Arab Academy for Science, Technology and Maritime Transport

College of Engineering and Technology

CONSTRUCTION AND BUILDING ENGINEERING DEPARTMENT

Development of a Conceptual Web-Based Construction Coordination Model

A Thesis

Submitted in Partial Fulfillment to the Requirements for the

Master of Science

In

Construction Engineering and Management

Submitted by:

Hady Mohamed Bassem Abdel Aziz Elborollocy

Under Supervision of

Dr. Mohamed Emam Abdel-Razek

Professor of Construction Engineering

College of Engineering and Technology

Arab Academy for Science, Technology and Maritime Transport

Dr. Emad Elbeltagi

Professor of Construction Management

Faculty of Engineering

Mansoura University

May – 2012

ACKNOWLEDGEMENT

Thanks to Allah who enabled me to do whatever I was able to accomplish. All praise goes to Allah, whose mercy and blessings shower the universe.

Thanks to my family, with all my love for sharing in my dream. Without their care, support, I would not be able to achieve whatever I have achieved.

I am deeply grateful to Professor Emad Elbeltagi and Professor Mohamed Emam my advisors for their insight guidance, instrumental advise and continuous supervision.

Thanks to all, who have been generous with their time and effort to contribute to this work and their diligent involvement that made this work come to its final destination.

ABSTRACT

Information plays a key role in construction project management. In order for a construction project to be well managed, data from past projects, stored in a database, as well as data from the project at hand, must be readily available. It serves as an essential and valuable resource for project planning, control, reporting, and decision-making. Effective management of information is an integral part of a successful project management system, whose primary objective is completing the project on time and within budget limitations while meeting established quality requirements and other specifications.

Web-based coordination tools offer many benefits in the management of construction projects and the flow of information within; however they still have not been widely implemented in the construction sector.

This research described the design and implementation of an Internet/Intranet-based project coordination model where the Internet is utilized as a mechanism for communicating project control data and information. The monitoring process is automated through the use of intelligent documents over the World Wide Web and database technology through which data collection and dissemination are similarly automated.

This research focused on identifying some of the needs in the available Web-based Project Management models and implementing a collection of new sub-models to meet these needs to help different project participants in efficiently control projects and effectively monitor and assess project performance.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Chapter (1)

1. Introduction

1.1 Research Overview

Communication and coordination of information in construction projects are becoming increasingly complicated. Projects are integrating more members and these members are often quite geographically apart. Limited projects' durations, their complex details, and sophisticated contracting methods are also requiring project participants to effectively communicate and share project information. Successful management of construction projects depends heavily on their access to documents and the standards of information within. A lot of projects undergo big challenges due to ineffective coordination of information. Communication is an integral part of project success and the process of effectively communicating has been shown to be an important factor in the success of a project. (Chassiakos and Sakellaropoulos 2008)

One way that project participants can improve communication is through the use of Information Technology (IT) and more specifically web-based project management systems (WPCS). These web based coordination tools have been developed as means to help project teams communicate and transfer information efficiently. They also assist in the collection process of good data in a timely manner that will be the base for future project management and decision making process.

The main target of WPCS is to facilitate rapid exchange of data and speedy access to project information through the use of the Internet and by creating a web-based coordination system. By utilizing the Internet, information is centrally stored and can be easily accessed by project participants. This easy access allows project participants to coordinate during design and construction more easily. By using the Internet over other forms of communication, users are able to take advantage of common standards to help overcome compatibility issues of different programs (O'Brien 2000). Information in a typical web-based system are centrally stored in a database engine and processed by a user friendly online interface. Data retrieval and reporting are then presented on-line using the interface website and controlled by providing passwords to authorized individuals according to their level of authorizations.

Utilization of WPCS has increased during the recent years but accompanied with difficulties in achieving complete successful implementation in many construction organizations. The most common reasons for failing to receive the full benefits from WPCS are: poor capture of user requirements, lack of strategic approaches, lack of proper planning, user resistance to change, lack of user involvement, and technical characteristics (Erdogan et al. 2008). Some of these reasons relate directly to how the system is modeled and developed. And hence there is a need to design and implement an efficient coordination system with standard intelligent documents avoiding any reasons of failure.

1.2 Problem Definition

Recently, construction projects were noticed to have grown in size, complexity and the number of stakeholders creating an urgent need for coordination. Multiple stakeholders and construction teams depend mainly on different project information, its accuracy, and its availability for the proper execution and timely delivery of the projects in hand. Web-based project management systems offer many benefits in the management of construction projects through developing a mechanism for overcoming the unparalleled fragmentation of the information in this industry as well as standardizing communication and information exchange during the construction process without duplicating information or losing quality.

Many reasons increased the complexity of the modeling and development of the components of the web based coordination systems, some of these reasons can be illustrated as follows:

- The big diversity in construction documents and multiple types of project information are required to be available at different stages of a construction project.
- Project information is being used by a broad range of stakeholders, professionals, and contractors of multiple disciplines for the purpose of coordination and execution of work.
- The information being coordinated is extremely dynamic and constantly changing even in small sized construction projects because of the continuous cycles of documents' adding, editing, formatting, exchanging and transmitting, and this usually happens on a daily basis. Any changes or modifications to information shall be recorded and disseminated automatically within the system thus ensuring that every discipline involved is working with the most up-to-date information (Aouad et al. 1995).

- The distance between headquarters and construction sites also adds to the complexity of communication and integration of construction documents and information
- Lack of integration: A high percentage of the available coordination systems focus on specific tasks such as project planning and monitoring, estimating, design, etc. These isolated applications have resulted in a broad spread of stand-alone application packages with no or ‘‘fixed’’ communication links. The industry lacks an integrated comprehensive system, which facilitates the smooth flow of information between the various stages of the project (Alshawi 2000)
- Mixing electronic and hard copy communication: Although many construction organizations are using IT to improve specific processes/applications, the construction industry still traditionally holds the view of issuing hard copy documentation as against electronic forms for auditing and record purposes. And hence, the communication in the construction industry is complicated by its structural and cultural problems (Deng et al. 2001).
- Incompatibility of computer platforms required for integration in a given project: The incompatibility between hardware and software have raised a serious problem, which have prevented project managers to easily access and manage project information. Therefore, IT systems that are available and currently used by the industry do not consider the needs of widely

dispersed participants in large construction projects (Underwood and Alshawi 1997).

These reasons among others show the importance and the need of creating an advanced coordination system that have a positive effect on the spread of the WPCS solutions and solve some issues in project management practices in the construction industry.

1.3 Research Objectives

The main objective of this research is to design and implement an advanced web based approach for integrating, incorporating and coordinating main construction projects related documents in an advanced standard accessible platform. The internet or intranet is utilized as a mechanism for interrelating project information between different parties.

The research aims at developing a systematic and unified model for coordinating project activities and all its related construction documents. The advanced model development avoids the challenges existing in the construction industry as illustrated in the literature review. It also attempts to add some needed features that are missing in electronic coordination of construction activities. The structure of the documents inside the system not only acts as a source of correct and updated project information as a part of a standard system but also makes them active for later follow up and monitoring processes. Remote data entry into the centralized database will be performed on line using appropriately designed web forms developed as a part of the overall project coordination system. Reports can then be automatically generated and presented on-line using Web technologies.

The resulting goal of this research is ultimately to create a new improved WPCS system. Such development allows better communication and efficient information transfer between project participants. As a result, project coordination and access to projects information is improved leading to enhanced project performance.

1.4 Research Methodology

Literature review and the background study (covered in Chapter 2) are considered as a pre-research stage and as a guide for the other research stages that includes the following:

1. Investigate relations between different documents and parties in a construction project.
2. Develop a coordination flow model between different project stakeholders
3. Design a framework structure for an Intranet-based coordination system
4. Implementation of the designed framework
5. Develop conclusions and recommendations for future researches

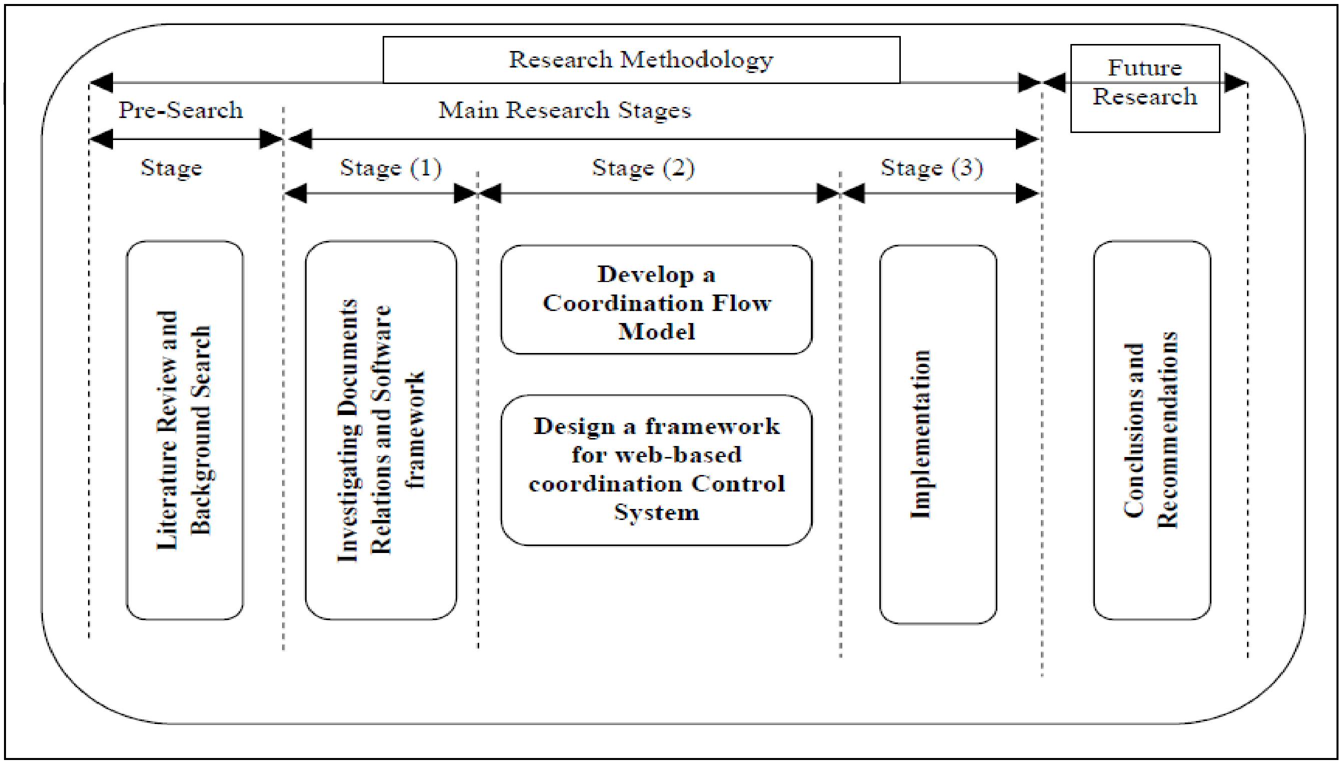

Figure 1-1: Research Stages

1.5 Thesis Contents

The thesis is organized into six chapters. Chapter 1 defines the problem of the thesis and shows the research objectives and methodology followed , while chapter 2 is a comprehensive literature review for various definitions of coordination and the web-based coordination models in construction industry. The system modeling and architecture is reviewed in chapter 3 in details while the system development itself is illustrated in chapter 4. Chapter 5 discusses system implementation from a comparative perspective against the traditional documentation system. It also discusses a case study from a system evaluation perspective. Finally chapter 6 concludes the thesis and gives future recommendation for future research.

Chapter (2)

2. Literature Review

2.1 Introduction

This chapter reviews literature related to the development of the management and coordination systems in the construction industry. The scope of the literature review ranges from definitions of the different coordination models and systems to discussing challenges in implementing these systems

A background introduction on the need for web-based coordination systems and the use of internet in facilitating the management of construction project is discussed. This chapter also discusses different definitions of coordination not only in construction context but also when referring to coordination through the web. Different strategies and models of both coordination systems and web-based coordination systems are reviewed in this chapter along with a small list of the commercially available web-based management solutions. The review is finalized in this chapter by discussing the factors affecting the implementation of coordination systems and the challenges that appears while implementing them.

2.2 Background

During the construction process documents concerning any element is collected, analyzed and recorded for incorporation into the proposed project. These documents sharing graphical and textual information are the base resource where information is cataloged, stored and distributed and they will be evolved and modified as the project is heading towards completion and the different users interact in the project.

The users of construction documents are a changing group of individuals and organizations that participate during the different phases of the project. The initial users of these documents may consist of the team members traditionally brought together to design or to construct a project; owner, design professionals, and contractor. Other users may include owner representatives, consultants, along with the subcontractors that form the next tier of the project team. There is also a broader group of users that include material suppliers, product manufacturers, government officials, accountants, attorneys, lenders, and other construction professionals.

Each of these individuals accessing these documents brings a different level of experience, understanding, capability, and purpose to the project. This group of individuals may constantly evolve and change throughout each phase of the project. As one project phase leads to another, the user group forms, disbands, and reforms many times. With the development of a project, there is a continuous need for clear, correct, complete, and coordinated documents that do not get duplicated, misplaced, nor conflicted with previously generated information. Proper organization of the construction documents facilitates cost estimating and aids in the preparation of bids (Merrit and Riicketts 1994).

The Construction Specification Institute (CSI) publishes a master list of section Titles and Numbers organizing the technical specifications into divisions, which have generally become the accepted industry standard for coordination in construction documents (AIA 1994). Fisher and Kunz used the master list and said that Computer Integrated construction can be defined as a business process that links the project participants into a collaborative team through all phases of a project (Fisher and Kunz 1995).

2.3 Coordination Definition and Description

Coordination of work was described in different contexts according to the area of research as follows:

- In construction management; coordination systems are described as the tools that provide the stakeholders access to the project updated accurate information. These tools present the status of each project allowing management to monitor progress (Attaran and Attaran 2002).
- In design context; coordination is described as tools and technologies that exchange design documents faster and allowing real-time collaboration and audit of the design process (Chim et al. 2004)
- In the context of visualization; coordination systems permit project members to view project documents with complicated information in a visual format that is easily recognizable. This type gives means for changes to be made easier and earlier in the project life cycle (Sriprasert and Dawood 2005).
- And in the general context; coordination systems are described as the use of technology to enable project stakeholders to exchange information and communicate easier on projects (Li et al. 2004).

The coordination definition that we adopt in this research is the combination of all these definitions together.

There are also different forms of coordination in construction projects as adopted by Attaran and Attaran (2000). Table (2.1) shows four modes of coordination i.e. collaboration and their typical forms of use

Table 2-1 Forms of coordination and typical uses (Attaran and Attaran 2002)

Type of collaboration	Description of collaboration	Typical uses
Face-to-face collaboration	Same time – same place	Information centres Team rooms Task delegation
Asynchronous collaboration	Different time – same place	e-mail Computer conferencing Data sharing
Synchronous distributed collaboration	Same time – different place	Tele-conferencing Video-conferencing Conference publishing
Asynchronous distributed collaboration	Different time – different place	Electronic meeting rooms Design conferences Project management

2.4 Web-based Coordination Definition and Description

The basic definition of a web-based project coordination system (WPCS) is the availability of a website specific to a project accessible for all users through any internet connection. The project website "provides a centralized, commonly accessible, reliable means of transmitting and storing project information" (Nitithamyong and Skibniewski 2004). Beyond this definition, WPCS vary considerably according to their features and way of setup.

When talking about web based project management systems (WPCS), it is important to differentiate them from other systems that only allow the transfer of information via the internet, such as the File Transfer Protocol (FTP) sites. File Transfer Protocol sites allow posting of files in a folder structure similar to those in internal networks. However, these FTP sites do not act as coordination and follow up tool like WPCS solutions and typically their user interface is not very user friendly.

WPCS can be broken down into three main categories. The first category is the Project Collaboration Network (PCN), which focuses on facilitating project management by assisting project participants with sharing documents, communications, and workflows. It also tracks what is accessed and when, and manages the versions of documents. The second category is the Project Information Portal (PIP), which are usually used to track codes, permits, economic trends, cost data, and project planning information. The third category is the Project Procurement Exchange (PPE), which are used to electronically manage bidding and procurement. (Nitithamyong and Skibniewski 2004).

