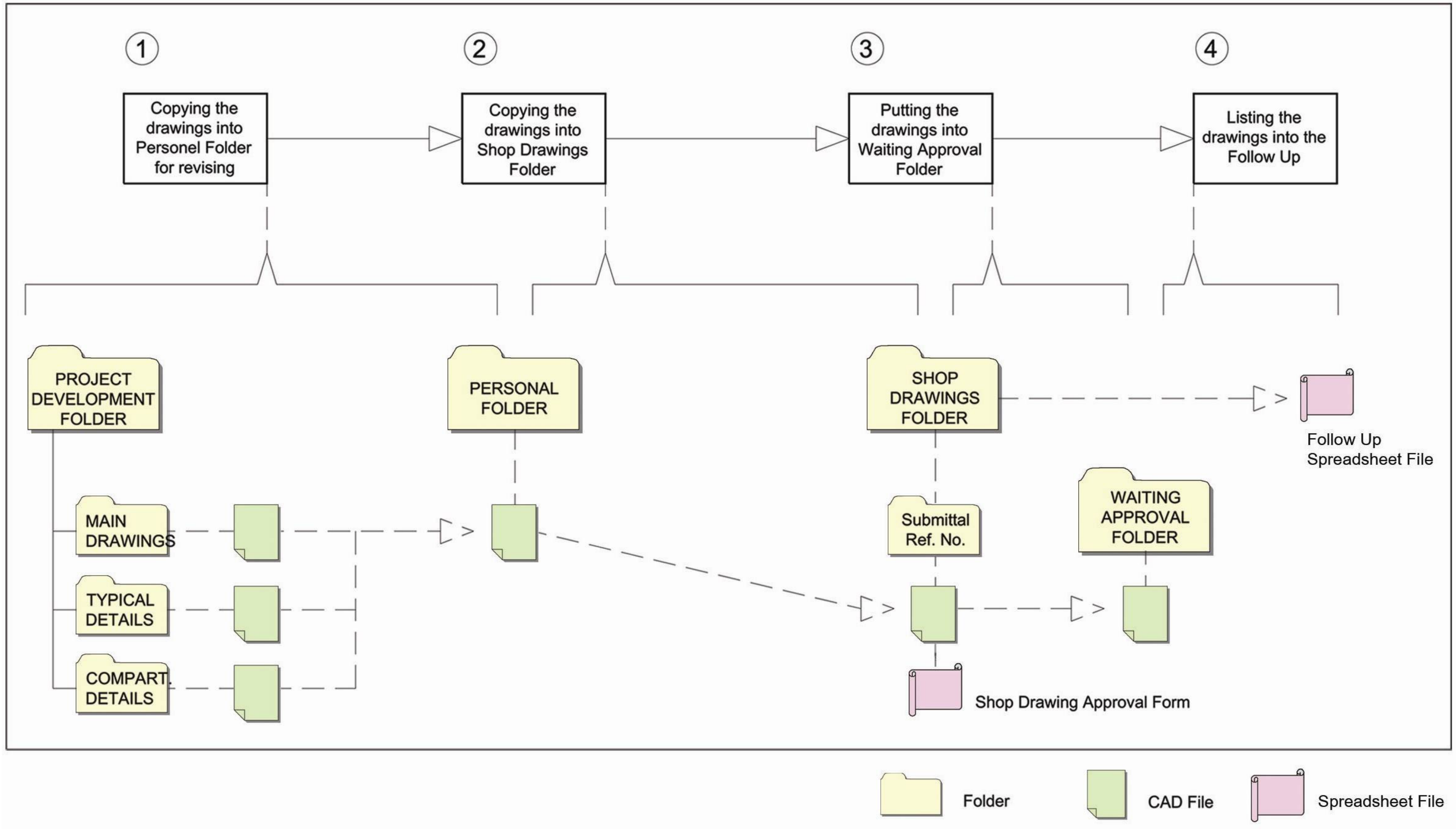

Figure 3.2. The Working Principles of the Documentation Structure Proposed

The proposed documentation structure was used as the below stated sequence;

1. Whenever a revision was needed, the related files were copied by the architects from the *project development folder* into their own *personal folders* that they work on. When the revisions were finished, the drawings were controlled by the technical group chiefs and printed out to be sent to the consultant for checking purpose.

2. After they were sent to the consultant for checking purpose, the drawing were copied in a folder naming the submittal reference number and put under the shop drawings folder. The soft copy of the shop drawing approval form which was sent to the consultant was also added into the same folder.

3. Then the drawings were put into the waiting approval folder which takes place in the project development folder to wait until they come back from the consultant. The purpose here was to inform everybody that the drawings inside this folder are at the consultant for checking purposes. It was created to overcome the risk of using these waiting drawings at site. When looking at the project development folder, the first file to be examined should be the waiting approval folder because some of the drawings may not be approved yet.

4. The shop drawings sent to the consultant should also be included into the file Follow Up spreadsheet file to control their statuses.

Till now the steps that should be taken before the submission of a shop drawing to the consultant for the checking purposes were described. In the Figure 3.3 and 3.4 the working principles of the system after the shop drawings turn back from the consultant can be followed and described briefly in the following part.

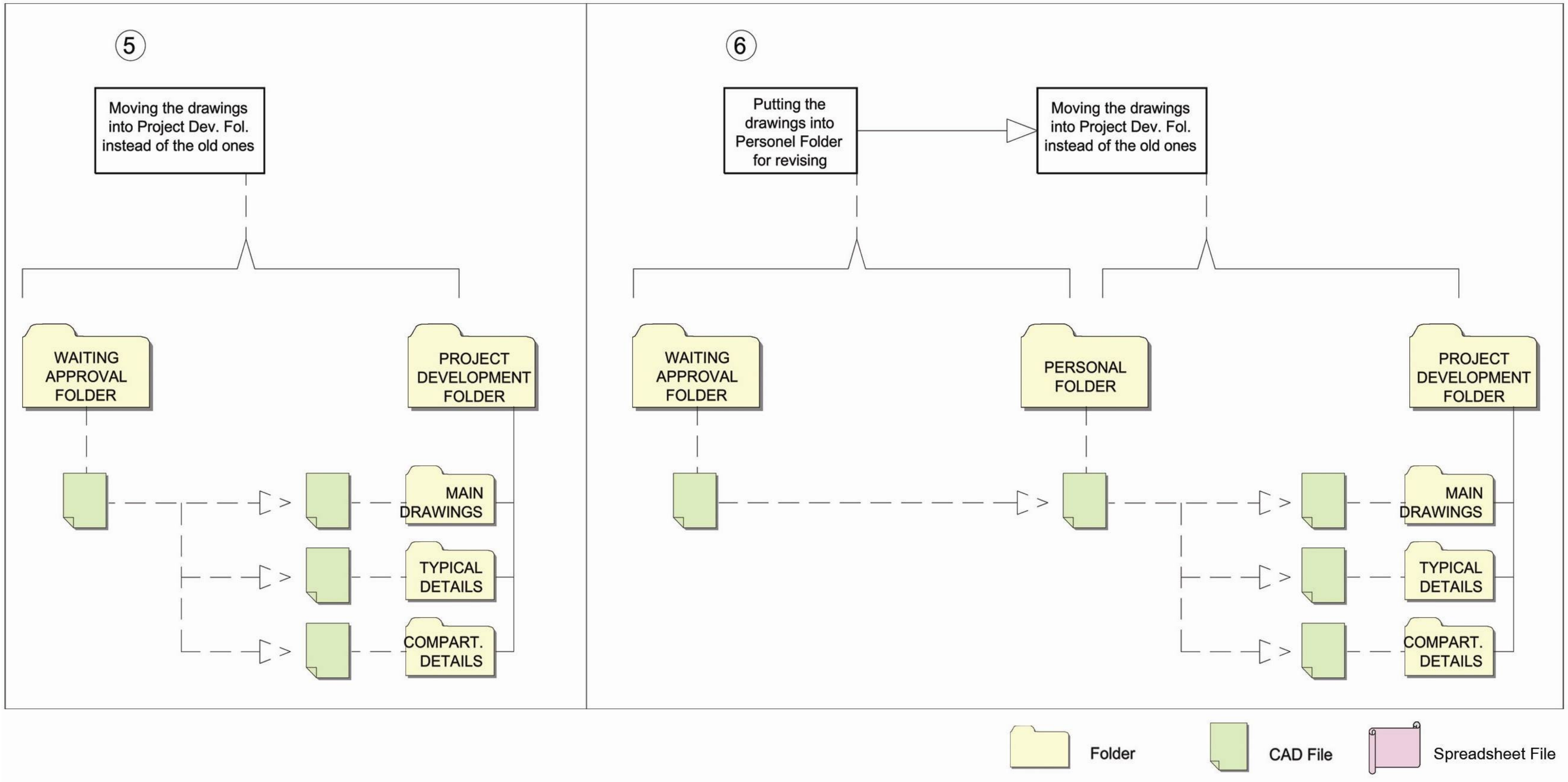

Figure 3.3. The Working Principles of the Documentation Structure Proposed According to the Status of Approval of the Shop Drawings