Another three forms of WPCS were mentioned by Nitithamyong and Skibniewski when discussing system acquisition; first option is developed and hosted by the system owner, second is purchased and hosted “in-house” by the system owner, and finally is purchased as a service while a vendor hosts the system (Nitithamyong and Skibniewski 2004).

2.5 Need for Coordination Systems

Construction industry by definition is an industry of multi organizational nature and geographically separated projects. Many coordination tools and systems are currently used; however the industry is constantly searching for new, more proficient and effective coordination methods that will bring projects and their stakeholders closer.

The use of advanced visualization technologies has great potential to increase the coordination ability within the project team members. However, their use as an effective coordination tool to extract, interpret and process information is still limited and not completely explored (Dawood and Sikka 2008).

2.6 Development of Web based Management Systems

The use of project management softwares to assist managers is not new to the construction industry. Project management software systems have been used for years to coordinate many types of information from financial data to scheduling to document management (Suchanic 2001). The use of project management systems has been progressively improving over time to help meet the needs of the industry. Throughout the history of project management software there have been a number of outside factors that have dramatically changed the way they have been used. The increased availability of personal computers since 1990’s allowed project management softwares to be much more available to individual users and easy access to the Internet recently has made the transfer of information much more efficient.

By utilizing the Internet, companies were able to transfer documents much quicker and cheaper than before (Anumba et al. 2007). By incorporating the internet into project management, users were able to coordinate activities by sending and receiving information much faster and thus reduce avoidable delays. Web-based collaboration was designed to help overcome the chaotic nature of communication in construction that often leads to drops in communication, poor understanding, conflict, and cost and schedule overruns. As web-based collaboration matured, it allowed the development of project websites in the late 1990's. The idea behind project websites was that each project would have its own website which would serve as a centralized location to store information so that it would be easily accessible to the project participants (O'Brien 2000). This increased availability was because the project website stored the information on central servers which were connected to the Internet. This allowed all project participants access to the same information at any time (Mead 1997). Since the introduction of project websites as a means for collaboration in the 1990's, the use of these systems has been steadily increasing (Nitithamyong and Skibniewski 2004).

2.7 Coordination Strategies and Models

There are two types of coordination strategies; technical and managerial. Technical coordination strategy focuses on the data interoperability of software applications that support different disciplines. Managerial coordination strategy puts an emphasis on the collaboration between a client and various disciplines of specialists within the project teams (Zhu et al. 2001).

Integrated Project Delivery (IPD) is an approach that coordinates people, systems, business structures and practices into a process that collaboratively connects the talents and insights of all members to diminish waste and optimize organization through all project phases. Integrated Project Delivery teams should contain all members involved in the project. Any IPD should include a tight coordination between the client, the architect, and the main contractor responsible for construction of the project, during all project phases. The success key of the IPD lies in assembling a team that is dedicated to coordination processes and is capable of working in cooperation effectively (AIA California Council 2007) .

Another approach for the coordination of engineering information is Building Information Model (BIM). It can be defined as the digital representation of physical and functional characteristics of a project. As such it serves as a shared knowledge resource for information about a project forming a reliable basis for decisions during its lifecycle from inception onward (NIBS 2007). BIM can be considered as a model for coordination as it integrates work independent on time and place. It allows different stakeholders at different phases during the life cycle of a project to add, retrieve, modify information. BIM in its ultimate form, as a shared digital representation founded on open standards for interoperability, can become in future researches a virtual information model to be handed from the design team to the contractor and subcontractors and then to the client (Sebastian et al. 2009).

2.8 Web-based Coordination Strategies and Models

A range of Internet coordination applications, models and development strategies can be noticed in the literature review.

Mead (1997) categorized four main areas that Web coordination systems are designed to address: project information, design information, management information, and financial information. The project information category contains general project information, photos, and directories of project participants. Design information contains contract drawings, revisions, and specifications. Management information contains meeting minutes, submittals, change orders, as built drawings, requests for information (RFI), logs, and schedules. Financial information includes all information related to the accounting of the project. Other areas such as bidding and procurement have been incorporated into Web Coordination systems more recently (Nitithamyong and Skibniewski 2004)

Workflow management is an important part of WPCS. By making workflow a part of the coordination system, users can set a predetermined route for information. For example, a workflow can be setup to allow project manager to assign “tasks” to users, such as responding to an RFI. When the user has completed their task the system automatically prompts the next task for that item and the user who is affected (Chan and Leung 2004)

There are four approaches that have been developed to solve the data fragmentation problem (Rezgui et al. 1996). These approaches are as follows:

1. Communication between applications: Using a neutral data format that allows different software systems to share data. A Commercial example of such an approach is AutoCad IGEs Translator.

2. Knowledge based interface: This is one of the early strategies for integration based on linking multiple applicants and multiple databases. KADBASE was a classic example of this approach.

3. Shared project Information Model: The idea of this model can be defined as creating a dynamic repository for project specific information that can be appropriately accessible to all project participants. One of the major advantages of this approach is that it is independent of any particular implementation or application. Therefore, different applications may eventually be able to share and communicate with the same information model. Examples of this model include COKE (Construction Knowledge Expert), OPIS (Object Model Based Project Information System), COMMIT (Computer Models for the Building Industry In Europe), and ICON (Integration of Construction Information). A similar model is being developed by the International Organization for Standardization (ISO) to develop a universal standard for the representation and exchange of product data. This standard is usually referred to as STEP (Standards for the Exchange of Product Data). Formally ISO 10303 objectives is to provide a mechanism capable of describing product data throughout the life of a product independent of any particular computer system.

4. Integration through Geometry. This is often the case in CAD packages where integration is based on and limited only to geometrical information.

Zhu (1999) showed that there are three types of web-based applications for the construction industry: The fee-based project management service; the build-it-yourself solutions; and the web-enabled on shelf software. The subscription fee project management services are provided by professional information technology (IT) companies called Application Service Providers (ASPs). Benefits of this type include low implementation cost, minimal in-house IT expertise required, easy application, continuous upgrade, and simple client system requirements. Its limitation lies in information security and service quality. The build-it-yourself solutions are suitable for extremely large companies, so that they can tailor the application to best fit their business environment and maintain their own business style. The limitation is obvious in that it requires lots of investment, outsourcing, and a long development cycle. The last type, on shelf Web-enabled software, refers to a software set that is bought as a readymade application and maintained by construction companies. This solution is a balance of the former two. It reduces the need for outsourcing, shortens the development cycle and at the same time, preserves the sensitive information of the company. Limitations of this system are a higher initial cost, greater know-how required from staff, and software limitations that do not attend to all the requirements of the organization (Zhu 1999).

The existence of the technology of Intranet and its possible application in specific projects was discussed by Mead (1997). Three systems are outlined: (a) basic; (b) expanded; and (c) comprehensive Intranet system. The principle of the basic Intranet is to present Internet access to major members of the project team and to grant descriptive and marketing information about the project. The spirit of the basic Intranet is an e-mail distribution system that can be used to transmit communication and files between team members. The basic Intranet make use of a project homepage to give access to project descriptions, project links and construction progress photos of the project. This system uses project information that does not change frequently. While minimal in scope, this system helps train members to start the coordination process by providing access to simple Internet tools like e-mail and the World Wide Web. The expanded project Intranet includes a store of integrated management information that can improve the performance of the project team. That information includes updated project schedule, logs for meeting minutes, pending change orders, request for information, submittals status log and action items. In this system, selected project members with proper security access the project management store. Project information within this system change rapidly and hence files have to be updated regularly. Finally the Comprehensive project Intranet adopts a process of complete re-engineering of the construction information process. In this system, construction information is divided into four main groups: project, management, design and financial information.

In the area of coordination between construction project stakeholders, Tam (1999) studied improvement using Information Technologies in facilitating information transfer in construction projects in Hong Kong. A system called "Total Information Transfer System" (TITS) was created including six major criteria: internet chat with live drawings demonstration, remote login, data exchange, live video-cam, search-engine and an e-mail system. This system formed an integrated communication system, which connects with the Internet using its simple existing features for everyday construction information exchange. Construction project members can easily correspond with other branches using "Internet Chat". Video captured at site can be transmitted to the main offices using live video-cams. Supplementary office activities like recruiting are done through the company web page. Search engines are used to search for information that help the decision making process. It is concluded that it is better for coordination to use internet for data exchange between distant projects rather than using a local area network as dial-up and virtual private lines.

An automated code-checking system using an integrated client/server framework was studied by Han et al. (1998). The checking of building designs are made online through using a website and controlled from client server settings. The code-checking software is located on the server and the codes of both the client and server are in Java, creating an independent system. In this system, the interaction is done through submitting information and getting results in a generated web page. The web page contains information with hyperlinks to specific comments. When applicable, these comments have hyperlinks to the actual information needed.

Rojas and Songer (1999) introduced the concepts of a web-centric paradigm, and a model for developing web-centric systems and provided a trial product called the Field Inspection Reporting Systems (FIRS). Web-centric system is illustrated as an integrated network of computers and other information application devices for processing of dynamic information. A pen-based computer is used within FIRS to capture inspection information on site which are then sent via modem to the Web server. The server stores the data and makes it accessible to the owner, contractors, sub-contractors, construction managers, architects/engineers, and suppliers through the internet accessibility. More than 150 different reports are created instantly using FIRS. FIRS is created using client-server structural design. The server processes requests from users by maneuvering the database in order to produce proper reports. A case study proved that 20% savings was recorded when comparing FIRS versus the Paper Based Inspection System (PBIS). Administrative overhead was three times as much for the PBIS system and mistakes were reduced by one third for the FIRS system. The main savings came from the fact that FIRS produces reports automatically since all data are located in a centralized database while PBIS required manual work to produce a report.

Bentley highlighted the process of system implementation by discussing the six steps that should be used to integrate a Web-based network into an organization without disturbing normal workflow (1998). The steps can be summarized as follows: the “project web”, the engineering back office, introducing Java, project data management, component modeling, and the life-cycle integration.

The project control over the Internet was discussed by Seesing to show its need and its importance (Seesing 1996). The research talked about security and safety pitfalls of such a practice but concluded that benefits prevail over risks.

Wills (1998) discussed the increasing usage of Internet as the fundamental solution for making project management easier. He stated that although the Internet is very attractive it may not be the complete resort. The arrangement must be able to correspond information efficiently instead of just sending vast amounts of information that are un-usable. Communication ability is not the mere solution in itself; however the communication content is the means to project success.

2.9 Commercially Available WPCS Solutions

Table (2.2) lists some of the commercially available coordination and management systems.

Table 2-2: Sample of Available Coordination Softwares:

No	Software Name
1	Planbox
2	ProjectManager.com
3	Primavera Project Planner
4	Project.net
5	Planisware 5
6	Projectplace

2.10 Factors Affecting Implementation of Web Based Coordination Systems

Reviewing the literature revealed some factors that can lead to high success of system implementation if they are well managed or to failure if overlooked and poorly managed. Some of which are listed below:

- Top management support. Top management support has been reported as the most critical factor that significantly contributes to the success of web based coordination systems (Chan and Liu 2007).
- Presence of an implementation leader: Studies concerning usage of web based systems showed the need for leader within the project and continuously promoting system implementation (Allen et al. 2005)

- Proper Training: Formal training with good explanation of all management practices used in the project is necessary for system implementation (Hjelt and Bjork 2007).
- Simplicity of use: System simplicity is one of the most important factors to system adoption and implementation (Mitchell and Demian 2008)
- System reliability. Reliability is an important component of the technical quality of the implemented system. If the system faces many technical difficulties users will quickly revert to others channels of communication, such as e-mail, phone, fax, etc (Andresen et al. 2003).

2.11 Challenges in Implementation of Coordination Systems

There are some challenges and issues that faced the coordination systems during their implementation. According to Laudon (2000), full benefit from coordination systems was affected due to; weak understanding and implementation of the user requirements, improper planning and management of implementation phases, and system resistance by users. Another challenge emphasized by Baldwin (2004), is the tendency of coordination systems for solving only short term problems without taking into consideration the organizational expansion strategy. While Sebastian (2009) showed that the competency level of the different project members and their capacity to organize the project procedures plays an important role in the effectiveness of the coordination systems applied. Coordination system providers' little or no background in construction may also represent a defect in the system implementation. Ruikar (2005) stated that a service provider must have a good understanding of an end-user's business tasks and problems to ensure the success of system implementation. System security was also emphasized to be one of the main concerns in web based coordination systems. Since the construction business is competitive in nature, most stakeholders are worried about the possibility of their online data being accessed and/or stolen by unauthorized users or competitors (Chan and Liu 2007). Another challenge is the inadequate computer experience of team members. Studies by Hjelt and Bjork have showed the significance of team members' computer experience and IT skills for successful implementation of collaboration tools in construction (Hjelt and Bjork 2007).

2.12 Factors affecting Assessment of Web Based Coordination systems

The assessment of a system in an organization depends mainly on how a project team can successfully employ specific WPCS (even for an ideal system with no technical problems) and achieve most of the system stated benefits. In order to start evaluation process for a system, the factors (technical and non-technical) that influence the performance of the system has to be identified as well as the measures that should be used to assess such performance. The most relevant factors and measures to our research scope are those done by Nitithamyong and Skibniewski (2006). The main groups of factors that are thought to affect the performance of the system are; characteristics of the project, project team, service provider, and system itself .These factors are used to assess the performance of proposed system from six important management improvement perspectives which are: strategic, time, cost, quality, risk, and communication. The project characteristics factor includes the following sub factors; Project location, Type of client, Type of contract, Type of project, Project size, Project value, Project duration, Complexity related to design and engineering, Complexity related to construction tasks, Starting stage of WPCS development. The Project team sub factors can be listed as follows; Project team characteristics Party deciding for the use of the WPCS, Internet access availability, Type of internet access, Presence of a champion, Prior experience with WPCS, Alignment of WPCS objectives to project objectives, User involvement during implementation planning, Top management support, Team attitudes toward WPCS, Team attitudes toward IT, Adequacy of training, Adequacy of resources, Ability of project managers, Computer experience, Frequency of WPCS's features usage. And as for the Service provider characteristics factor, it can also be divided into a number of sub factors as follows; Contact facilities, Promptness of responses, Attitudes of staff, Technical competency of staff, Knowledge in construction. And finally the System characteristics factor includes the following sub factors that will be used in the assessment procedure as follows; Type of hosting options, Number of users, Frequency of software/version update, Ease of use, Output quality, System reliability, Data quality and reliability, Data security, Integration among WPCS features, Integration with external software, Integration with team's internal systems.

Nitithamyong and Skibniewski (2007) listed a number of measures that can be used to assess the WPCS during implementation given in Table 2-3.

Table 2-3: Assessment Measures for Performance Perspective Factors:

No	Performance Perspective	Assessment Measures
1	Strategic improvement	• Helping in tracking project activities • Enhancing organization's image • Enhancing competitive advantage • Improving project team's computer literacy • Improving customer/supplier relations • Increasing capability for global corporation • Helping in attracting more sophisticated clients • Improving integration with other business functions
2	Time improvement	• Facilitating document transfer and handling • Helping in searching for files and documents • Enabling immediate report and feedback • Reducing response time to answer queries • Helping in preparing correspondence
3	Cost improvement	• Reducing number of faxes • Reducing number of postage and shipping • Reducing amount of paperwork • Reducing telephone usage and expense • Reducing travel expense • Reducing number of face-to-face meetings
4	Quality improvement	• Improving quality of documents • Facilitating forecasting and control • Easily identifying errors and inconsistencies • Reducing rework • Reducing number of design errors
5	Risk improvement	• Improving decision making of project team • Helping in conforming with contracts • Reducing number of claims • Reducing number of requests for information (RFIs)
6	Communication improvement	• Enhancing coordination among team members • Reducing bottlenecks in communications • Reducing barriers in communications

2.13 Summary and Conclusions

The use of Internet for exchanging information in a work environment has become very important and will be more in years to come. Industries such as construction that are interdependent and involve a large number of participants, information, and resources, tend to benefit from the use of coordination systems through better communication, easier retrieval of information, work collaboration, and management.

Using internet for project coordination is a sophisticated yet still a young market and continuously growing in diversity, quality and persistence over the years. There is a significant and widespread change that is being driven by the rapidly spreading adoption of web-hosted project coordination tools within the construction and engineering industries, leading to the creation of a strong relationship between coordination technologies and the construction business. Hence there is a continuous need for development of coordination tools and systems.

With the development of coordination systems, they shall eventually be used as the basis for a decision-making framework that facilitates strategic planning and implementation of working policies and protocols. Coordination through internet is still the ideal case for the construction industry since it is cheap, widely available, and not too difficult to use. It provides the best coordination solution to the construction fragmented nature.

Chapter (3)

3. System Modeling and Architecture

3.1 Introduction

This chapter is devoted to the development of a coordination model. The coordination model takes into consideration some important needs that have to be satisfied to create a fully integrated model that solves most of the challenges faced. The main coordination model is an integrated compromise between different sub-models each of which answers to a certain challenge and solves an implementation problem. There is a big need for a model to relate to organizational strategy as well as the short term plans and projects and hence the organizational strategy sub-model is created. There is also a need to create a flexible model that relates to the needs of the users and continuously takes their requirements into consideration and hence the documents categorization sub-model is also created. Another two sub-models are created to tackle the challenge of construction data fragmentation and quick and ease of access to such data. These sub-models are active standard documents sub-model and documents' hierarchy flow sub-model. To satisfy the need of the simplicity and the easiness of the future coordination system, project technical categorization sub-model documents categorization sub-models are added to the main model as well. Each of these sub-models alone tackle some problems, however collectively all sub-models combined together solves challenges and creates an integrated main model.

3.2 Developed Model Components

The model consists of a number of sub-models with different concepts combined together as shown in (Figure 3.1). The model starts from implementing an organizational strategic sub-model to gather people and business with available technology. Then using this available technology to develop a hierarchy sub-model through which active structured documents are used for project monitoring purposes. These active documents are used in a flexible information flow sub-model that improves the communication process and ties between multiple professional disciplines involved in the construction industry. An Internet/intranet sub-model is used as a media through which information flow is conducted. Construction technicality sub-model is introduced to allow for the use of intelligent construction documents whether were they categorized under a project or just used inside the organization in a general sense. Project technical categorization sub-model gives six standard divisions for each project. These six divisions constitutes the heart of the proposed project coordination process; general project coordination, contract coordination, communication, site coordination, design coordination, and reports center. Under the document categorization sub-model, each division branches into many standard intelligent documents to allow for flexibility of adding new user defined requirements and hence proper monitoring, updating and integrated alerting system.

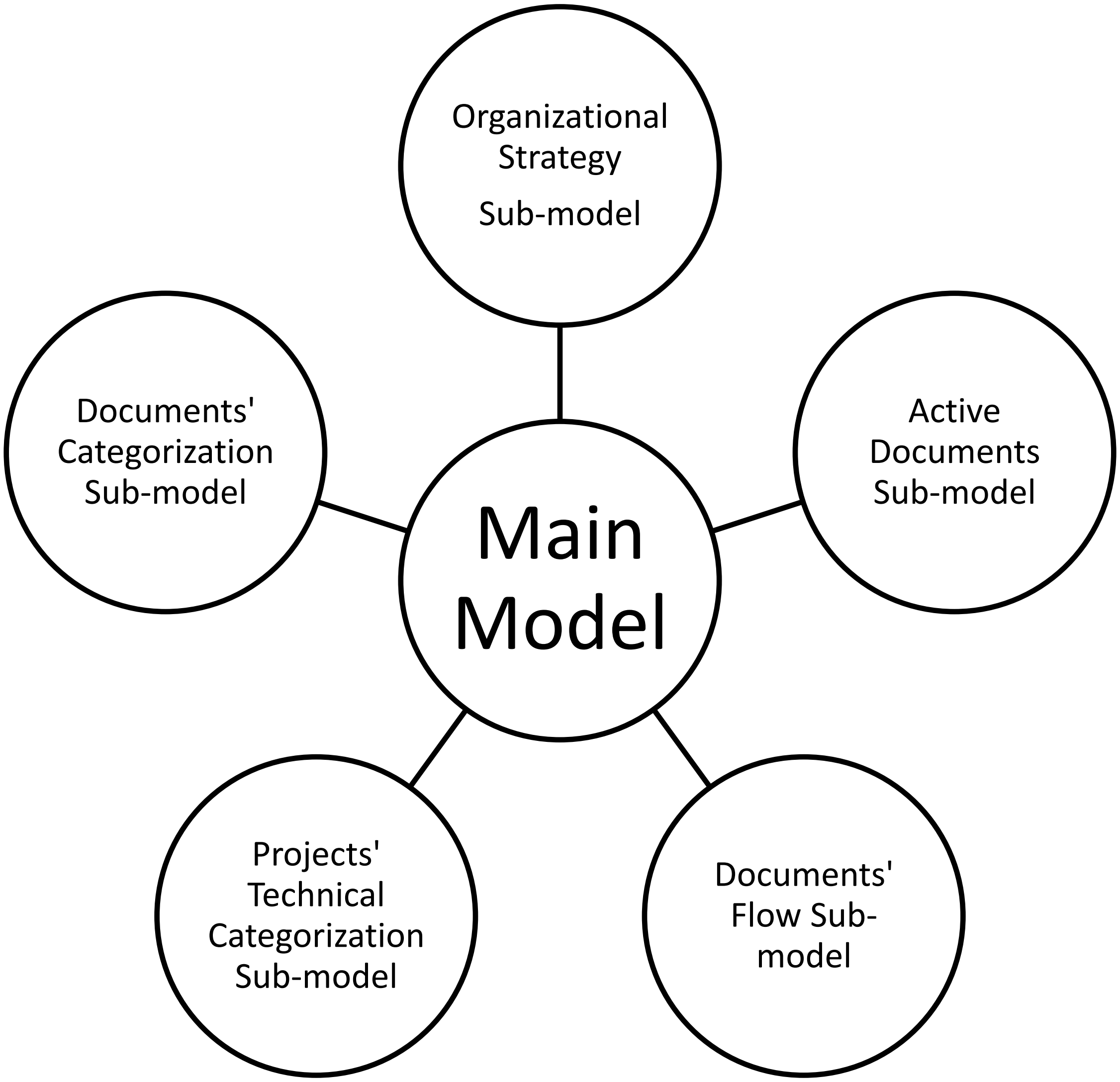

Figure 3-1: Main Model and Components

3.3 Organizational Strategies Sub-model

The objective of organizational strategies sub-model is to reduce document fragmentation, duplication and doubt about activities information. This is achieved by intelligently using available resources, enhancing staff and organizational motivation and bringing together the three strategic areas of business, people and technology. Figure 3-2 shows the alignment of these three strategies in the sub-model design.

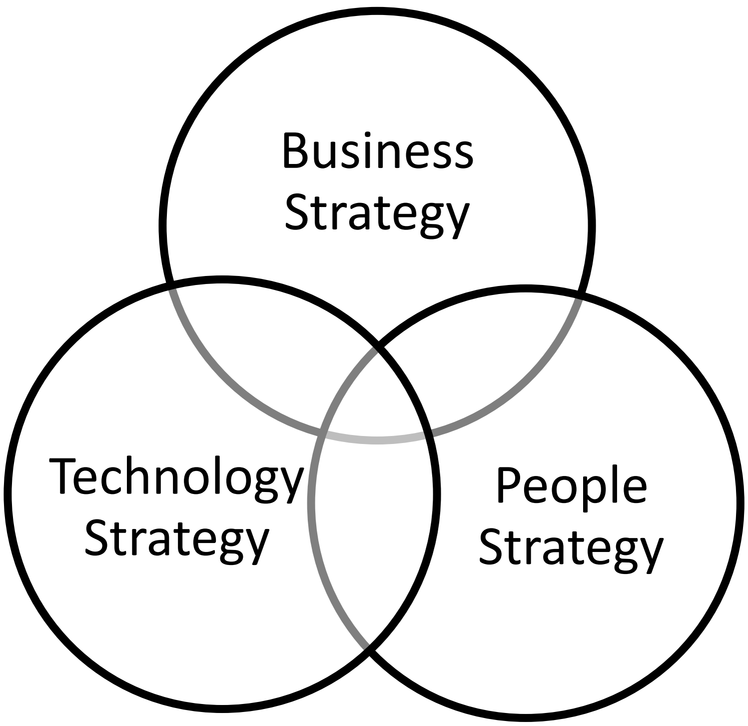

Figure 3-2: Organizational Strategies Sub-model

This sub-model design enables participants to build capacity to complete a set of tasks that their organization would find difficult to achieve without such a model. This sub-model combines organization business, the people resources and the technology used to form the enterprise project structure for such an organization. The enterprise project structure within this sub-model allows for business strategy to be fully implemented and for the future system to be unlimitedly expandable. The advanced communication structure of the model allows for stakeholders to be fully engaged to ensure that all key strategies shall be employed during the coordination process. The technology of the model will automate the process of coordination between all key participants and monitor the work on a day-to-day basis

3.4 Active Documents Sub-model

The search for information means quick access to required information; searching for valuable information in various documents, synchronizing related data in different documents to form an alerting and monitoring scheme used for decision making. One of the main milestones of this model is to reach the objective of creating an active document. Active document can be defined here as a document that has a standard form identical or very much similar in its fields to other documents in various international organizations concerning the same subject. Creating these standard fields give the model a way through which these documents can be intelligent when connected to any alerting mechanism in creating the future system. Each document in each project has the capability of having a unique alert designed according to the situation of each project and thus making the follow up, alerting techniques, tasking, and monitoring means more advanced and intelligent.

The value of the documents is not that it has a lot of words representing information but that it has a lot of information that can be easily used. The more simple and standard documents are, the better it is. These active documents were developed by creating certain fields that contain related pieces of information in order to make the document more informative, standard and intelligent. Accordingly, any user that has the permission can retrieve or call upon any documents by using these standard fields.

Each and every document has some fields different than other documents, but there are main fields that are available in all active documents as follows:

1. Project Name
2. Project Serial Number
3. Project Code
4. Document Number
5. Document Date/Opening date
6. Close date
7. Document Status
8. Document Subject.
9. Document Creator details
10. Document Action by
11. Document Body
12. Document Version Code
13. Document Reference Number

These elements are found in all documents to control and coordinate such documents and perform monitoring, follow up procedures or any other actions through the model. These elements are considered as an identification card for each document making them active documents that can be send as a task or to another entity as a message or even can be send to a printer. Since each document is connected to a number of dates associated with certain information about the document such as creation date, required due date, closing date, opening date, approval date and today's date, therefore intelligent information and alerting is setup through comparing today's date with all other associated dates. This comparison will result in a number that is the basis of an online monitoring and tracking mechanism changing normal documents to intelligent and active document. Figure 3-3 illustrates actions of active document.

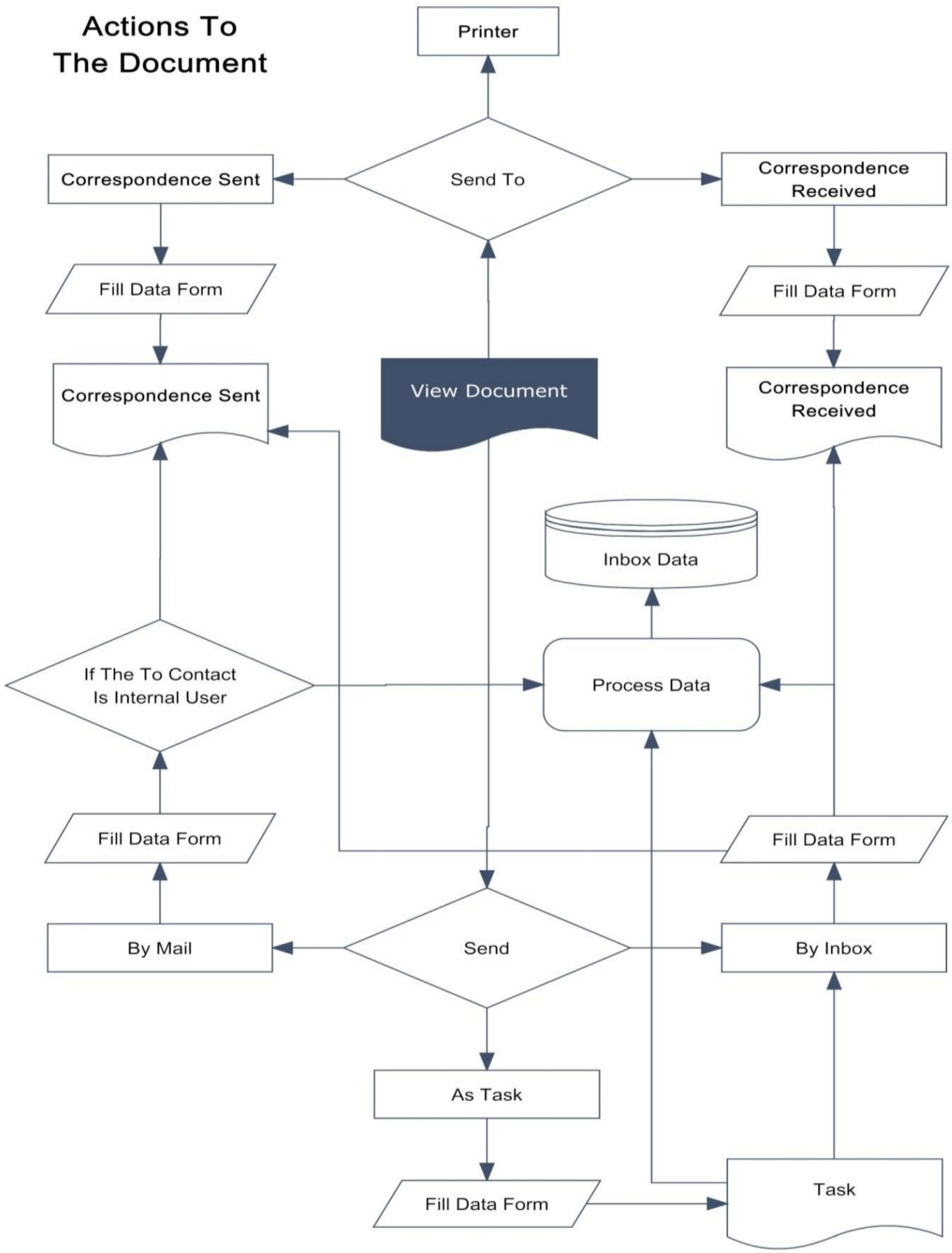

Figure 3-3: Active Document Actions

The main difference between traditional, inactive documents and active documents in the model design is that active documents were given a different structure. The active documents are connected to the system database through many fields that are interconnected by an alerting mechanism for each document in each project. These alerts change the property of a traditional document into an active documents that automatically update the future system dash boards after each new calendar day and gives automatic alert when appropriate to all or selected number of system users.

3.5 Documents’ Flow Sub-Model

In construction projects, a massive amount of information is created in unstructured documents and hence coordination of such documents presents some challenging issues related to their use. In the process of coordination of construction documents related to a particular project or any of its specific components, the intent is to arrange all the available information about any specific component into a comprehensive interrelated set of data.