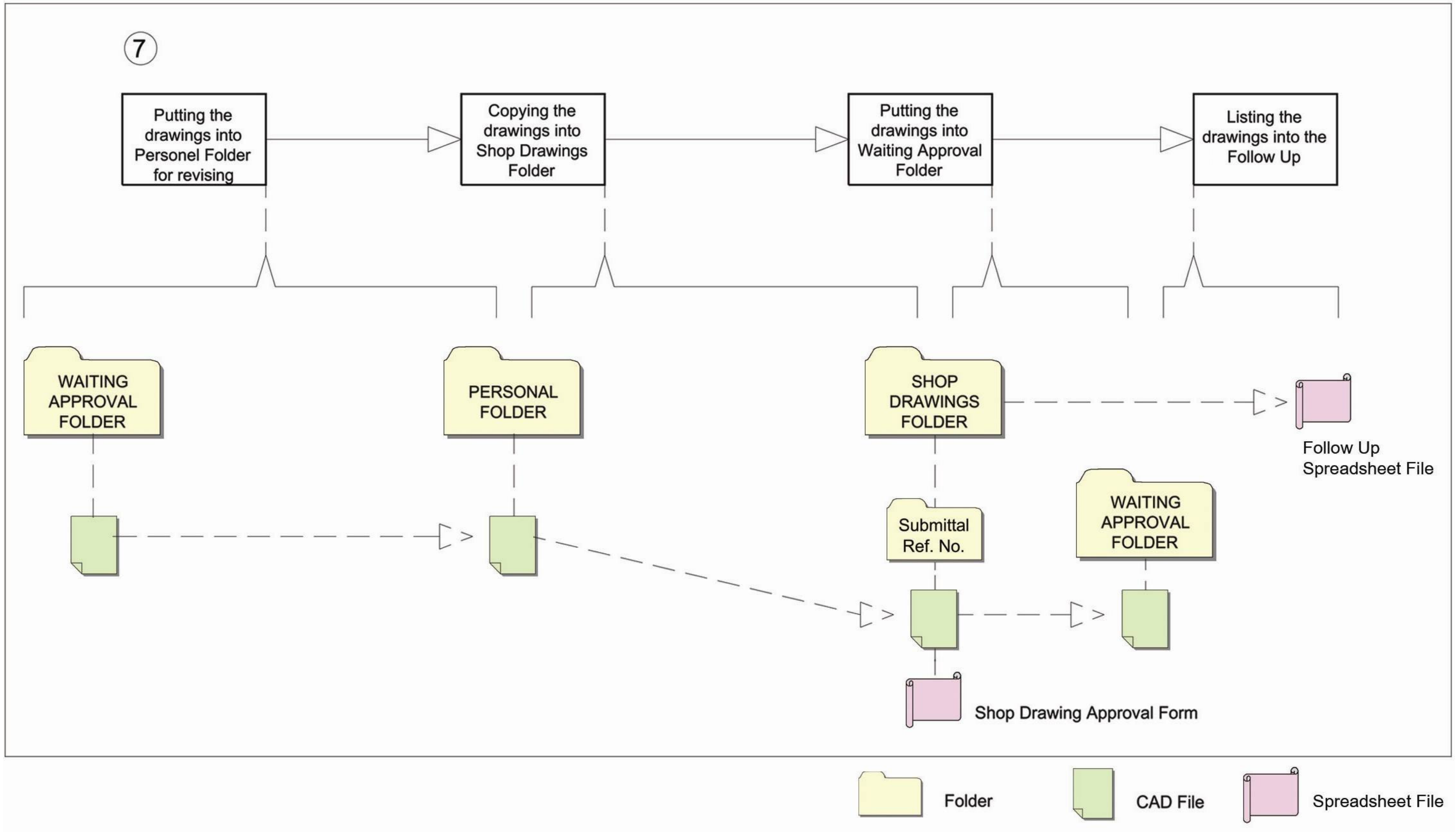

Figure 3.4. The Working Principles of the Documentation Structure Proposed According to the Status of Approval of the Shop Drawings (continued)

When the shop drawings returned back from the approval, according to the approval status, there may be;

5. Approved with No Comment; the soft copies of the shop drawings in the waiting approval folder were moved to the project development folder instead of the old files.

6. Approved with the Following Comments. Do not Resubmit; the soft copies of shop drawings in the waiting approval folder were taken to make the corrections according to the consultant comments and afterwards moved to the project development folder instead of the old files.

7. Approved with Following Comments, Resubmit; the soft copies of the shop drawings in the waiting approval folder were taken to arranged with the necessary corrections and sent for approval again.

8. Not Approved; the soft copies of the shop drawings in the waiting approval folder were taken to arranged with the necessary corrections and sent for approval again. The steps taken were the same for the Approved with Following Comments, Resubmit or the shop drawings might not be submitted again.

In this system; the drawing of the tender project or the previous SD numbered drawing carrying the same name was removed from the project development folder. Instead, the approved shop drawing was replaced. By this way, the updated drawings which were applied at the site were kept in the project development folder. That means; the drawings in the project development folder became as-built drawings at the end of the construction.

Sometimes the previous versions of the shop drawing might be required. In those cases, these shop drawings could be reached from the shop drawings folder which was arranged with respect to the submittal reference numbers and having shop drawing approval forms inside.

The original tender project was kept in the original project folder as read only. By this way, the development of the project could be viewed and the necessary documentation as soft copies could be done.

At the project completion, there remained three folders left; original project folder that was the approved tender project; project development folder which included as-built drawings and the shop drawings folder which included all of the shop drawings done throughout the construction process. By this documentation structure, the management of the drawings was arranged manually, the documents were stored orderly and the construction process was controlled.

3.2.2. System Application

The system was tested through semi structured interviews that were carried out via net-meetings. Since this was a project with a long life span, the proposed documentation structure was tested with the architectural group of the company for about two weeks period of time.

The steps taken in the system proposal sub-section to create the proposed documentation structure were carried on again for the system application. First the selected project's architectural production drawings were arranged according to the drawings identified and named by using the "The AEC (UK) CAD Standard". Then the main folders of the proposed documentation structure were created in the company's server and the working principles of the structure were introduced to two of the users selected over six architects in the architectural group.

After the semi structured interviews carried on through net-meetings it was understood that there was not a standard documentation system in this firm. The documentation of drawings and the standards used for CAD model file-naming were arranged according to the responsible site technical person of the architectural group and change from project to project. In this project, people were working on their personal computers and after the drawings were finished they were attached to the server. They were also influenced from the tender drawings that come from the designers. The names of the tender drawings were also used for CAD model file-naming and these change from project to project as the tender drawings change.

The selected project had many buildings with different functions so they had to be distinguished because in the proposed documentation structure if the project was a complex, the architectural production drawings were firstly distributed according to the buildings. Some abbreviations were used in the firm for the building names; such as GH01, GH02, GH03, *etc*. The real project which is still under construction was assumed to be a base point for the study, and a hypothetical project was created referring to the GH01 Building.

As described earlier, the first step to be taken for the application of the proposed documentation structure was the adaptation of "The AEC (UK) CAD Standard for Model File Naming v1.1 (2005)" to the architectural production drawings used at the company. So firstly the selected project drawings were organized according to the drawings identified and named by using the "The AEC (UK) CAD Standard". The Table 3.5 below shows the final view of the model file-names in the company. The sequence field in the model file-naming of the selected project was left empty because the shop drawings related with the GH01 building had not been produced yet and were going to be produced in the following two weeks when testing the system.

Table 3.5. The Final View of the Drawings of the Project based on the Model File Naming Convention of the AEC (UK) CAD Standard

	project	discipline	zone	view	level	content	seq. No	.ext
Notation Legend	GHQB	A	GH01	X	XX	A12	-	.dwg
Drawing List	GHQB	A	GH01	X	XX	A94	-	.dwg
Site Application Plan	GHQB	A	GH01	P	XX	B33	-	.dwg
Application Plan	GHQB	A	GH01	P	0 0	B32	-	.dwg
Area List	GHQB	A	GH01	X	B1,00,01,02	B4	-	.dwg
Working Drawings	GHQB	A	GH01	P,E,S	B1,00,01,02, RF,A,B, N,E,S,W	A1:A94	-	.dwg
Notation Plans	GHQB	A	GH01	P	B1,00,01,02	A12:A94	-	.dwg
Reflected Ceiling Plan	GHQB	A	GH01	R	B1,00,01,02	JK4	-	.dwg
Tiling Plans	GHQB	A	GH01	P	B1,00,01,02	G22:JM	-	.dwg
Furnishing Layout	GHQB	A	GH01	P	B1,00,01,02	G4	-	.dwg
Stair Enlargement	GHQB	A	GH01	D	XX	G23	-	.dwg
Wet Areas Enlargement	GHQB	A	GH01	D	B1,00,01,02	G44	-	.dwg
System Details	GHQB	A	GH01	D	XX	A94	-	.dwg

	project	discipline	zone	view	level	content	seq. No	.ext
System Details Enlargement	GHQB	A	GH01	D	XX	A94:L2	-	.dwg
Wall Finish Details	GHQB	A	GH01	D	XX	G25:JM	-	.dwg
Floor Drain Details	GHQB	A	GH01	D	XX	G22:H135	-	.dwg
Floor Finish Details	GHQB	A	GH01	D	XX	G22:JM	-	.dwg
Roof Details	GHQB	A	GH01	D	XX	G24	-	.dwg
Expansion Joint Details	GHQB	A	GH01	D	XX	G73	-	.dwg
Miscellaneous Details	GHQB	A	GH01	D	XX	KN	-	.dwg
Stairs & Balustrade Details	GHQB	A	GH01	D	XX	G23:G74	-	.dwg
Skirting Details	GHQB	A	GH01	D	XX	G22:G74	-	.dwg

	project	discipline	zone	view	level	content	seq. No	.ext
Door Types & Details	GHQB	A	GH01	D	XX	G32:JL	-	.dwg
Window Types & Details	GHQB	A	GH01	D	XX	G32:JL	-	.dwg
Wall Types & Details	GHQB	A	GH01	D	XX	G25	-	.dwg
Façade Cladding Types & Details	GHQB	A	GH01	D	XX	F6:JH	-	.dwg

After the standardization of the drawings, the previously mentioned folder creation system was applied. The structure of the documentation system which denotes creation of folders was organized in 6 steps.

a. Creation of Folders;

First, the main name of the architectural group's server was identified and the following folders were created. The name of the architectural group server was "GHQB Architectural Server" and the folder names created were as follows:

Step 1 *Creation of Original Project Folder;* the tender project which was standardized above was copied into this folder as "write protected".

Step 2 *Creation of Project Development Folder;* in this secondly created folder the tender project was copied to be used for the revised drawings. As it was explained previously, as this folder was always changing, developing and including the latest situation of the project, it was not write protected. During the application of this system the backup files were saved in other created folder under the main server.

Step 3 *Creation of Personal Folders;* these folders were created according to the number of the architects working at the architectural group. For the verification of the system two users over six architects in the architectural group were selected of which one of them was a senior and the other was a junior one. The senior architect was selected to have the opinion of the one also controlling the other's work throughout the system while producing drawings and the junior architect to take the opinion of the one only using the system for producing drawings.

Step 4 *Creation of Shop Drawings Folder;* the shop drawings prepared were put into that folder. The shop drawings were stored under the folders naming the submittal reference numbers and also the soft copies of the shop drawing approval forms were kept beneath the drawings they belong.

Step 5 *Creation of Waiting Approval Folder;* to store the drawings until they come back from the consultant this folder was created under the project development folder. People in the architectural group were requested to check this folder when a drawing was needed from the site.

Step 6 *Creation of Follow Up Spreadsheet File;* the statuses of the submitted drawings were stored in this file to follow the shop drawings before and after they were sent for approval. Everyone in the group and also in the company was able to follow this file.

b. Implementation of the System;

After the arrangement of the folders in the server, the working principles of the proposed documentation structure was introduced to the participants. They were requested to use the system while producing shop drawings.

The users followed the steps described below;

Step 1: When making the shop drawings of the GH01 First and Second Floor Plans for different subjects of the building they took the related drawings under the project development folder and copied into their personal folders. They worked under their personal folders and completed the shop drawings to be given to the consultant. The shop drawing approval forms were arranged for these submissions. One of the forms that were prepared during these submissions is seen in Table 3.6.

Step 2: The submitted shop drawings that are seen in the shop drawing approval form in Table 3.6 were copied into the shop drawings folder under the folder with the name of submittal reference number which is ‘123’. The soft copy of the shop drawing approval form was also put into the same folder.

Table 3.6. Shop Drawing Approval Form

XYZ Consultant Co. Ltd.		ABC Co.Ltd.

SHOP DRAWING APPROVAL FORM

Project:	Military Complex	**Submittal Date:**	08 July 2007
		Submittal Ref No:	123

Name of Building :	Architectural Drawings for GH01 Building

	Description	**Shop Drawing Name**	**Status**
List of Attachments :	GH01 Stair Enlargement	GHQB-A-GH01-D-XX-G23-SD01	
	GH01 System Details	GHQB-A-GH01-D-XX-A94-SD01	
	GH01 System Details Enlargement	GHQB-A-GH01-D-XX-A94:L2-SD01	
	GH01 Stairs and Balustrade Details	GHQB-A-GH01-D-XX-G23:G74-SD01	

STATUS OF APPROVAL

- A. Approved with no comments
- B1. Approved with the following comments. Do not resubmit.
- B2. Approved with the following comments. Resubmit.
- C. Not approved. Resubmit in accordance with the following comments

Comments:

Contractor's Name

Submitted by : ABC Co.Ltd. Signature:

Client's Name

Returned by: XYZ Consultant Co.Ltd. Signature:

Step 3: After making the submission the drawings were put into the waiting approval folder which takes place in the project development folder. This folder was checked by the users when there is a need of drawing from the site.

Step 4: The shop drawings sent to the consultant were also written into the Follow Up spreadsheet file.

Step 5: The submitted shop drawings returned back within 10 days from the consultant. The status of the returned documents for GH01 Stair Enlargement, GH01 System Details, GH01 System Details Enlargement, GH01 Stairs and Balustrade Details were B1, B2, C, and C respectively. Since A and B1 status do not require resubmission only the next 3 of the returned drawings would be resubmitted.

- A status drawing was taken out from the waiting approval folder and replaced with the previous drawing in the project development folder.

- B1 status drawing was taken out form the waiting approval folder. The required comments were corrected in their own personal folders and then replaced with the previous drawing in the project development folder.

- B2 and C status drawings were also taken out from the waiting approval folder and put into their personal folders to be worked on them. After the necessary corrections and revisions were applied they were copied into the shop drawings folder again with a new submission number and the submission process restarted.

During these two weeks of system trial period the submitted drawings and their statuses can be followed from the Follow Up spreadsheet file that is given in Table 3.7.

Table 3.7. Follow up Spreadsheet File of the Military Complex

ABC Co. Ltd.	NAME OF THE PROJECT	Military Complex
	APPROVED	A, B1
	RESUBMIT	B2
	REJECTED&RESUBMIT	C
	WAITING APPROVAL	W
Architectural Group	as of	21.07.2007

Submittal Reference Number	Building NO.	Description of Drawing :	Submittal Date	Number of days passed	Status of Approval	Return Date	Notes Related with Drawings	Shop Drawing Names
122	GH01	GH01 First Floor Plan	07.07.2007	9	A	16.07.2007	Position of some of the walls changed.	GHQB-A-GH01-P-01-A1:A94-SD01
122	GH01	GH01 First Floor Reflected Ceiling Plan	07.07.2007	10	A	17.07.2007	Position of some of the walls changed.	GHQB-A-GH01-R-01-JK4-SD01
123	GH01	GH01 Stair Enlargement	08.07.2007	9	B1	17.07.2007	Revised as to structural drawings.	GHQB-A-GH01-D-XX-G23-SD01
123	GH01	GH01 System Details	08.07.2007	10	B2	18.07.2007	Revised as to stairs.	GHQB-A-GH01-D-XX-A94-SD01
123	GH01	GH01 System Details Enlargement	08.07.2007	10	C	18.07.2007	Revised as to stairs.	GHQB-A-GH01-D-XX-A94:L2-SD01
123	GH01	GH01 Stairs and Balustrade Details	08.07.2007	10	C	18.07.2007	Revised as to structural drawings.	GHQB-A-GH01-D-XX-G23:G74-SD01
124	GH01	GH01 First Floor Tiling Plans	10.07.2007	9	B1	19.07.2007	Revised according to new materials.	GHQB-A-GH01-P-01-G22:JM-SD01
125	GH01	GH01 Second Floor Plan	11.07.2007	8	A	19.07.2007	Position of some of the walls changed.	GHQB-A-GH01-P-02-A1:A94-SD01
125	GH01	GH01 Second Floor Plan Reflected Ceiling Plans	11.07.2007	8	A	19.07.2007	Position of some of the walls changed.	GHQB-A-GH01-R-02-JK4-SD01
126	GH01	GH01 Wall Finish Details	14.07.2007	7	B1	21.07.2007	Revised according to new materials.	GHQB-A-GH01-D-XX-G25:JM-SD01
126	GH01	GH01 Wall Types & Details	14.07.2007	7	B2	21.07.2007	Revised according to new materials.	GHQB-A-GH01-D-XX-G25-SD01
127	GH01	GH01 System Details	17.07.2007	4	W	-	Revised according to comments.	GHQB-A-GH01-D-XX-A94-SD02
128	GH01	GH01 Miscellaneous Details	18.07.2007	3	W	-	Revised according to new materials.	GHQB-A-GH01-D-XX-KN-SD01
129	GH01	GH01 Skirting Details	19.07.2007	2	W	-	Revised according to new materials.	GHQB-A-GH01-D-XX-G22:G74-SD01

3.2.3. System Evaluation

After the application of the proposed documentation structure to the selected construction project, usability testing was applied for the system evaluation. The test was decided to be carried on according to the ISO (1993) parameters and usability metrics were arranged to evaluate the system. The two users selected for the system application were used again for the system evaluation and the participants were requested to evaluate the proposed documentation structure. Following questions were determined to test the proposed system according to the usability metrics created as can be seen in Table 3.8.

Table 3.8. Usability Evaluation Questionnaire

Usability Attributes	Usability Metrics	Questions
Efficiency	Time Spent	♦ Does the time you have to spend in order to complete the tasks increase?
	Effort Spent	♦ Does the effort you have to spend in order to complete the tasks increase?
Effectiveness	Facilitation to Documentation	♦ Does the documentation maintained by the proposed system appropriate for the site technical offices?
		♦ Does the system maintain orderly organized documents for the project completion?
	Facilitation to Communication	♦ Does this system improve communication between the project members?
		♦ Do you think the Model File Naming Convention can be applied by the architectural design offices in future projects?
		♦ Does the CAD standards improve communication?
	Facilitation to Control	♦ Do you think this system will help to overcome the possible claims arising at the end of the project?
		♦ Does the system maintain easiness when following the status of the documents?
User Satisfaction	Accuracy	♦ Are you satisfied with the accuracy of the system?
	Ease of Use	♦ Is the system easy to use?
	Global Measures	♦ Are you satisfied with the system?

As mentioned above this usability evaluation aimed to reveal advantages and disadvantages of the documentation structure proposed according to three main categories: efficiency, effectiveness and user satisfaction.

- *For the Efficiency*; to evaluate the proposed documentation structure time and effort metrics was used that are mentioned in ISO (1993).

    - Time; The questions were arranged to learn about how the time spent changed for using the system in the shop drawing submissions, controls and documentation in the construction site technical offices with respect to the traditional working system of the company.

    - Effort; The questions were arranged to learn about how the effort spent changed for using the system in the shop drawing submissions, controls and documentation in the construction site technical offices with respect to the traditional working system of the company.