Documents’ flow sub-model is designed for linking all construction documents with each other by utilizing available internet technology. The objective of this sub-model is to convert traditional, unstructured and inactive documents into structured active ones that can be used for coordination, monitoring, alerting, and searching purposes where it is accessible for all project team members. Figure 3-4 shows how this transformation is done by taking the active document created in the previous sub-model and stores it into a central depository accessible on the internet

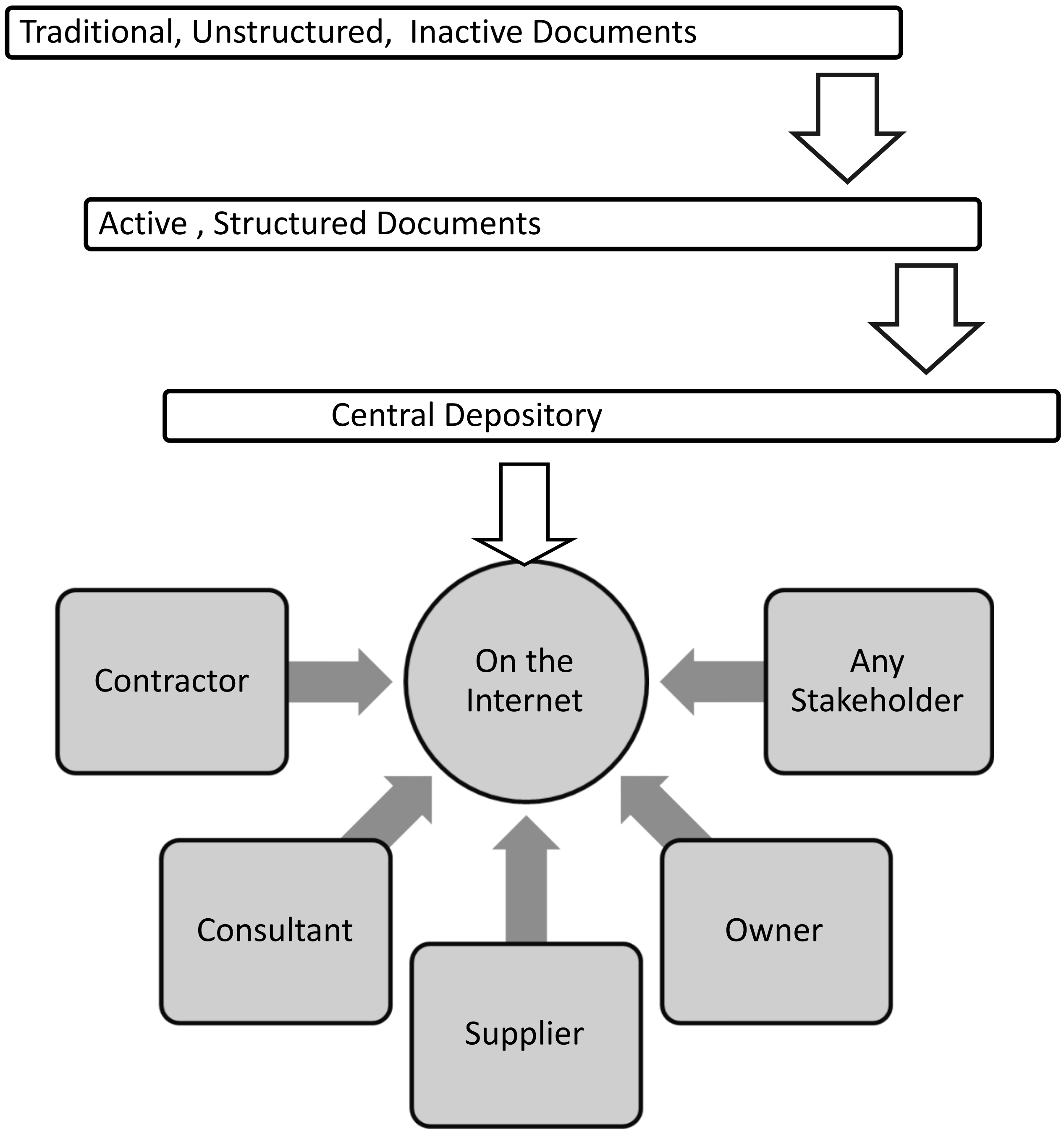

Figure 3-4: Documents Flow into a Central Depository on the Internet

The need for appropriate project information inside each document type is extremely important because regularly the information in one stage of the project is the basis for creating new piece of information in another stage. It is also crucial that this information be accurate, ordered and structured in such a way that facilitates easy retrieval and reuse.

The sub-model objective is to enhance quality and intelligence of construction documents and then make them a portal for monitoring, follow up and coordination of project components in a way that allows users to combine and share documents inside the project. This sub-model develops an easy mechanism for organizing construction documents with accurate information for various project components, which are active, interrelated and easily retrieved in different representation and reports. These documents are the most valuable resource because information is stored within, easily reached by different links and distributed for stakeholders and continuously evolving through the cycles of the same project.

3.6 Projects Technical Categorization Sub-model

There are key construction technical categories that are considered to have a wide affect on the coordination process, and accordingly were used as the basis for design of the model. These categories include people, communication, cost, time, quality, claims, issues resolution, performance and contract relations and others.

These categories can either be divided into sub-categories or grouped together to create one or more form of coordination concepts in construction projects according to practicality of the construction industry, simplicity of use, similarity to widely used models and systems, type of information, location, frequency of usage, discipline of information, etc. The model gives freedom to each organization to create unlimited number of these categories under each project. The sub-model using these technical categories gives each active document in the model a standard parent, and hence each document in the project is related to a specific work category. For example; schedules are related to general coordination, change orders are related to contract coordination, daily reports are related to site coordination, drawings are related to design coordination, and requests for information are related to communication

Figure 3-5 shows how the model automatically divides any project under the company six main technical categories as follows:

1. General Coordination
2. Contract Coordination
3. Site Coordination
4. Design Coordination
5. Communication Coordination
6. Report Center

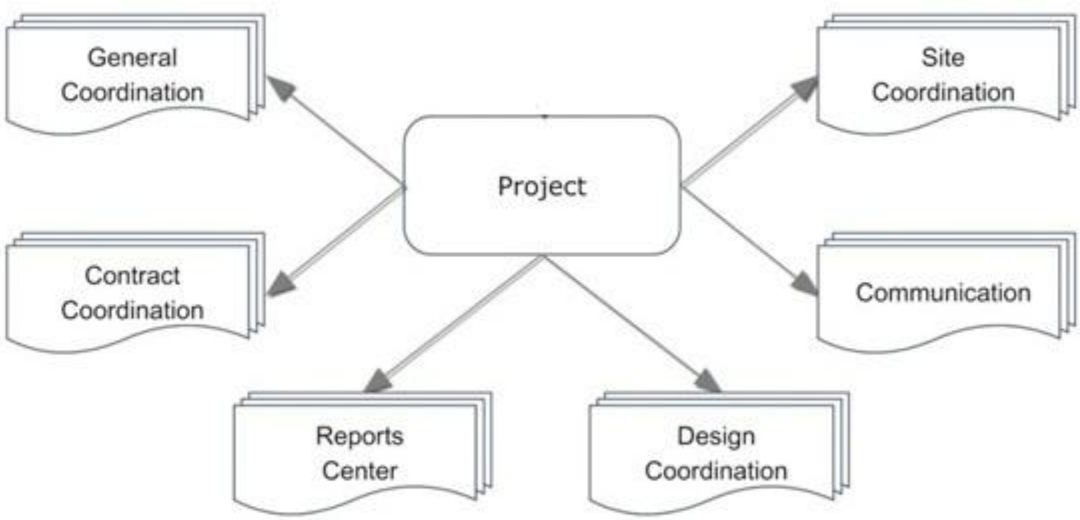

Figure 3-5: Project Coordination Main Categories

In the event of creating an active document it shall fall into a unique category in this model. This unique category has two major characteristics. First, it is company and project related and therefore allow for the created document to follow and be part of a specific company and/or project. Second, the document has a general standard form to give practicality of usage. In that essence, the active document shall be part of two not similar categories at the same time. The model design introduced a flexible tool to create a tree of all company related structures ending with a specific project as a first step. Inside this project and as a second step, the standard more general set of documents will then appear to be used within.

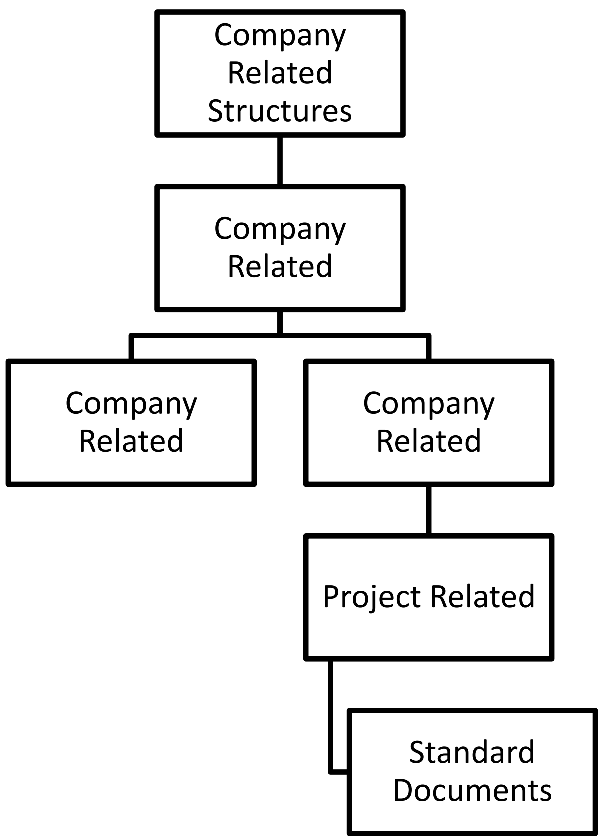

Figure 3-6: A Model for Combining Categorization of Company Related and General Standard Industry Documents

3.7 Documents Categories Sub-Model

In this sub-model standard and active documents are modeled according to common standards of the construction documents in the engineering industry as illustrated below:

General coordination category contains active standard documents that are related to the project as a whole and have no relation to the contract, site, or design information Examples of such documents are:

a. Project information
b. Companies information
c. Schedule information
d. Tasks information
e. Organization chart of the project
f. Issues arising in the project
g. Header and footer for documents in the project

On the other hand, contract coordination contains active standard documents that are related to the contract administration of the project such as:

a. Bill of quantities
b. Cost Breakdown structure
c. Cost coding of BOQ
d. Purchase orders
e. Contracts
f. Invoices
g. Payment requisitions
h. Proposals of change orders
i. Change orders

Figures 3-7, 3-8, 3-9, 3-10 and 3-11 show how these active documents are involved in multiple actions with other documents in the model. They also show how all these documents are categorized under each project and then under each technical category. Simplicity of the model is maintained by duplication of actions under each category; for example; the schedule as an individual document under the technical category of the general coordination can be logged, viewed, edited, sent, printed, and transferred to a task and many other actions. Following the same scheme other documents such as contracts in the contract coordination technical category or requests for information under communication category are treated the same way. Each document category under the technical category acts as a central depository for other documents from the same type under the same project. This sub-model will facilitate different parties accessing chosen document categories under chosen projects with chosen actions to be done for each active document.

More close coordination and interrelation between documents exists under certain technical categories such as the contract coordination as illustrated in Figure 3-8. Contracts are closely related to payment requisitions, and change orders are closely related to proposals of change orders and contracts, while bill of quantities are closely related to cost coding and contracts. These interrelation creates a sense of unity between all active documents and information can be accessed and view in different layouts and presentations.

The same concept shown in Figure 3-11, which shows the interrelation between design resource team members and the drawing list allocated to each one. This relation allows for the proper allocation of design drawings to any design member in the resource pool. After the allocation of resources the model allows for tracking and monitoring design performance for each drawing under drawing list

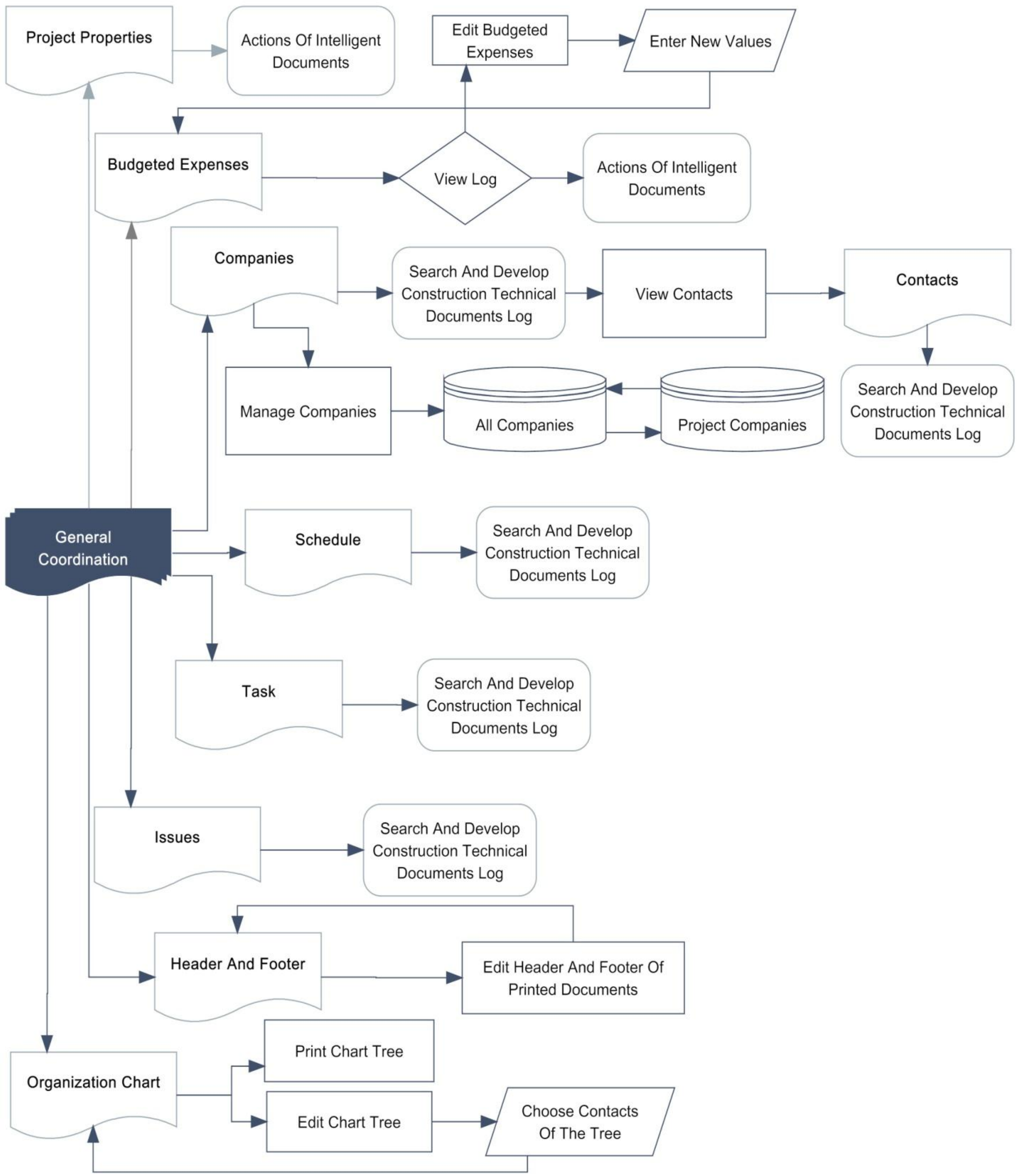

Figure 3-7: General Coordination Active Documents

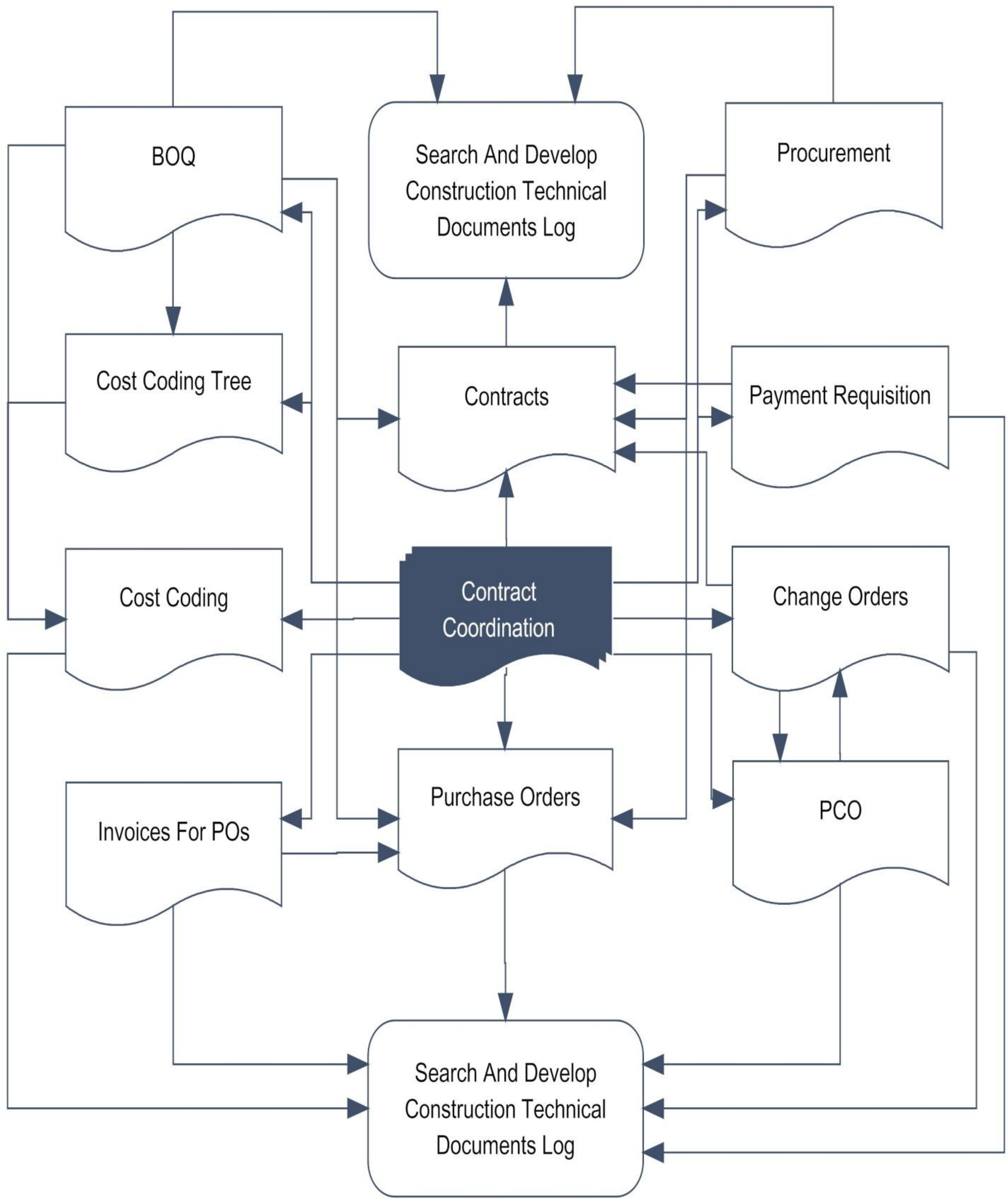

Figure 3-8: Contract Coordination Active Documents

The third category is the communication coordination, under which goes all communication related active documents as shows in Figure 3-9:

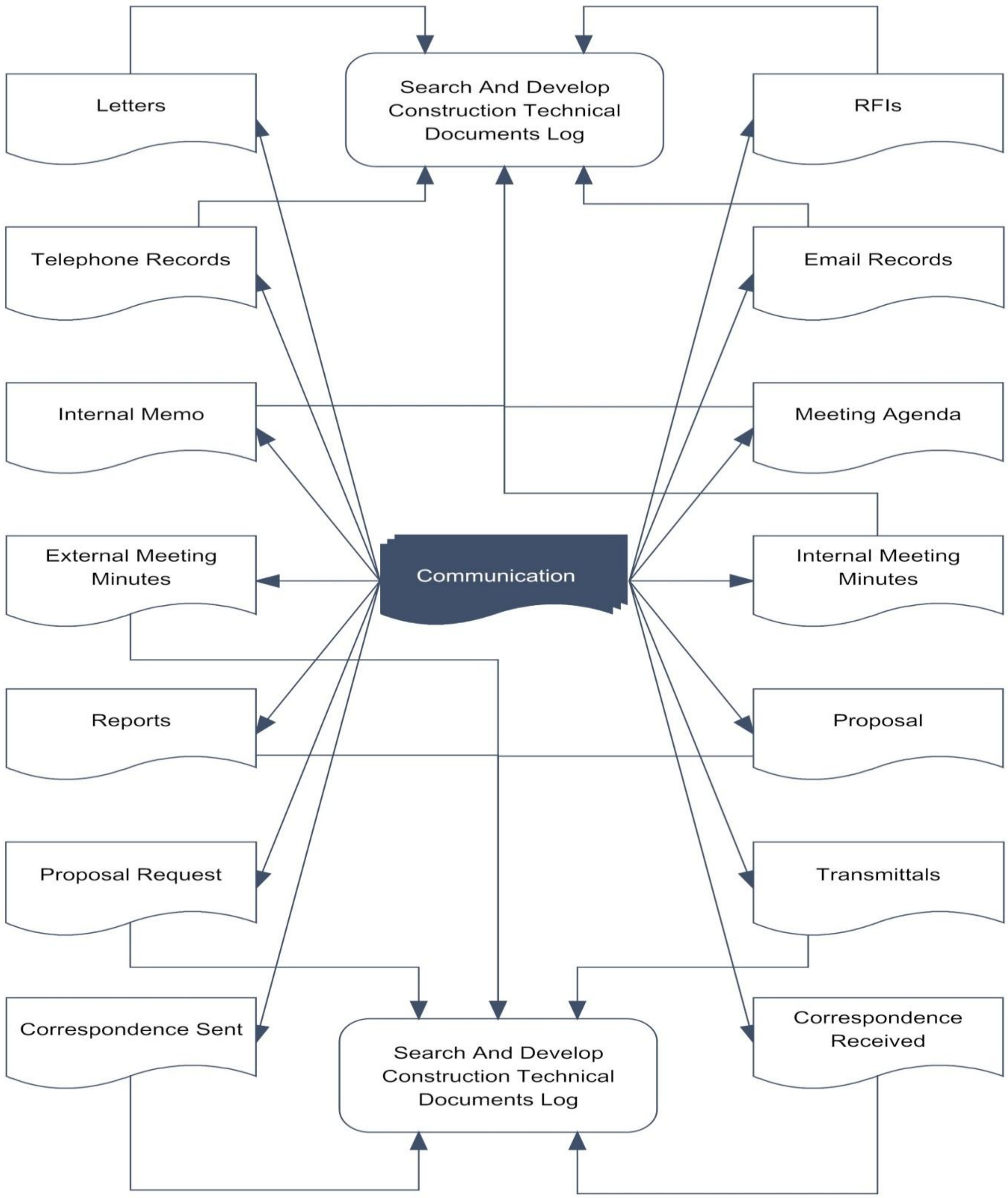

Figure 3-9: Communication Coordination Active Documents

The fourth subcategory is site coordination created under each project and it consists of the following interrelated active documents:

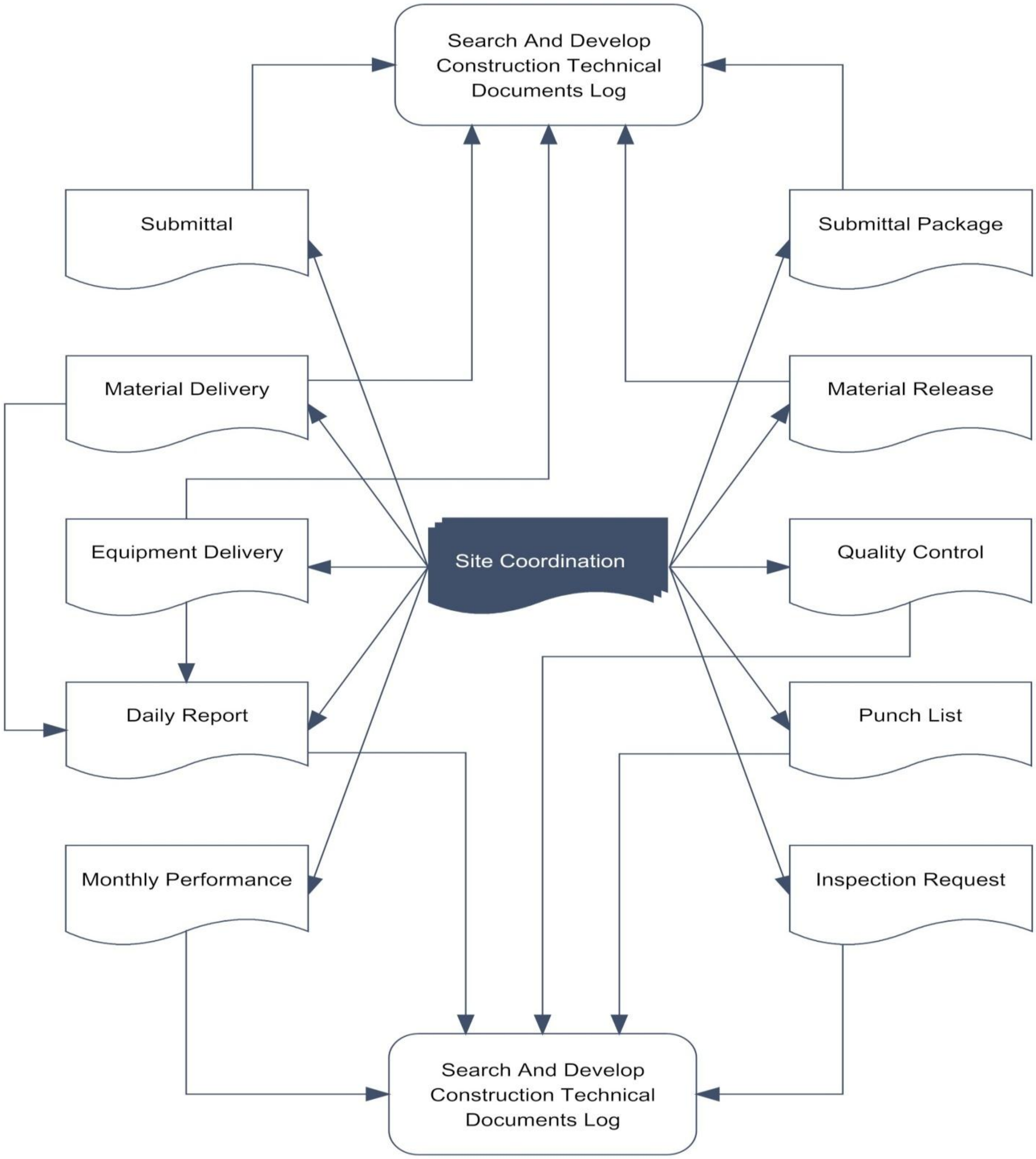

Figure 3-10: Site Coordination Active Documents

The design coordination subcategory contains the active documents shown in Figure 3-11.Finally the report center includes reports specifically relating to this project.

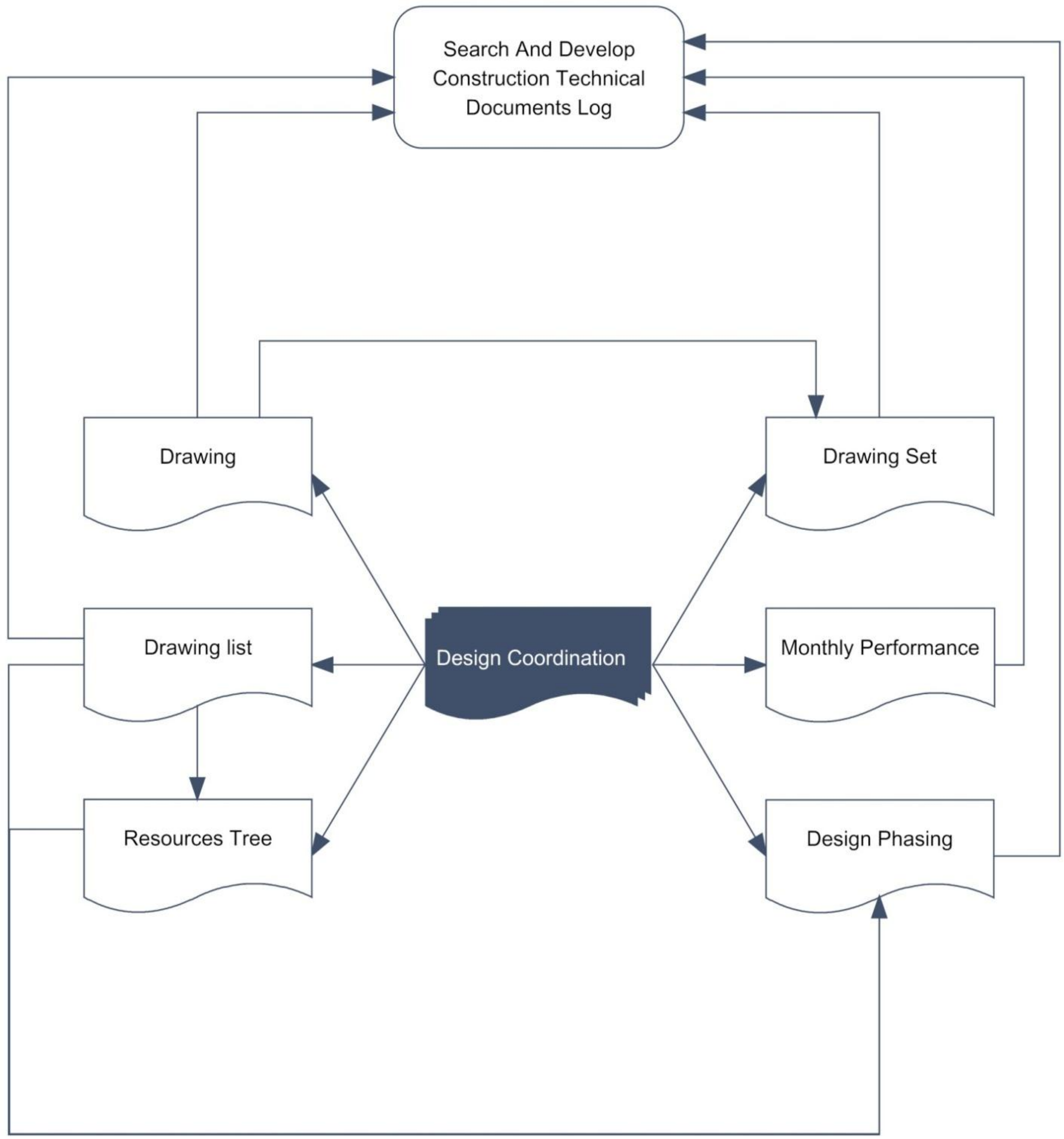

Figure 3-11: Design Coordination Active Documents

3.8 Summary and Conclusions

System modeling corresponds with and supports the project team’s strategy and business needs as well as technology strategies. The responsibilities of the people and the documents work flow are defined to create an advanced model based on structured, active documents to facilitate automated tracking and monitoring techniques. The model forms a frame work that aids the smooth flow of information within the construction technical categories. Document categories allow for standardization of different unstructured construction document and their availability and continuous ease of access. The model takes into consideration the interrelation between active documents within the same and/or different project, technical category or document category. The main model combines all these sub-models together in one integrated model that tackles all challenges of implementation

Chapter (4)

4. System Development

4.1 Introduction

This chapter discusses system development based on the literature review in chapter two and the modeling concepts discussed in chapter three. The system is developed into central SQL database with interconnected relationships between all active documents. The system tackles such network of relation using a web browser and web-based application equipped by permissions for each user to limit or extend his ability to maneuver active documents within each project. The developed solution is customizable to allow for personalized interfaces and customizable to projects, which means it is suitable for all kinds of projects varying in size, type and degree of complexity. The framework of the solution is also compatible with the upload of any application extension and compatible with major engineering software such as Primavera, Microsoft project and Excel. The development allowed for complete document management through uploading, downloading and automated log creation.

The main modules of the system are developed in a way to overcome common nature of data fragmentation in the construction business. Coordination among various participants throughout the construction process is developed within the system using macro and micro modules. The exchange of information between project players is developed in an advanced intelligent standard form. The system takes into consideration different involvement and backgrounds of different users as well as different phases of the construction industry with login and access right features.

4.2 Implementation Media

System programming starts by creating a database designed for the model needs supported with a user-friendly interface with a user permission system, and also stable static Internet connection to ensure reliability and security.

The Language adopted in programming is the ASP.net, an advanced programming language that facilitates interactive interface and supports powerful databases, thus requiring relatively low resources. ASP.net is a widely used source scripting language that is especially suited for Web development with database applications. The advantages of using ASP.net are the capacity to be embedded into HTML and to enable Web designers to write Web pages relatively quickly. The greatest advantage in using ASP.net is that it offers many advanced features for more sophisticated programmers and web designers to accommodate our model special needs and specific requirements. One of the most important special requirements is to make the whole construction coordination process strictly online with no downloading required.

Another advantage of using ASP.net is its compatibility with many operating systems such as Linux, Unix, Microsoft Windows, MacOS X, and RISC OS. ASP.net can also be supported by many Web servers, such as Apache, Microsoft Internet Information Server, Personal Web Server, Netscape and iPlanet servers, and many others. Therefore, the use of ASP.net can provide freedom of choosing an operating system and a Web server. Furthermore, ASP.net can be supported by a wide range of databases, including SQL, Adabas D, dBase, Oracle, and Solid. With all these advantages, ASP.net was selected as the programming language leading to the final database sub-model.