- *For the Effectiveness*; since the main aim of this study was to propose a documentation structure which was based on CADD Standards to manage the control of the drawings while documenting them; certain goals of the system were pointed out as documentation, communication and control. The questions were arranged to expose the subjects listed below in the metrics.

    - Documentation; The proposed system was important with respect to documentation because it documented the shop drawings produced in the site technical offices throughout the project life cycle and for the project completion.

    - Communication: The proposed system used CADD Standards to improve communication between the project members. The drawing were identified and arranged according to model file-naming convention of AEC (UK) CAD Standard.

- Control: The proposed system arranged the control of the drawings produced at site technical offices. The statuses of the drawings were kept in a file to overcome possible claims in the future.

- *For the user satisfaction;* In this study for the user satisfaction attribute, the metrics of EUCS was decreased to three that fit with the content of the proposed documentation structure, these are; accuracy, ease of use and global measures.

  - Accuracy; was selected because right drawings should be found when searching so this requires the correctness of the output information maintained by the system.

  - Ease of use; was selected to learn if the system could easily be used or not.

  - Global measures; were selected to learn if the system satisfied the users or not.

The previously selected architects were requested to evaluate the proposed documentation structure. Participants replied the questions by giving scores 1 to 5 for the evaluation of the system. The scores *under '3'* means that the system does not contribute to the stated objective and the scores *above '3'* means that the system contributes to the stated objective positively. Finally, the score of *'3'* represents that the party is neutral about the contribution of the stated objective. In the light of the findings, a semi-structured interview was carried on by the participants to maximum capture the advantages and the disadvantages of the proposed system.

CHAPTER 4

RESULTS AND DISCUSSIONS

This chapter entails the results of the usability evaluation according to the replies of the junior and senior architects. In the following sub-sections they are explained briefly with some graphics.

4.1. Efficiency of the Proposed Documentation Structure

The efficiency of the documentation structure was tested according to two usability attributes. These were time and effort spent to complete the tasks.

Junior Architect;

When making the shop drawings of the GH01 first and second floor plans both of the two architects, the junior and the senior one, followed the necessary steps mentioned in the previous section. The junior architect used the system first in the drawings GH01 First Floor Plan and GH01 First Floor Reflected Ceiling Plan to make the necessary revisions due to changing of walls for mechanical reasons. For this purpose he copied the related drawings from the project development folder into his own personal folder and wrote SD01 to the sequence no field of each one. After making the necessary corrections, he prepared them for submission by carrying out the necessary steps; first, shop drawing approval form was prepared and the number ‘122’ was given for the submittal reference number. As a next step, he copied them into the shop drawings folder under a folder naming ‘122’ and listed the drawings into the

Follow Up spreadsheet file, and lastly they were put under the waiting approval folder. All these were the first study carried by the junior architect.

The junior architect found the proposed documentation structure time consuming and effort needed. Since there were different folders in this structure, the one sending the shop drawings to the consultant for checking purpose should have to place them according to the working principles of the system. The shop drawings should also have to be listed in Follow Up spreadsheet file which was requiring additional time and effort. Besides, the junior architect stated that taking the necessary steps in the system needed much effort and it had the risk to be forgotten causing deficiency in the work. For that reason, all of the steps should have to be followed carefully without skipping any of them. The junior architect claimed that the proposed system helped to gain time for document searching since you knew where to find the documents which were well organized. However, it was also stated by him that human performance, which was important for correctly placement of related folders, had important role to gain time by this system.

Senior Architect;

The senior architect also followed the necessary steps. Firstly, he used the system in the drawing GH01 Stair Enlargement. Afterwards, he underlined the time and effort requirement for the use of the folders. However, in his second drawing GH01 System Details, he stated that it took less effort to use the system because he got accustomed to the steps. In other words the system needed effort but it was easily learnable.

It is also stated by him that the documentation structure helped to gain time during the search of a document. Every person working on the project, such as the other disciplines, could also reach any document whenever they want and without loosing any time for searching. The reason for this was the location of the folders which were placed in server to be directly reached according to the function of them. Since the users followed the status of the documents from the Follow Up spreadsheet file, while reaching the drawings, they did not take the wrong drawings that were not approved. This property of the system helped to overcome time loses that might happen due to the usage of wrong drawings.

Summary of Efficiency;

To summarize; they stated that the documentation structure proposed increased the time and effort that they have to spend when working on the shop drawings since there were many different folders arranged according to the functions for controlling of the drawings. According to the senior architect, the effort spent decreased by time while using the system. But, they both underlined that although usage of the system needed more time and effort, searching and finding the drawings were shorter. In other words, the system helped to decrease time for searching documents but at the same time increase time needed for usage. The results of the efficiency evaluation of the proposed documentation structure can be viewed in Figure 4.1.

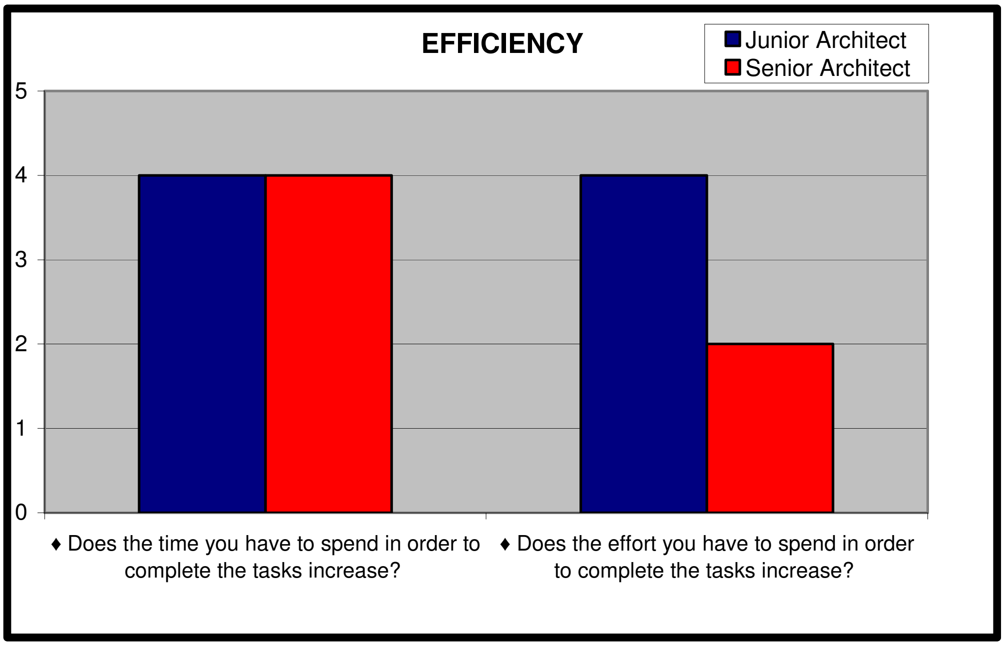

Figure 4.1. Efficiency of the Proposed Documentation Structure

4.2. Effectiveness of the Proposed Documentation Structure

The effectiveness of the documentation structure was tested according to three usability attributes; facilitation to documentation, facilitation to communication and facilitation to control.

Junior Architect;

In terms of documentation, the proposed documentation structure found helpful and sufficient for future needs by the junior architect. He stated that as all the shop drawings given were restored in the shop drawings folder, the old version of the drawings could be reached whenever it was needed. Since the documentation structure was arranged according to folders with different functions, the right drawings could be found without a suspicion of finding the old version of the drawing when it was required.

In terms of communication, the junior architect stated that standardization in drawing names increased communication within the group since everyone was using the same names for the same drawings without causing any confusion. But he also mentioned that arranging the drawing names according to the naming convention of the CADD Standard used was hard since the codes in the content field was a bit complicated. It required a period of time for learning for the users to understand the type of the drawings according to the codes in the ‘content’ field. The junior architect suggested using abbreviations related with the drawings instead of codes for the drawing names. For example, he gave some abbreviation examples for drawing names such as for “Tiling Plans” “TP” could be used or for “System Details” “SD” could be used. He found these abbreviations more understandable and preferable.

Junior architect mentioned that the communication in the group increased since every drawing could be reached when needed. To give an example; he was making the GH01 System Detail Enlargements and it had to be made according to the revisions done in the GH01 System Details which was prepared by the senior architect. By controlling the personal folder of the senior architect he understood that the drawing was still being done and not finished yet.

In terms of control, the junior architect said that the status of the drawings could be controlled easily in the proposed documentation structure. During the testing period of two weeks some of the drawings were required by the other groups and the waiting approval folder was controlled for this purpose. They noticed that the required drawings were not in this folder and they easily understood their status was submitted. To conclude, the system had positive effects on the drawing control.

Senior Architect;

In terms of documentation, the senior architect stated that the proposed documentation structure maintained documentation of the drawings done throughout the construction process in an easily follow able way such that every shop drawing that were submitted to the consultant were stored in the system. As a main important point for the project closure the as-built drawings could be created by the documentation structure since the project development folder was changing throughout the construction with respect to shop drawings. But the senior architect underlined that the documentation should not be thought as only soft copies; the hard copy of these shop drawings should also be arranged to be used in the future.

In terms of communication, the senior found the model file-names too long and complex. It was also stated by the senior architect that the other parties might need drawings to work on so they had to learn their names to understand the drawings. As architectural group, after using the system for a period of time they got accustomed to these names, but it was really hard for the other parties. The senior architect found the usage of CADD Standards for drawing names necessary and helpful but he stated that he was expecting easily understandable names such as abbreviations instead of numbers. He preferred to understand type of the drawing directly when seeing the names, instead of spending time.