4.3 System Database

To support the use of ASP.net in constructing a database, a structured data collection and retrieval system was used. The well known Database ‘SQL’ has been used. It is one of the most popular Database systems, being designed for velocity, authority, and accuracy in operation critical, heavy load use applications.

SQL is a relational database management system that stores data in separate tables rather than putting all of the data in one large store space. This helps advance speed and flexibility. SQL is ready software, available for use and adjustment to suit different projects. The following list describes some of the key characteristics of the SQL database software.

1. Security: the password system is very flexible and protected, and allows host-based verification. Passwords are secured by encrypting all password traffic connected to a server.
2. Database Limitations: SQL can handle huge databases, with some databases capable of handling millions of records, tables, and rows.
3. Connectivity: customers have the choice of connecting to the SQL server by using TCP/IP sockets, Unix Sockets (Unix), or Named Pipes (NT) and other means.
4. Stability: Consistent evaluation of the SQL occurs to ensure bugs are strongly monitored and fixed in the latest version.

4.4 Centralized Data Center

The key requirement for any improved communication process is coordination of information exchange. The system developed an improved communication process that meets different needs of multiple professional disciplines involved in construction process. This system will not only embark upon communication and information sharing during the actual construction of the project but also, the information exchange as a process of transferring information from one project member to others. It is based on evolving IT facilities of the Internet, World Wide Web (WWW) in connection with central database technology. The proposed framework is shown in Figure 4-1.

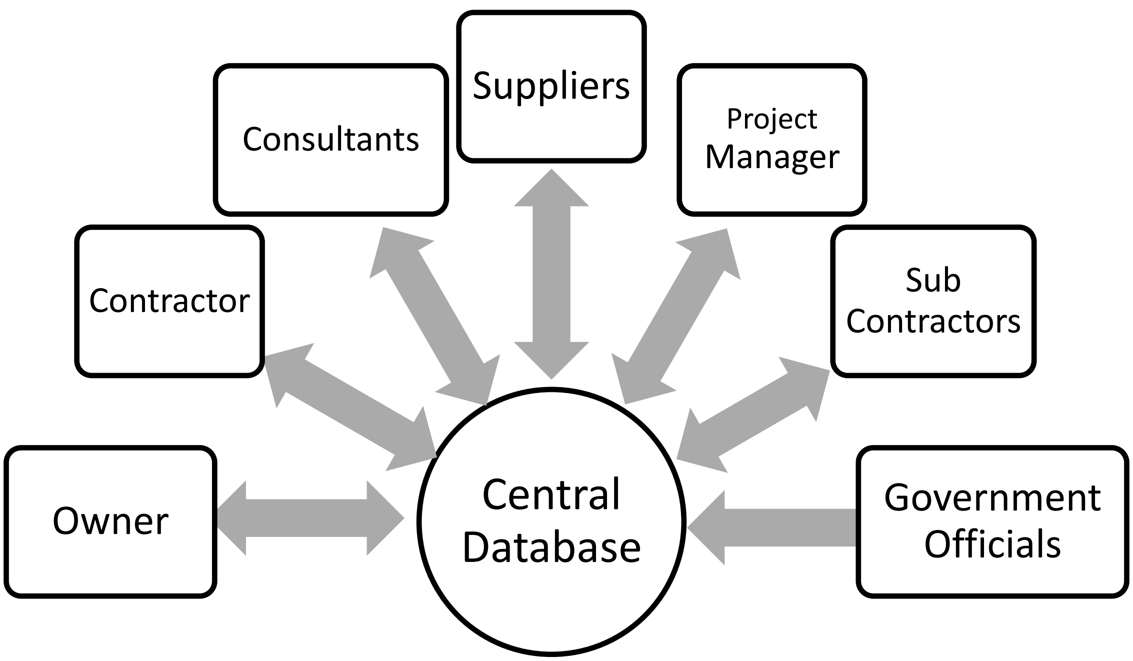

Figure 4-1: Improved communication process through a central database

4.5 Internet/Intranet Coordination framework

The system is coordinated between both Internet/Intranet mediums as shown in Figure 4.2. It consists of a web server containing user interface, which is setup as a web Browser. The web server contains a central SQL Database storing both project and general information. The client side of the system consists of any available computer workstation, which contains an internet browser and Internet connection. The browser allows certain documents to be viewed by the user according to a set of permissions in the central database. The user interface is a very simple regular website with a set of web pages, menus and buttons, which enable the user to create, edit, delete, retrieve data to or from or through the central database and into another entity.

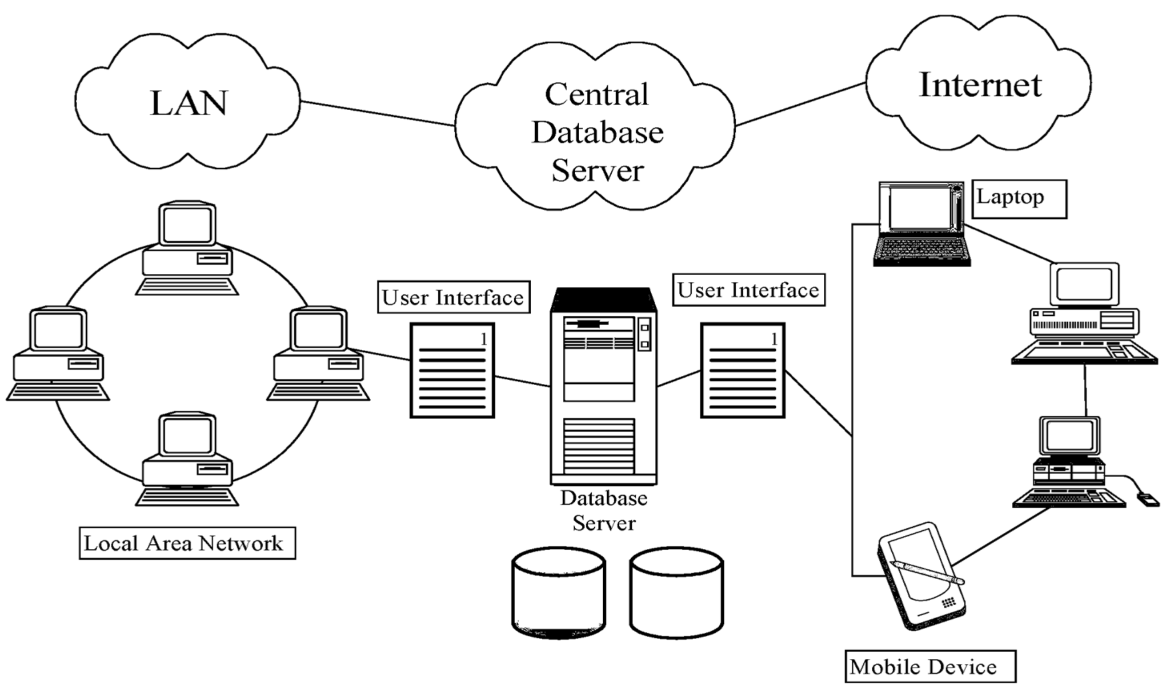

Figure 4-2: Framework for Internet and Local Setup

4.6 System Architecture

System architecture consists of two main sections: Project Based and Company based. Therefore all the modules of the system interface are divided into two main categories to cope with these two sections as shown in Figure 4-3. The first Company category called here as the macro section consists of all the data related generally to the company and/or related to some or all of the projects. This category includes general inbox, human resources related features, enterprise project structuring, general projects settings, accounts configuration, general reporting, summary dashboard and logout features. The second project specific category or micro contains all project directly related features. It consists of the system six main modules; general coordination, contract coordination, site coordination, design coordination, communication and report center. These two categories are interconnected together through the development of database and programming framework. All macro modules are positioned at the top of the webpage while all micro modules are positioned inside each project at the left hand side of the webpage allowing user friendly interfacing throughout the system.

Illustration of the macro and micro features and their webpage positions is shown in Figure 4.3

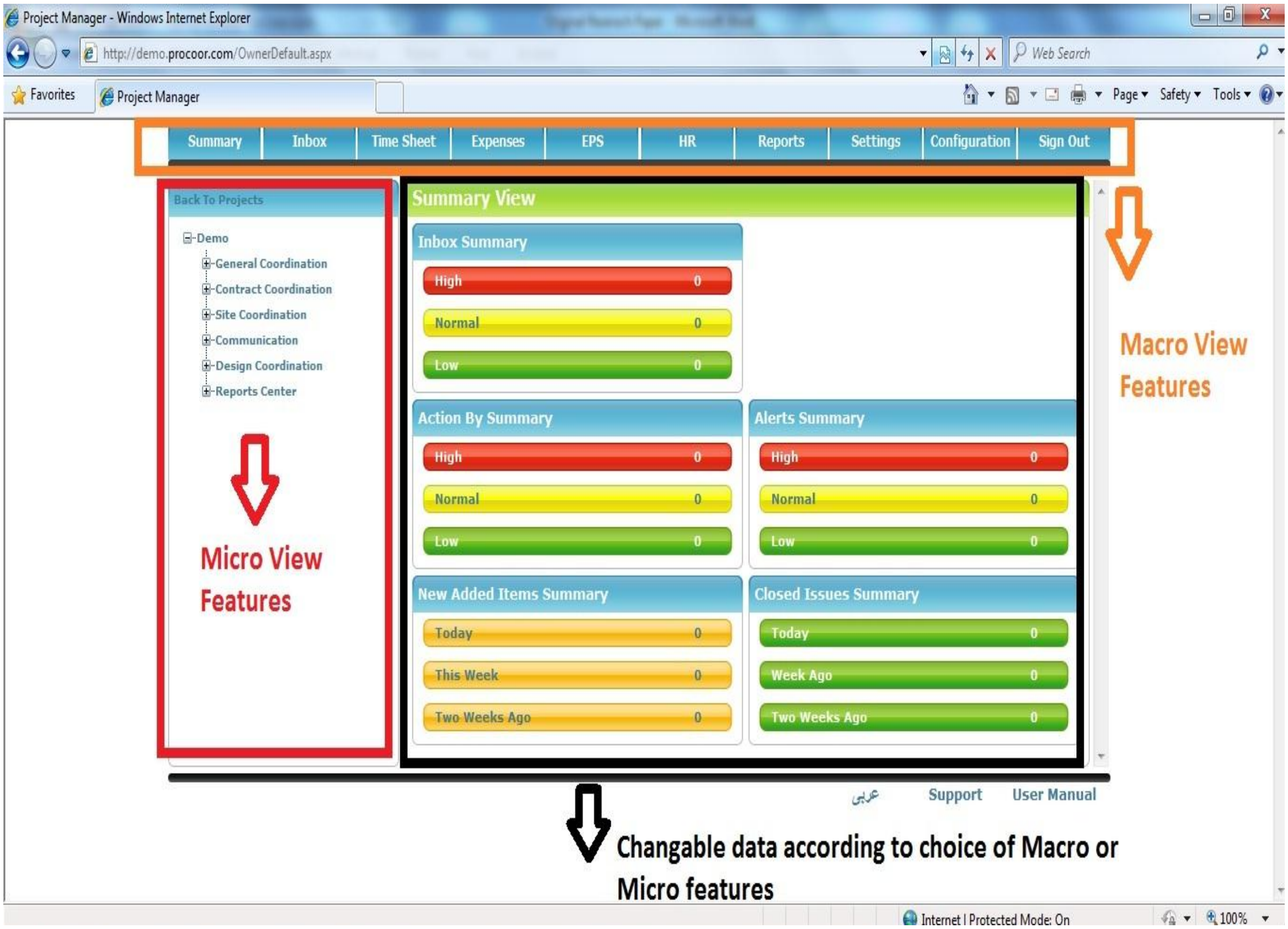

Figure 4-3: Macro and Micro Modules

4.6.1 System Macro Modules

The macro modules are typically related to any data that is not project specific. This type of data may include messages inbox that gathers all messages from different projects in one central inbox categorized by priority. A combined task list is also developed as part of the macro features as it includes all tasks related to the user in all projects. This macro feature makes it very easy for each user to follow up and track tasks on a very timely manner. Enterprise project structure feature is a company convenience feature and customizable in lieu of the structure and the strategies of each company. Reports are also an important module of the macro level. Some reports are default in the system while all others are customizable and accordingly implementing the needs of the client to get the full system benefit during implementation.

Figures 4-4, is an example of macro inbox messaging module divided into high, medium and low priorities. This function relates to the organization as a whole and not just to an individual project

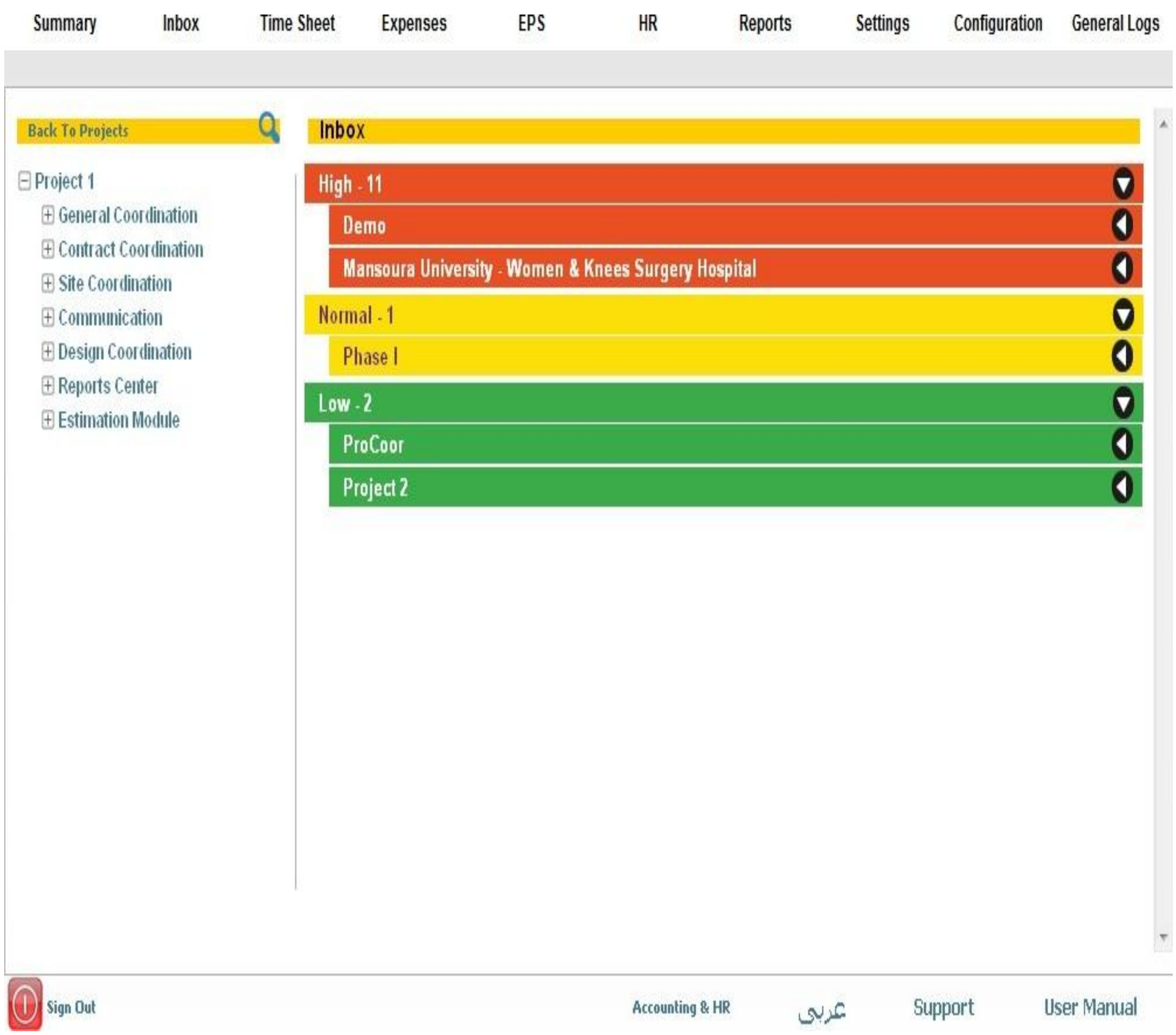

Figure 4-4: Inbox Items by priority for each project

4.6.2 Project Micro Modules

There are six default modules in each created project, representing four important categories: tasking and workflow management, document management, site, contract and design coordination through effective team Communication, and reporting. Figures (4.1 to4.5) illustrate the main components of each module of the first five modules. The sixth module is the report center which is designed to be customizable and different from each company to another and hence overcoming user resistance by attending closely to their requirements.