According to senior architect, it was a hard process for the architectural design offices to adapt their drawings into the drawings identified and arranged as to the model file-naming convention used. This was because they may want to use their own standards because they were accustomed to them. They might not want to apply that naming convention but if it was put into the contract clauses they had to obey. But senior stated that if they got accustomed to this system, as a common standard supplied between the designer and the contractor, it would significantly increase the communication and data exchange between different professionals. It was also thought by the senior architect that this system did not have an effect on the company communication; it only maintained communication in the group to such an extent that the system was used manually that needed human effort. This was one of the disadvantages of the system.

In terms of control, the senior architect found the system understandable to follow the drawings. It helped control of the drawings in the construction sites. Every work could be followed on server and every document could be reached. Since people were working on the folders in the server, the work done by the people could be checked meanwhile. All of the status of the shop drawings could be controlled by checking the Follow Up spreadsheet file and the days passed for the return could be seen. By this, in future if there happen possible claims between the parties they could be proved by just looking at this file.

The senior architect suggested the usage of the date in the model file-names also, but it was not necessary since there was not a need for versioning in the proposed documentation structure. In other words, the folders were arranged according to the last version of the drawings and the old ones were restored under the shop drawings folder according to the submittal reference numbers.

Summary of Effectiveness;

Although both of the users found CADD Standards necessary for the drawings, they were not happy with the drawing names. This might be because of the reason that they were not accustomed to them and wanting to use their own file-names. Since there was not enough time for the system application due to company limitations, they could not have the chance to get accustomed to the drawing names. Both of the users found the facilitation of control aspect of the proposed documentation structure the most successful attribute of effectiveness. Second successful attribute was the documentation aspect. However, especially the senior architect thought that the system did not have positive effects on company communication. The results of the effectiveness evaluation of the proposed documentation structure can be viewed in Figure 4.2.

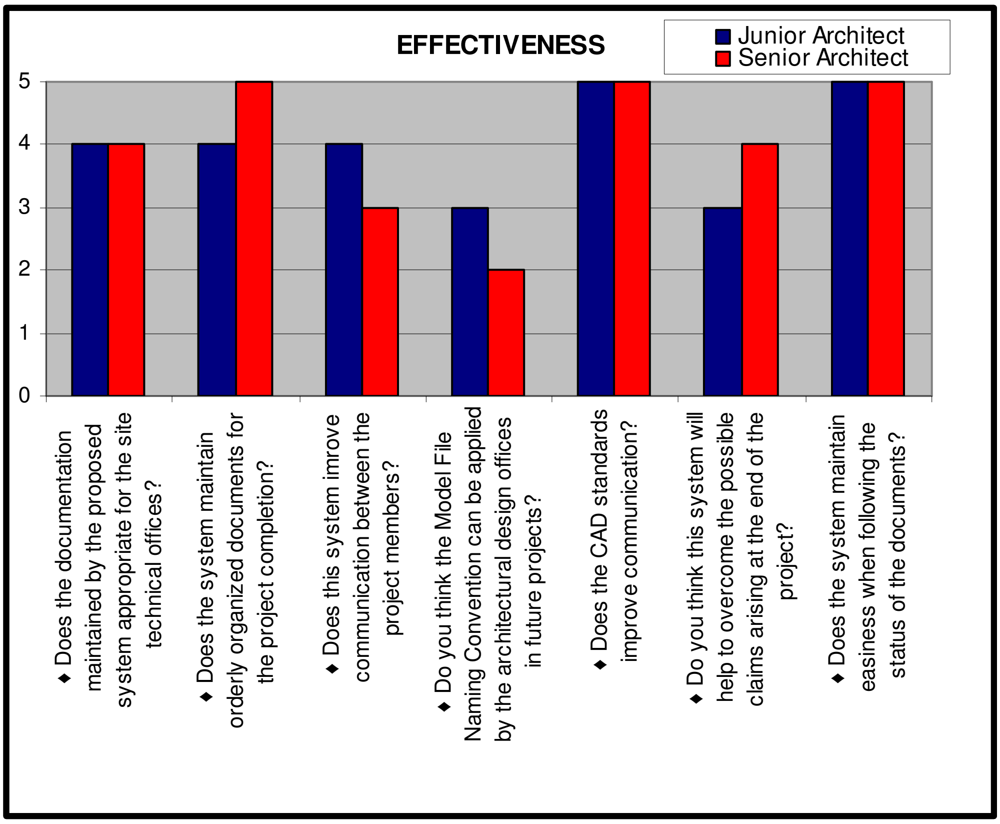

Figure 4.2. Effectiveness of the Proposed Documentation Structure

4.3. User Satisfaction of the Proposed Documentation Structure

The user satisfaction of the documentation structure was tested according to three usability metrics which were accuracy, ease of use and global measures.

Junior Architect;

The documentation structure helped the junior architect to find the needed documents. It was mentioned by the junior architect that although searching a drawing depended on manual efforts, correct drawings could be found. In terms of accuracy, junior architect stated that if the necessary steps are taken, the system maintains accurate information.

Junior architect mentioned that although the steps to be taken were easy, they were too much and might not be obeyed exactly, *i.e.* some might be forgotten which could cause deficiencies.

The junior architect was satisfied with the system but he said that as the system used manually, the success of the structure depended on the human performance. So the users working on the system should be trained carefully. And he found this as a disadvantage, because as the technical personnel was always changing at the sites, the new ones should be taught for the system usage.

Senior Architect;

In terms of accuracy, the senior architect stated that the system maintained the correct information as the status of the drawings could be followed from the Follow Up spreadsheet file. But he found the documentation structure open to risk because the other group members might reach and change the ingredients of the drawings. This could be prevented by arranging the drawings as write protected for the ones in the server out of the group. Every one could view each document they wanted but only the related parties might have the right to make changes on the documents. Senior also stated that the system was easy to use and after a short training period it could be carried on by each technical personnel in the group.

Summary of User Satisfaction;

The users were satisfied with the proposed documentation structure. But as it was arranged manually, the system depended on human performance to work correctly. The results of the user satisfaction evaluation of the proposed documentation structure can be viewed in Figure 4.3.

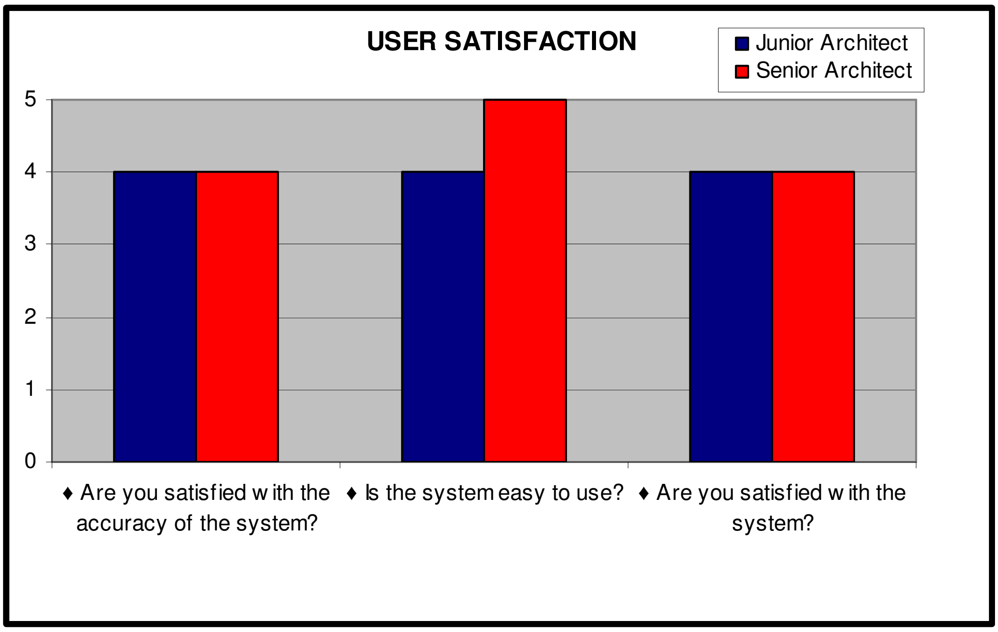

Figure 4.3. User Satisfaction of the Proposed Documentation Structure

4.4. Summary of the Usability Evaluation

The usability testing revealed the advantages and disadvantages of the proposed documentation structure from the end users point of view.

There are several advantages of the system;

- Creating the necessary documentation of the shop drawings throughout the construction process and for the project completion.
- Maintaining the control of the shop drawings in the technical offices of construction sites.
- Adaptation of CADD Standards to the model file-names of the drawings.

On the other hand there are some disadvantages, such as;

- The increase in the time and effort spent for the usage of the documentation structure proposed.
- The manual usage of the system depending on human performance.

CHAPTER 5

CONCLUSION

In this study, a proposal for the structure of production drawings of “design / build” construction projects in computer environment was made. The main aim of this proposal was to maintain control of the drawings in the construction sites while documenting them for project completion. Another aspect was to maintain communication between the parties throughout the construction process. For this respect the proposal depended on CADD Standards.

As an assumption, the social aspects such as the adaptation process of the users to the proposed documentation structure and the psychology of the participants to accept using a new system were disregarded in this study. As a second point, the system was intended for companies that were not using electronic document management systems (EDMS).

To perform this study, first a literature survey was carried out to explore the topics related with the documentation systems and CADD Standards in the construction industry. Since there was not a current CADD Standard used in the Turkish construction industry, an ISO compatible CADD Standard decided to be selected that was the AEC (UK) CAD Standard. In the light of this, the proposed system was developed; firstly, the architectural production drawings were identified and then arranged according to the model file-naming convention of the selected CADD Standard. As a next step the main folders of the system were created in the company’s server and working principles were distributed. The system was applied to a real construction project that was a military complex in Amman / Jordan for a period of two weeks. Finally, the system was tested according usability considering three usability attributes; efficiency, effectiveness and user satisfaction.

5.1. Comments about the System

As it was stated in the previous chapters the proposed methodology is not without flaws. Since the proposed documentation structure depends on the knowledge of the people using, this is an error sensitive system. If users do not save the drawings into the right locations, there appears the risk of loosing the drawings and no one can find the related drawings. In coping with this commitment, back up files may be taken from the project development folder periodically but this creates another disadvantage as causing the system slow down because of too many safe guards but otherwise the system may crush. A small program can be written to follow the steps of the system such as software that generates commands for saving folders at the right locations. A Visual Basic® program can be used that automates the saving process and guides the users for the next steps to be taken. By this, the working principles of the system would be facilitated.

This system was basically designed for the design / build type construction projects where the design goes throughout the life cycle of a construction project. The arrangement of the folder structure was created to manage the change and revise of the design process. If the system is to be applied to other project types, such as a design/bid/build, construction management, or owner/agent, the structure should be rearranged to create a basis according to the type of the construction project.

Dealing with two architects for the system testing was a limitation of the study since there are many other technical personnel that also use the proposed system such as the civil engineers, electrical engineers, mechanical engineers, *etc*. Although the architectural production drawings were selected to be used in the proposed system, the folder structure could be used by each discipline. As for the other disciplines if the drawing identification was assumed to be done, the model file-naming could be arranged accordingly and the system could be used directly through their drawings. Since that system was proposed for the architectural drawings, participants for the system testing were selected within that group. However, the other parties also used that structure for taking the related drawings so this created a communication basis as an advantage for the system. The system has advantages and disadvantages on the view of the other disciplines, such as the communication platform, CADD Standard usage as advantages and security problems related with open access to everybody as disadvantage.

Within the context of this research the identification of the architectural production drawings were arranged basically for column/beam type construction projects. The challenge is if a different type of construction project, *e.g.* dome construction, is taken, the structure of the architectural production drawings changes on a large scale which is a disadvantage of that study. In coping with that commitment, the drawing list was left open to make additions or subtractions for some different drawings that were not included such as the special kind of details but for a totally different type of project it should be rearranged.

In terms of efficiency, the implementation of the proposed documentation structure needs time and effort. This is because of the much number of the steps that have to be taken when documenting the electronic copies of the shop drawings. Using a Visual Basic® program can also diminish this time loss and effort spent since it automates the related steps of the system. As a positive outcome of the proposed documentation structure, the system maintains time gain when searching a document.

According to effectiveness, the results of the usability evaluation revealed that, the system provides advantages in terms of the control of the shop drawings and documentation of them for the project completion. But in terms of communication, the results showed that the proposed documentation structure do not maintain communication easiness. Since the documentation of the shop drawings are arranged meanwhile producing the drawings for the submission; there is no need of extra time for the documentation process. As the system maintains orderly documentation of the shop drawings, it has a positive effect in as-built drawings. This is because in the proposed documentation structure the project is always changing and developing meanwhile the construction process and includes the latest approved shop drawings. As an advantage, the system maintained a basis for the shop drawing submission and approval period. Shop Drawing Approval form to be used during these submissions was generated and presented in chapter 3.

To comment on communication, it can be said that the CADD Standard should fit into the country it is used. Since each country has different local specifications, the construction terms may change from country to country. In Turkey there is not a country specific standard used for CADD. TSE uses ISO 13567, directly by translating it as TS EN ISO 13567-1 and 2, not any country specific modifications are made on it. Since there is no model file-naming convention in ISO, some other countries take it as a basis, make modifications on it and arrange their own CADD Standards. Same process should be carried out in the Turkish Construction Industry. If the CADD drawings can be arranged according to the specific CADD Standards that fit into Turkish construction industry norms, the proposed documentation system would be more successful in terms of communication.

Using a spreadsheet file to control drawings is a positive attribute of the system since in that file all of the drawings submitted can be controlled according to the replies of the consultant, days passed from the submission, approval statuses, *etc*. which means the document flow throughout the construction with respect to drawings are viewed. So this file may help to overcome the possible claims that may happen between the parties in future.

5.2. Propositions for Further Studies

The proposed documentation structure can be used as propositions for the future studies;

- The systems principles can be integrated with EDMS and WPMS systems. As a result, the system can be automated.
- Databases can be arranged instead of the spreadsheet files since information search can be facilitated in database systems.
- The hard copy documentation can be ordered on the light of this system if it is wanted in the contract clauses.
- The application of CADD Standards to the other partie's drawings can be carried as another study.

This study had the positive effects of identifying the necessary steps to be taken when working in the site technical offices. It also emphasized the importance of CADD Standards in the construction industry. It underlined the importance of documentation in the construction industry. As a final statement the need for a proper documentation control system at construction sites was mentioned.

REFERENCES

Arkitera (2005) "Digital Publications Arkiteracom", [Online], Available at: http://www.arkitera.net/index.php?action=engine&ID=40&lid=en [accessed August, 2007].

Arkiteraforum (2005) "CAD Standartları Oluşturulması", [Online], Available at:http://forum.arkitera.com/yazilimlar/714-cad-standartlari-olusturulmasi.html [accessed August, 2007].

Arkiteraforum (2005) "Ulusal CAD Standartları", [Online], Available at: http://forum.arkitera.com/projeler/7423-ulusal-cad-standartlari.html [accessed August, 2007].

Bevan N. and Macleod M. (1994) "Usability Measurement in Context", *Behaviour and Information Technology*, vol. 13, no. 1, pp. 132-145.

Björk, B. (2002) "The Impact of Electronic Document Management on Construction Information Management", *Proceedings of the International Council for Research and Innovation in Building and Construction CIB W78 Conference*, Aarhus School of Architecture. June 12-14.

Björk B., Löwnertz K. and Kiviniemi A. (1997) "ISO DIS 13567 - The Proposed International Standard for Structuring Layers in Computer Aided Building Design", *Electronic Journal of Information Technology in Construction,* vol. 2, pp. 32-55, [Online], Available at: http://www.itcon.org/1997/2 [accessed May, 2007]

Bowden S.L. (2005) "Application of Mobile IT in Construction", *Doctoral Thesis*, Department of Civil and Building Engineering, Loughborough University.

Caldas C.H. and Soibelman L. (2003) "Automating hierarchical document classification for construction management information systems", *Automation in Construction*, vol. 12, no. 4, pp. 395-406.

Chinowsky P.S. and Rojas E.M. (2003) "Virtual teams: guide to successful implementation", *Journal of Management in Engineering,* vol. 19, no. 3, pp. 98-106.

Cleland, D.I. (1999) *Project Management; Strategic Design and Implementation*, McGraw-Hill, United States of America.

Forcada, N. (2005) "Life Cycle Document Management System for Construction", *Doctoral Thesis*, Department of Construction Engineering, Technical University of Catalonia.

Fryer, B. (1990) *The Practice of Construction Management, 2nd ed.,* BSP Professional Books, Great Britain.

Hall D.J. and Green C.R. (2006) *The Architect's Guide to the U.S. National CAD Standard.,* John Wiley & Sons, New Jersey.

Hendrickson C. and Au T. (2003) "Project Management for Construction, Fundamental Concepts for Owners, Engineers, Architects and Builders, Ver. 2.1.", [Online], Available at: http://www.ce.cmu.edu/pmbook/index.html [accessed February, 2007]

Hjelt M. and Björk B.-C. (2006) "Experiences of EDM usage in construction projects", *Electronic Journal of Information Technology in Construction,* vol. 11, pp. 113-125, [Online], Available at: http://www.itcon.org/2006/9 [accessed March, 2007]

Howard R. and Björk B. (2007) "Use of standards for CAD layers in building", *Automation in Construction*, vol. 16, no. 3, pp. 290-297.

Jay-Jones A. and Clegg D. (1976) *CI/SfB construction indexing manual, 3rd ed.,* RIBA Publications, London.

Kang L.S. and Paulson B.C. (2000) "Information Classification for Civil Engineering Projects by Uniclass", *Journal of Construction Engineering and Management*, vol. 126, no. 2, pp. 158-167.

Last C. W. (2000) "Construction Project Documentation: A Basic Checklist of Documents That Should Be Maintained to Prove a Construction Claim", *Find law for legal professionals, Find law, a Thompson Business*, [Online], Available at: http://library.findlaw.com/2000/May/1/ 128077.html [accessed March, 2007]

Mead S. (1997) "Project-specific intranets for construction teams", *Project Management Journal*, vol. 28, no. 3, pp. 44-51.

NCS 3.1 Presentation (2005), "Knowledge for Creating & Sustaining the Built Environment", *CSINet-Home of The Construction Specifications Institute, The Construction Specifications Institute*, [Online], Available at: http://www.csinet.org/s_csi/docs/10500/10490.ppt?DocTypeID=12&TrackID= [accessed March, 2007].

Nitithamyong P. and Skibniewski M.C.J. (2004) "Web-based construction project management systems: how to make them successful?", *Automation in Construction*, vol. 13, pp. 491-506.

Oberlender, G.D. (2000) *Project Management for Engineering and Construction*, 2nd ed., McGraw-Hill, United States of America.

Radford, K.J. (1973) *Information Systems in Management*, Reston Publishing Company, Reston.

Rezgui Y. and Cooper G. (1998) "A Proposed Open Infrastructure For Construction Project Document Sharing", *Electronic Journal of Information Technology in Construction*, vol. 3, pp. 11-25, [Online], Available at: http://www.itcon.org/1998/2/ [accessed March, 2007].

Rosenau M.D.Jr. and Githens G.D. (2005) *Successful Project Management; A Step-by-Step Approach with practical Examples, 4th ed.*, John Wiley & Sons, Hoboken N.J.