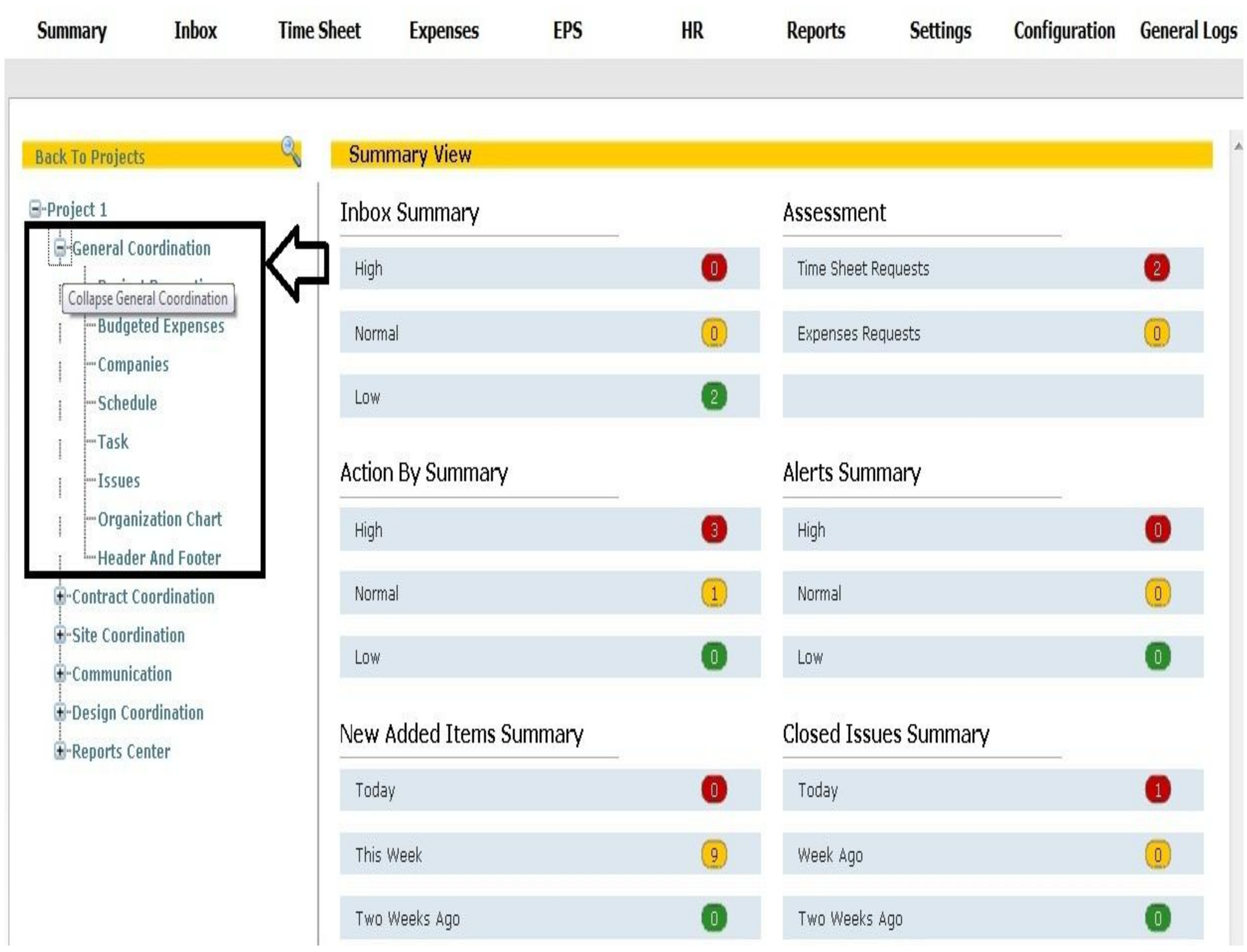

Figure 4-5: Module 1 (General Coordination)

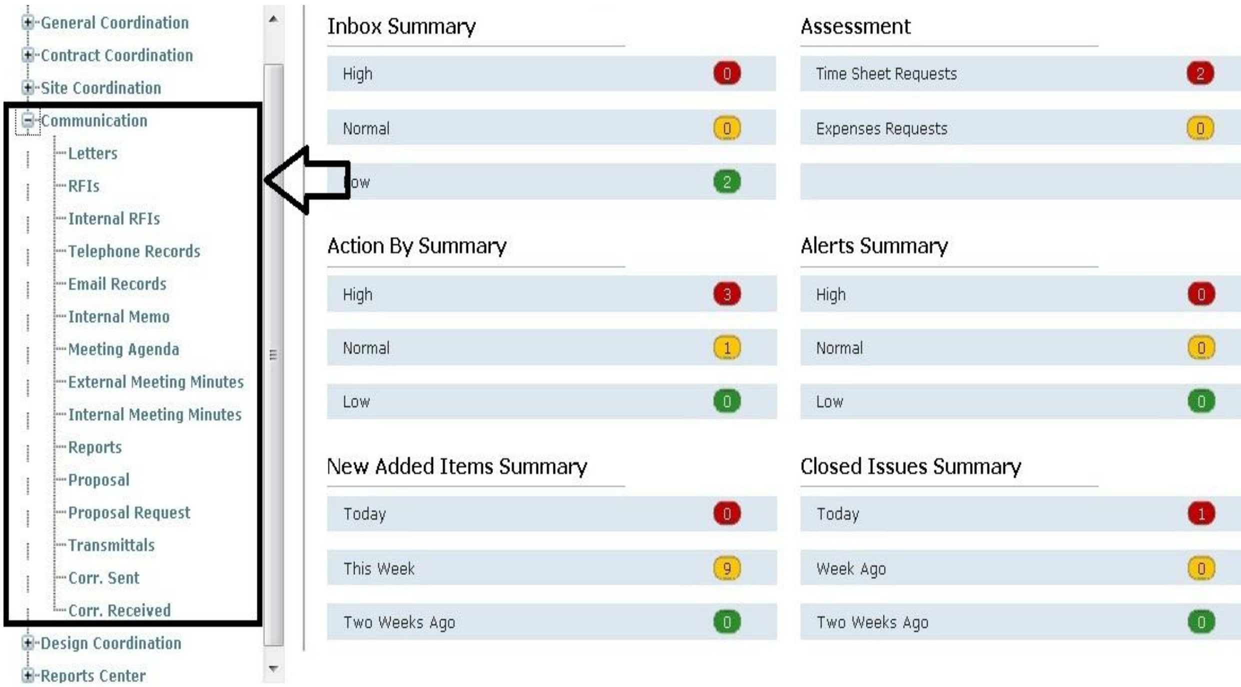

Figure 4-6: Module 2 (Communication)

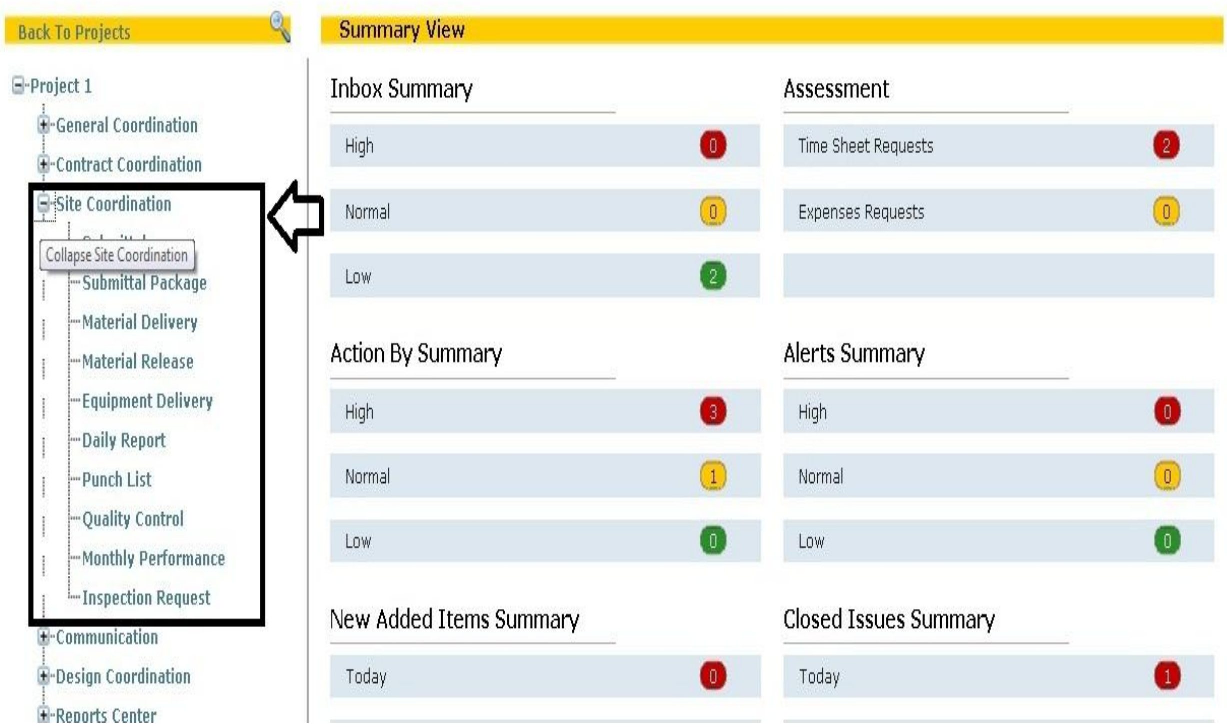

Figure 4-7: Module 3 (Site Coordination)

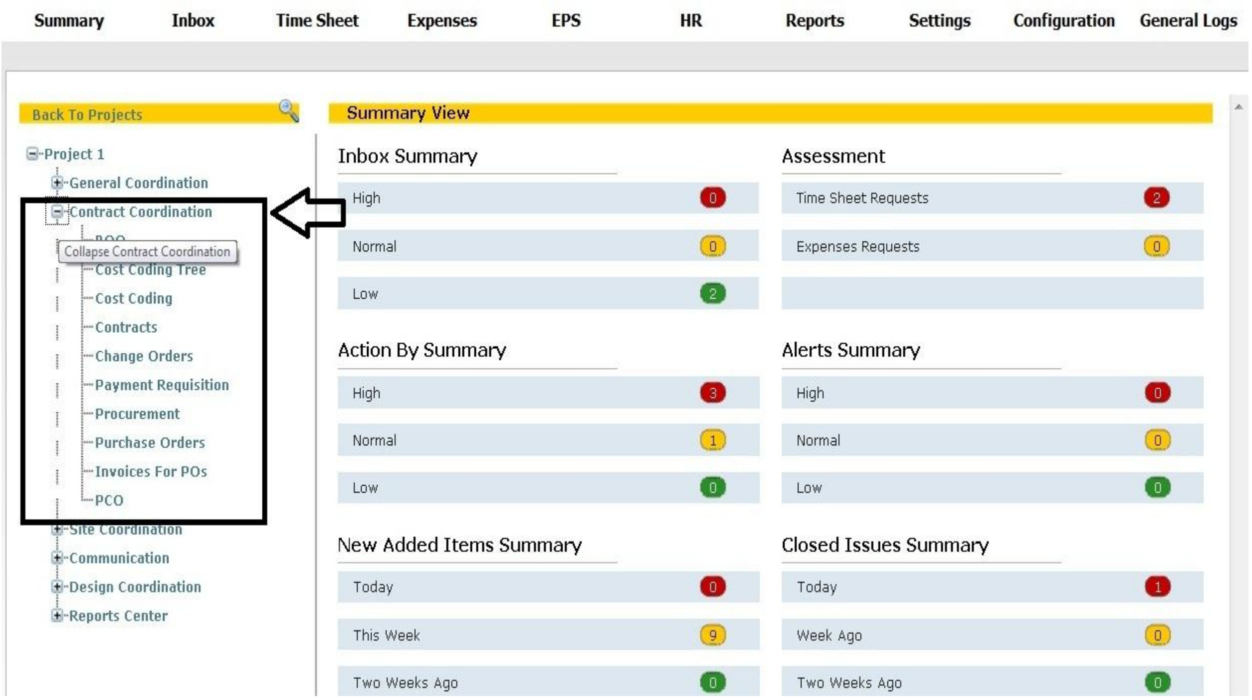

Figure 4-8: Module 4 (Contract Coordination)

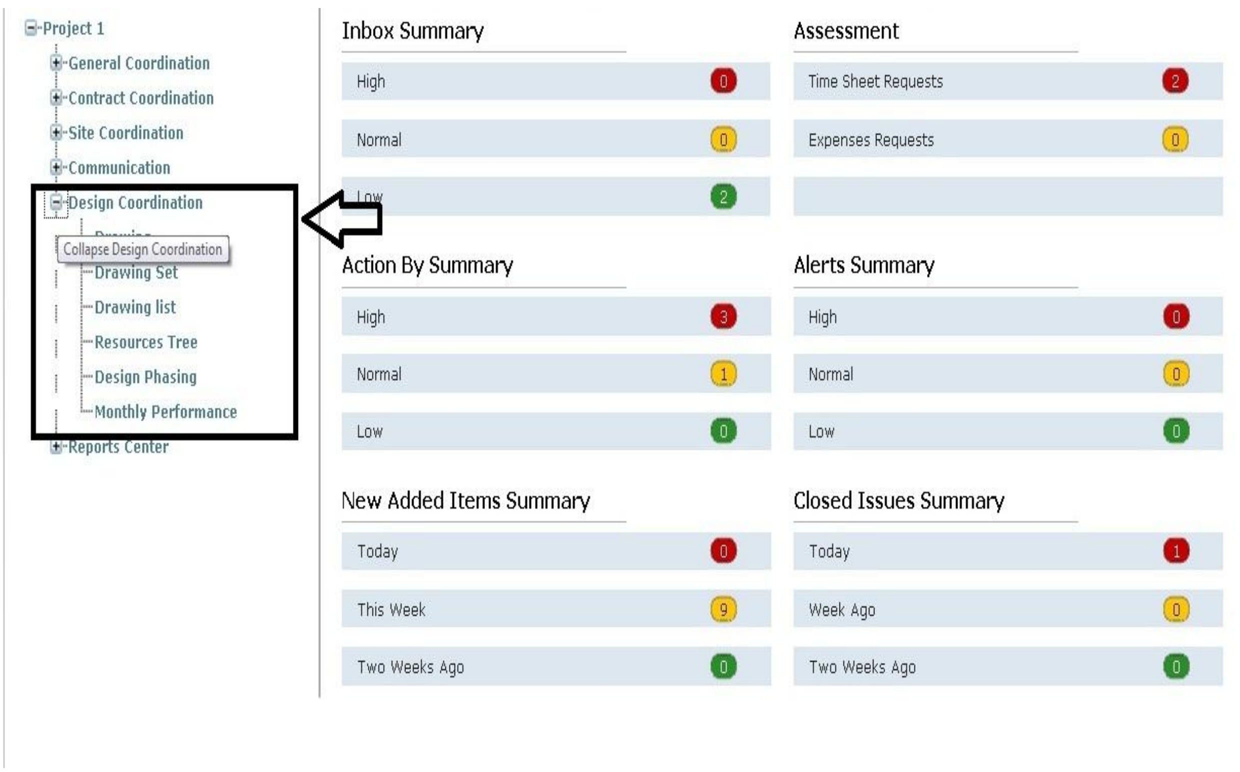

Figure 4-9: Module 5 (Design Coordination)

4.7 System Features

4.7.1 Login and Access Rights

As a development of Internet/Intranet coordination sub-model illustrated in section 3.6, the system allows connection through both local network setup and internet hosted setup. The only difference between connecting through the internet and connecting through a local setup lies in a special arrangement of the IP address inside the system server. This arrangement will allow local users to connect to the database through a local IP address that does not exist on the internet, while external users will connect through the database by using a normal HTTP website name, which is (demo.procoor.com) in our case. The connection will be made through any normal internet browser using a login page prompting for username and password entry. In order to support security of the system no access to the system will be allowed without using the encrypted credentials of each user

4.7.2 Enterprise Project Structure

As a development of the organizational strategies sub-model illustrated in section 3.2, the system should be customizable to persons and projects; scalable according to construction project size and level of IT infrastructures in the companies; and extendable enough to allow project participants to define a tailor-made solution that fits their company and projects structure.