Senn, J.A. (1989) *Analysis and Design of Information Systems*, *2nd ed.*, McGraw-Hill, New York.

Shaheen, S.K. (1987) *Practical Project Management*, Wiley Inter Science Publication, New York.

Shipman D.C. (2006) "Document management throughout plant construction, Case study: Use of Document Management Systems At Amoco", *Sword Group*, [Online], Available at: http://www.cimage.com/news/casestudies/doc manage.htm#plant%20spec [accessed February, 2007].

Tanyer A.M. (2005) “Developing and Implementing Standards for CAD Data Production and Exchange: A Case study”, *Unpublished Report*.

Tanyer A.M. (2006) “Usability Evaluation of Computer Integration for Construction”, *submitted to ASCE Journal of Computing in Civil Engineering.*

The AEC (UK) CAD Standard for Model File Naming v1.1 (2005) *AEC (UK) CAD Standards Website, AEC UK Architecture, Engineering and Construction*, [Online], Available at: http://195.167.181.224/Asp/uploadedFiles//file/AEC(UK)CADStandardsForModelFileNaming-v1.1.pdf [accessed April, 2007].

The AEC (UK) CAD Standard for Advanced Layer Naming v2.4. (2005) *AEC (UK) CAD Standards Website, AEC UK Architecture, Engineering and Construction*, [Online], Available at:http://195.167.181.224/Asp/uploadedFiles//file/AEC(UK)CADStandardsForAdvancedLayerNaming-v2.4.pdf [accessed April, 2007].

The AEC (UK) CAD Standard for Basic Layer Naming v2.4 (2005) *AEC (UK) CAD Standards Website, AEC UK Architecture, Engineering and Construction*, [Online], Available at: http://195.167.181.224/Asp/uploadedFiles//file/AEC(UK)CADStandardsForBasicLayerNaming-v2.4.pdf [accessed April, 2007].

TSE (2004) *TS EN ISO 13567-1: Teknik Ürün Dokümantasyonu-CAD için Katmanların Organizasyonu ve Adlandırılması – Bölüm 1: Genel Bakış ve Prensipler*.

TSE (2004) *TS EN ISO 13567-2: Teknik Ürün Dokümantasyonu-CAD için Katmanların Organizasyonu ve Adlandırılması – Bölüm 2: Tasarımın*

Oluşturulmasında Kullanılan Kavramlar, Format ve Kodların Dokümantasyonu.

Watson A. and Davoodi M. (2002) "Transferring project documents and associated metadata between company document management systems and project extranets", *eSm@art Conference*, Salford, [Online], Available at: http://www.engineering.leeds.ac.uk/civil/research/cae/papers/eSMART.pdf [accessed March,2007].

Wikipedia (2007) "CAD Standards", [Online], Available at: http://en.wikipedia.org/wiki/CAD_standards [accessed May, 2007]

Yalçınkaya Ş. (2005) "Mimarlık Bürolarında Bilgisayar Destekli Tasarım için bir Büro Standardı Modeli", *Yüksek Lisans Tezi*, Mimarlık Ana Bilim Dalı, Karadeniz Teknik Üniversitesi.

APPENDIX

Uniclass Tables
Table A (Form of Information)

A1 - General Reference Works
A11 - Dictionaries, encyclopedias
A12 - Guides, directories
A13 - Catalogues
A14 - Surveys
A15 - Statistics
A16 - Price books
A17 - Learning materials, textbooks
A18 - Reports
A19 - Other
A2 - Legislation, Legal documents
A21 - Primary legislation (Acts of Parliament), Constitutional law
A22 - Secondary Legislation, laws
A23 - Quasi-legislation (also called tertiary legislation), Ordinance
A24 - International, European legislation in EU, Regulation
A25 - Case law reports, Rule
A26 - Patents, licences, copyright
A29 - Other legislation, legal documents
A3 - National and international standards
A31 - British Standards
A32 - European Standards
A33 - ISO Standards
A34 - De facto standards
A39 - Other
A4 - Other rules, recommendations
A5 - Specifications
A6 - Contracts
A7 - Documents
A8 - Other forms of information
A9 - Types of medium
A91 - Books
A92 - Journals
A93 - Pamphlets, leaflets, unbound printed material
A94 - Drawings
A95 - Photographic information
A96 - Microfiche, microfilm
A97 - Video, film

A98 - Media accessed via a computer
A981 - Optical discs, CD-ROM, DVD
A984 - Online information, Internet information
A99 - Other special forms of information

Table B (Subject disciplines)

B1 - Architecture
B11 - Architecture by name of architect
B12 - Architecture by geographical region, guidebooks
B13 - History of architecture, periods and styles of architecture
B14 - Architectural design (excluding structural design), spatial design
B15 - Interior design, decoration
B16 - Landscape architecture
B2 - Engineering
B21 - Engineering by name of engineer
B22 - Engineering by geographical region
B23 - History of engineering
B24 - Civil engineering, general
B25 - Structural engineering, structural design
B26 - Services engineering
B27 - Other engineering
B3 - Surveying
B31 - Quantity surveying, cost analysis
B32 - Building surveying
B33 - Site surveying, land surveying
B4 - Contracting, building
B5 - Town and country planning
B50 - History and theory of planning
B51 - Planning control
B52 - Planning policy guidance (ppg)
B53 - Regional planning
B54 - Development plans
B55 - Rural planning
B56 - Urban planning
B57 - Environmental planning
B58 - Conservation
B59 - Other kinds of planning
B7 - Other construction-related disciplines
B71 - GIS (Geographical Information System) engineering
B9 - Other disciplines
B91 - Law
B92 - Science/technology
B93 - Computing, information technology
B94 - Behavioural sciences

B95 - Communication
B96 - Political science
B97 - Information science

Table C (Management)

C1 - Management theory, systems and activities
C11 - Corporate strategy
C12 - Quality management
C13 - Security, industrial espionage, trade secrets
C14 - Objective setting
C15 - Decision making
C16 - Problem solving
C17 - Co-ordination
C18 - Appraisal, assessment
C19 - Other
C2 - Management personnel
C21 - Top management, directors, partners
C22 - Other levels of management
C3 - Type of business/ organisation
C31 - Organisations by scale and location
C32 - Private enterprises
C33 - Mixed enterprises and partnerships
C34 - Government and related organisations
C35 - Public enterprises
C36 - Non-profit-making organisations, charities
C37 - Industrial and commercial associations
C38 - Construction industry
C39 - Other types of organisation
C4 - Specialist areas of management
C41 - Management of office services
C42 - Marketing, selling
C43 - Research and development
C44 - Finance and accounting, business economics
C45 - Personnel management and industrial relations
C46 - Management of computing, information technology
C5/C9 - Management of construction activities/project management
C50 - General techniques/information
C61 - Inception/procurement
C62 - Feasibility
C63 - Outline proposals/programme preparation
C64 - Scheme design/costing
C65 - Detail design/costing
C652 - Working drawings including CAD
C66 - Production information

C67 - Bills of quantities
C68 - Tender action
C71 - Construction preparation/project planning
C72 - Construction operations on site
C73 - Completion
C81 - Occupation/facilities management
C83 - Feedback
C84 - Refurbishment and recommissioning
C91 - Decommissioning
C92 - Demolition etc.
C93 - Redevelopment

Table D (Facilities)

D1 - Utilities, civil engineering facilities
D2 - Industrial facilities
D3 - Administrative, commercial, protective service facilities
D4 - Medical, health, welfare facilities
D5 - Recreational facilities
D6 - Religious facilities
D7 - Educational, scientific, information facilities
D8 - Residential facilities
D9 - Other facilities

Table E (Construction Entities)

E0 - Construction complexes
E1 - Pavements and landscaping
E2 - Tunnels, shafts, cuttings
E3 - Embankments, retaining walls, etc.
E4 - Tanks, silos, etc.
E5 - Bridges, viaducts
E6 - Towers, superstructures (excluding building
E7 - Pipelines, ducts, cables and channels
E8 – Buildings

Table F (Spaces)

F1 - Compound spaces of buildings, zones
F1/F4 - Building spaces according to complexity/scale
F2 - Rooms
F3 - Circulation spaces
F4 - Building sub-spaces

F5 - Internal spaces of buildings
F5/F6 - Building spaces according to whether they are internal or external
F6 - External spaces of buildings
F7 - Building spaces by degree and type of enclosure
F8 - Miscellaneous spaces, other spaces
F9 - Building space analysed

Table G (Elements for buildings)

Used in CAD layer definition and WBS
G1 - Site preparation
G11 - Site clearance
G12 - Ground contouring
G13 - Stabilisation
G2 - Fabric: complete elements
G21 - Foundations
G22 - Floors
G23 - Stairs
G24 - Roofs
G25 - Walls
G26 - Frame/isolated structural members
G3 - Fabric: parts of elements
G31 - Carcass/structure/fabric
G32 - Openings
G33 - Internal Finishes
G34 - Other parts of fabric elements
G4 - Fittings/furniture/equipment (FFE)
G41 - Circulation FFE
G42 - Rest, work FFE
G43 - Culinary FFE
G44 - Sanitary, hygiene FFE
G45 - Cleaning, maintenance FFE
G46 - Storage, screening FFE
G47 - Works of art, soft furnishings
G48 - Special activity FFE
G49 - Other FFE
G5 - Services: complete elements
G50 - Water supply
G51 - Gas supply
G52 - Heating/ventilation/air conditioning (HVAC)
G53 - Electric power
G54 - Lighting
G55 - Communications
G56 - Transport
G57 - Protection

G58 - Removal/disposal
G59 - Other services elements
G6 - Services: parts of elements
G61 - Energy generation/storage/conversion
G62 - Non-energy treatment/storage
G63 - Distribution
G64 - Terminals
G65 - Package units
G66 - Monitoring and control
G69 - Other parts of services elements
G7 - External/site works
G71 - Surface treatment
G72 - Enclosure/division
G73 - Special purpose works
G74 - Fittings/furniture/equipment
G75 - Mains supply
G76 - External distributed services
G77 - Site/underground drainage

Table H (Elements for civil engineering works)

H1 - Pavements and landscaping
H11 - Site preparation
H111 - Site clearance
H112 - Ground contouring
H113 - Stabilisation
H12 - Structure
H121 - Structural layers
H122 - Surfacing to pavements/hard landscaping
H123 - Edgework to pavements/hard landscaping
H124 - Planting/surfacing to major soft landscaping construction entities
H13 - Services
H131 - Mechanical engineering
H132 - Electrical installation
H133 - Communications
H134 - Protection
H135 - Drainage
H139 - Other services
H14 - Ancillaries
H141 - Decoration
H142 - Fittings
H1421 - Track fittings
H1422 - Signs
H1423 - Gantries
H1424 - Street furniture

H143 - Minor landscaping/planting associated with roads, railways, etc.
H144 - Enclosure, divisions
H2 - Tunnels, shafts, cuttings
H21 - Site preparation
H22 - Structure and tunnel formation
H23 - Services
H24 - Ancillaries
H3 - Embankments, retaining walls, etc.
H31 - Site preparation
H32 - Structure
H33 - Services
H34 - Ancillaries
H341 - Fittings
H3411 - Signs
H3412 - Ancillary items
H4 - Tanks, silos, etc.
H5 - Bridges, viaducts
H6 - Towers, superstructures
H7 - Pipelines, ducts, cables and channels

Table J (Work Sections for buildings)

JA - Preliminaries/General conditions
JB - Complete buildings/structures/units
JC - Existing site/buildings/services
JD - Groundwork
JE - In situ concrete/Large precast concrete
JE0 - Concrete construction generally
JE1 - Mixing/Casting/Curing/Spraying in situ concrete
JE2 - Formwork
JE3 - Reinforcement
JE4 - In situ concrete sundries
JE5 - Structural precast concrete
JE6 - Composite construction
JF - Masonry
JF1 - Brick/Block walling
JF2 - Stone walling
JF3 - Masonry accessories
JG - Structural/Carcassing metal/timber
JG1 - Structural/Carcassing metal
JG10 - Structural steel framing
JG11 - Structural aluminium framing
JG12 - Isolated structural metal members
JG2 - Structural/Carcassing timber
JG3 - Metal/Timber decking

JH - Cladding/Covering
JJ - Waterproofing
JK - Linings/Sheathing/Dry partitioning
JK1 - Rigid sheet sheathing/linings
JK2 - Timber board/Strip linings
JK3 - Dry partitions
JK4 - False ceilings/floors
JL - Windows/Doors/Stairs
JM - Surface finishes
JN - Furniture/Equipment
JP - Building fabric sundries
JQ - Paving/Planting/Fencing/Site furniture
JR - Disposal systems
JS - Piped supply systems
JT - Mechanical heating/Cooling/Refrigeration systems
JU - Ventilation/Air conditioning systems
JV - Electrical supply/power/lighting systems
JW - Communications/Security/Control systems
JX - Transport systems
JY - Services reference specification
JZ - Building fabric reference specification

Table K (Work Sections for Civil Engineering Works)

KA - General items
KB - Ground investigation
KC - Geotechnical and other specialist processes
KD - Demolition and site clearance
KE - Earthworks
KF - In situ concrete
KG - Concrete ancillaries
KH - Precast concrete
KI - Pipework - pipes
KJ - Pipework - fittings and valves
KK - Pipework - manholes and pipework ancillaries
KL - Pipework - laying and excavation ancillaries
KM - Structural metalwork
KN - Miscellaneous metalwork
KO - Timber
KP - Piles
KQ - Piling ancillaries
KR - Roads and paving
KS - Rail track
KT - Tunnels
KU - Brickwork, blockwork and masonry

KV - Painting
KW - Waterproofing
KX - Miscellaneous work
KY - Sewer renovation and ancillary work
KZ - Simple building works
Table L (Construction products)
L1 - Ground treatment and retention products
L2 - Complete construction entities and components
L21 - Civil engineering works products
L215 - Transport control and monitoring products
L2151 - Road signs
L21511 - Illuminated road signs
L3 - Structural and space division products
L4 - Access, barrier and circulation products
L5 - Coverings, claddings, linings
L6 - General purpose civil engineering and construction fabric products
L7 - Services
L8 - Fixtures and furnishings

Table M (Construction aids)

M1 - Pumps for ground water lowering
M2 - Formwork
M3 - Scaffolding, shoring, fencing
M4 - Lifting appliances and conveyors
M5 - Construction vehicles
M6 - Tunnelling, drilling, compaction
M7 - Concrete, stone production
M8 - Testing equipment
M9 - General equipment
M92 - Site equipment
M923 - Protective equipment
M9231 - Signals for construction sites
M92311 - Warning signs
M9233 - Road works equipment
M92337 - Traffic information signs
M923371 - Traffic control signs
M923372 - Traffic warning signs
M923373 - Illuminated traffic information signs

Table N (Properties and characteristics)

N1 - Descriptive
N2 - Context, environment

N3 - Performance
N4 - Applications, activities
N5 - Users, resources
N6 - Ease of use, workability
N7 - Operation and maintenance
N8 - Change, movement, stability
N9 - Other properties and characteristics

Table P (Materials)
Used also by EPIC.

P1 - Stone, natural and reconstituted
P11 - Stone, natural
P12 - Stone, reconstituted, reconstructed, cast
P2 - Cementitious, concrete and mineral-bound materials
P21 - Cementitious materials, binders
P22 - Concrete, general
P23 - Other mineral-bound materials
P3 - Minerals, excluding cementitious
P31 - Mineral-based materials
P32 - Soils, natural
P33 - Clay-based materials
P34 - Bitumen-based materials
P4 - Metal
P41 - Steel
P42 - Iron
P43 - Aluminium
P44 - Copper
P45 - Zinc
P46 - Lead
P49 - Other metals
P5 - Timber
P51 - Timber, wood, general
P52 - Timber, wood, laminated
P53 - Timber, wood, fibre building boards
P6 - Animal and vegetable materials, excluding timber
P7 - Plastics, rubber, chemicals and synthetics
P9 - Combined, other materials, undefined materials

Table Q (Universal Decimal Classification)

Q"+" - Christian Era AD
Q"-" - Antiquity BC
Q"05" - 6th century (500s)

Q"05/09" - 5th to 10th century
Q"141/149" - 1410 to 1499
Q"19" - 20th century (1900s)
Q"1914/1918" - the 1st world war years
Q"196" - the sixties (1960-69)
Q"20" - 21st century (2000s)
Q(1) - Place in general
Q(2) - Physiographic designation
Q(3) - The ancient world
Q(4) - Europe
Q(41) - British Isles (geographical whole)
Q(410) - United Kingdom of Gt Britain and N Ireland
Q(410.1) - England
Q(410.3) - Wales
Q(410.5) - Scotland
Q(410.7) - Northern Ireland
Q(415) - Ireland (geographical whole)
Q(417) - Irish Republic (Éire)
Q(430) - Germany
Q(436) - Austria
Q(437.1) - Czech Republic
Q(437.6) - Slovak Republic
Q(438) - Poland
Q(439) - Hungary
Q(44) - France
Q(450) - Italy
Q(460) - Spain
Q(469) - Portugal
Q(47) - Former European USSR
Q(470) - Russia
Q(48) - Scandinavia
Q(480) - Finland
Q(481) - Norway
Q(485) - Sweden
Q(489) - Denmark
Q(492) - Netherlands
Q(493) - Belgium
Q(494) - Switzerland
Q(495) - Greece
Q(497) - Balkan States
Q(5) - Asia
Q(61) - Tunisia, Libya
Q(7) - North and Central America
Q(71) - Canada
Q(72) - Mexico
Q(728) - Central America

Q(729) - West Indies
Q(73) - USA
Q(74) - N E States
Q(75) - S E States
Q(76) - S Central States
Q(77) - N Central States
Q(78) - W States
Q(79) - Pacific States
Q(8) - South America
Q(9) - South Pacific and Australia. Arctic. Antarctic
Q0 - Generalities
Q1 - Philosophy. Psychology
Q2 - Religion. Theology
Q3 - Social sciences
Q4 - Vacant
Q5 - Mathematics and natural sciences
Q6 - Applied sciences. Medicine. Technology
Q7 - The arts. Recreation. Entertainment. Sport
Q8 - Language. Linguistics. Literature
Q9 - Geography. Biography. History

Composition of complex codes
Samples using different tables

B2:D15 - Communications engineering
B2:D17 - Public health engineering
B5:A25 - Planning case law reports
B5:B91 - Planning law
B5:D11/D14 - Transport planning
B5:D137 - Coastal planning
B5:D15 - Telecommunications planning
B5:D16 - Planning for power supply, mineral supply
B5:D17 - Waste management, pollution control planning
B5:D261 - Trees and forestry planning
B5:D34 - Retail planning
B5:D4 - Health care planning
B5:D5 - Recreational planning
B5:D8 - Housing planning
B5:E7 - Planning for pipelines etc.
B91:B5 - Planning law
E:N246 - Earthquake resistant structures
F:D32 - Office space
F:D34 - Trading space
F:D41 - Medical space
F:D44 - Welfare space

F:D56 - Sports space
F:D6 - Religious space
F:D76 - Information/study space
G21:G311 - Foundations
G251:G322 - External doors