Therefore a feature called Enterprise Project Structure (EPS) is developed to allow for customization of each company structure and extension of their projects tree.

Figures 4-10 and 4-11 show EPS and how easily it can be tailored and customized to any company needs.

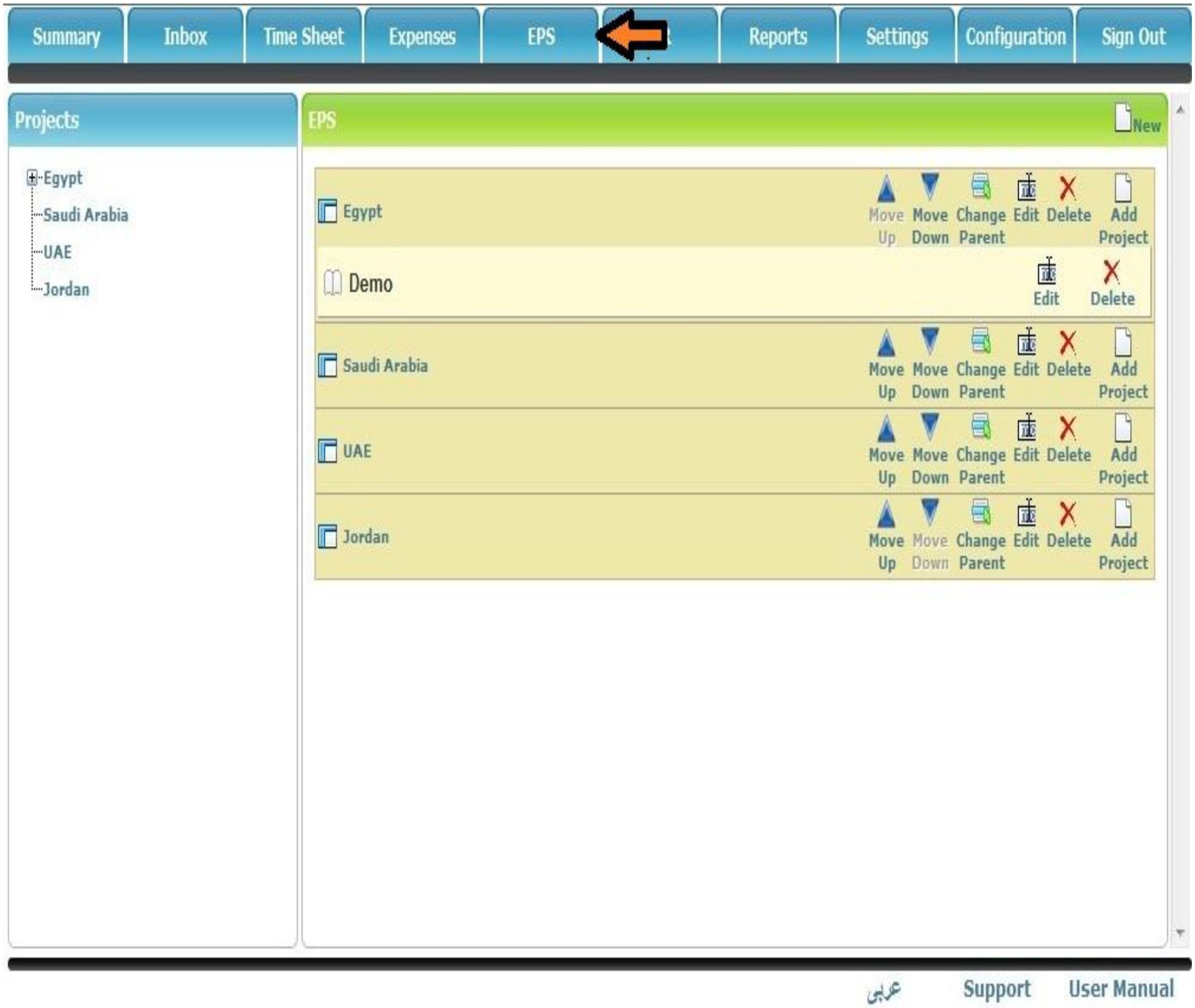

Figure 4-10: EPS Customization

EPS feature allows users in different companies with different organizational needs and strategies to tailor their needs on line by creating their own hierarchy of departments, branches, disciplines, etc. Any hierarchy tree will end with an option to add a project with all its micro features as a default as shown in Figure 4-11

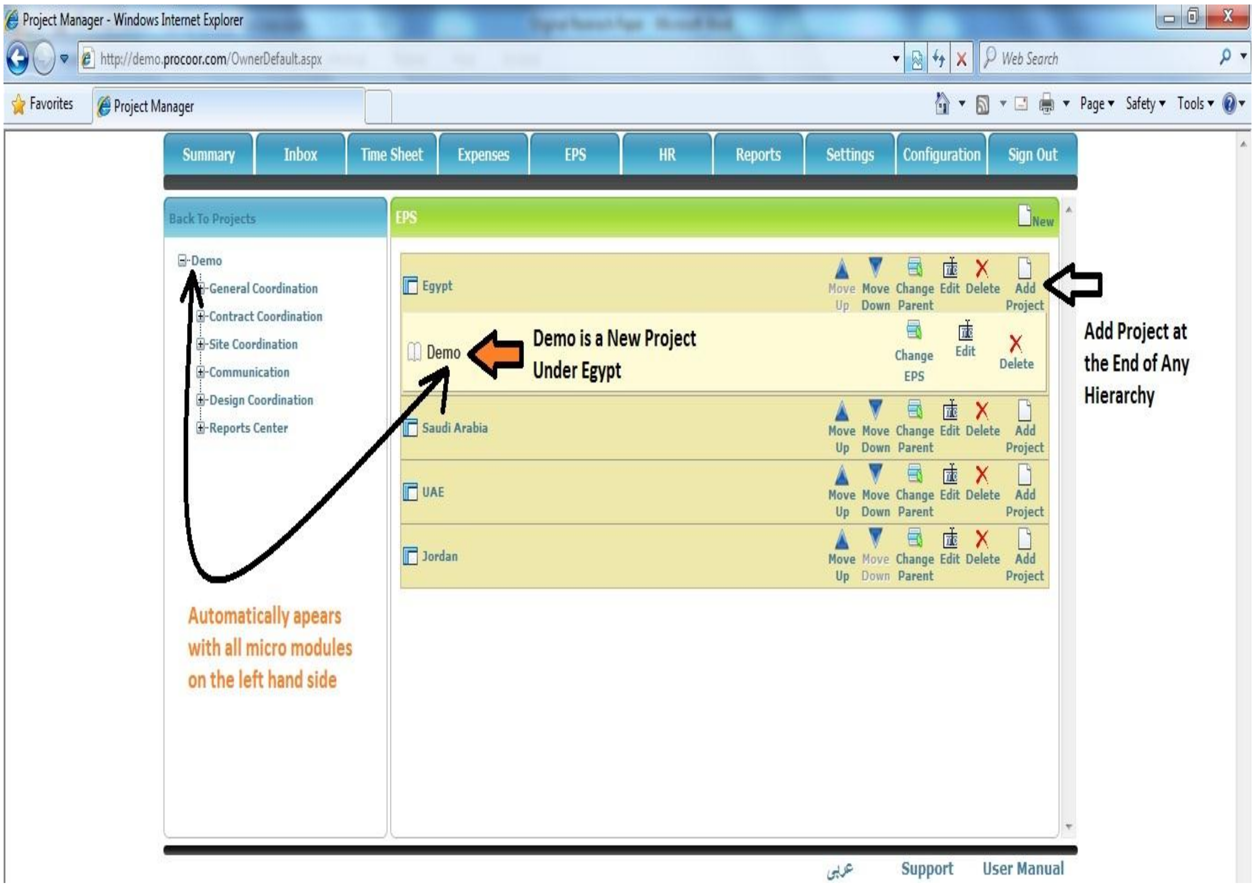

Figure 4-11: Customizability to Organizational Different Strategies and Structures

4.8 Summary and Conclusion

A system was developed following the main model developed in chapter three and all its related sub-models. The system is design to be compatible with all widely known application extensions. Therefore any file or folder can be attached to any active document. ASP.net was used as a programming language for flexibility, simplicity and availability, while SQL database was used as a system database because it is one of the popular, ASP.net compatible, flexible, and accurate databases.

System is developed to act as a central depository for each project through the actions done to each active document. Logs to these documents are created automatically through the system to give the central depository a simple accessible layout. System is developed to be accessed and used through any web browser and hence can be accessed through the internet or the intranet. The system addresses both organizational document and project specific document through creating Macro and Micro modules. Finally all documents are standardized and are set under specific technical categories for simplicity and ease of use.

Chapter (5)

5. Case Study & Verification

5.1 Illustrated Example:

This example shows the difference between the steps used in the original document exchange of information process from one project team member to another through a set of paper documents vs. using the web-based management system for issuing the documents; in our case study the document is a new design drawing.

5.1.1 Steps of traditional paper-based document exchange

The traditional paper-based process for document exchange of information consists of five main activities shown in Figure 5-1

Issue new drawing: this activity represents the process of how design team issues new drawings. The paper drawings are issued by post and on average take 2 days, depending on location of the designer and means of delivery.

Check and register drawing: this represents the process of checking and registration of issued drawing. The drawing is checked for errors or mistakes and if any is found, the designer is advised for correction, otherwise the details of the drawing are recorded in the register. The engineer send signed transmittal sheet to issuer to acknowledge that the drawing have been received.

Make copies of drawing: this activity involves reproduction of the registered drawings. Two copies of drawings are normally issued as original and the engineer then make copies; the number per drawing depends on the number of subcontractor/supplier that requires the drawing. On a mega type project, the number of subcontractors or suppliers often exceeds hundred depending on the size of the project.

Check and distribute drawing: this activity represents the drawing distribution process. The site engineer checks and attaches transmittal sheet for each of the drawings and sends them to relevant subcontractors.

Receive and document transmittal sheet: this activity describes the process of documentation of drawing distribution. The signed transmittal sheets received from the subcontractors are documented.

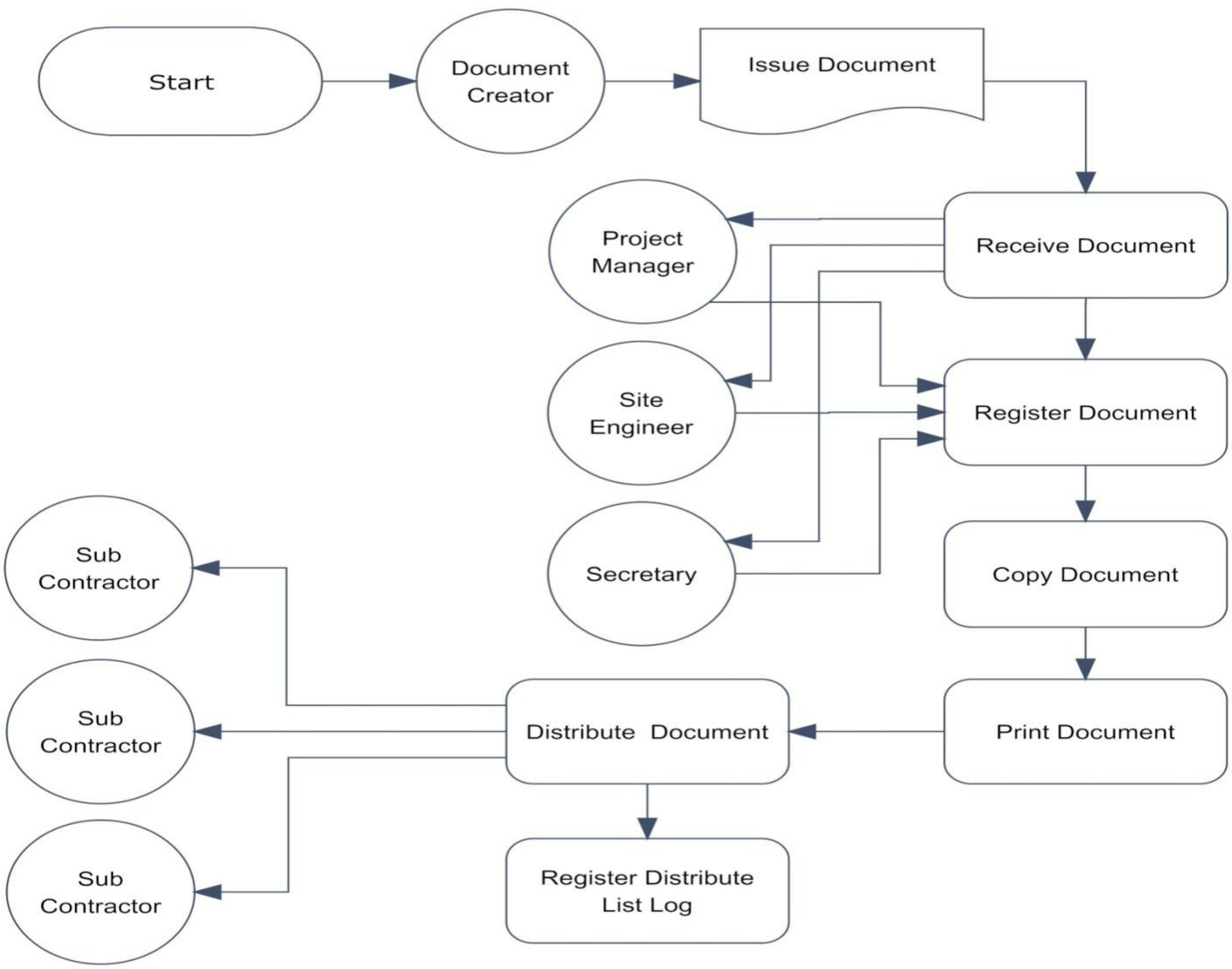

Figure 5-1: Original Document Process

Figure 5-1 shows the steps required to issue a new active document. In our illustrated example this active document is a new drawing. In the traditional document exchange process it goes into many steps between the different project team members. Client will give requirements and/ or changes to the design team, this request will go from the secretary of the design team to the design team. Request is accepted and drawing information is being input and the drawing is prepared. After finishing creating documents, the design team issues an advice of the issued drawing and sends it to the site engineer. Site engineer sends these drawings to project document controller to be registered. Document controller registers the drawing information and saves all drawing details, and the site engineer accordingly orders copies of this drawing. Therefore the drawing is moved once more to the plotter and printer shop and comes back after fulfilling copies requirements. At that point the site engineer arranges a distribution list of all related stakeholders for this drawing to be distributed among them. Comments from each stakeholder come back to the site engineer and timely consuming coordination is done between these comments to finalize the drawing.

Table 5-1 shows steps required for detailed movement of each drawing. The number of steps it takes to reach its final state shows that it goes through at least twenty three exchange steps

Table 5-1: Analysis of Traditional Drawing Exchange Steps

Step Description	Responsibility	Counter
Request a drawing	Client	1
Create a drawing	Design team	2
Request to issue drawing	Design team	3
Request Accepted	Design Team	4
Logs issued drawings	Secretary	5
Advise of an issued drawing	Design team	6
Request to register drawing	Site Team	7
Register the drawing	Site Secretary	8
Request a modification (duplicates all the above steps	Site Team	16
Request drawing copies	Site Team	17
Sent to Plotter	Secretary	18
Receive from Plotter	Secretary	19
Request the distribution list	Site team	20
Distribute drawings	Secretary	21
Receive and comment on drawings	All Stakeholders	22
Coordinate all comments on the drawings	Site Team	23

5.1.2 Re-Engineering Process using our Model

Using our model reduced the main drawing distribution activities from five activities to three activities regardless of the actual time involved, as illustrated by Figure 5-2. The actual time involved in the process have dramatically decreased by using this model. The model also decreased the number of detailed movement that the drawing undergoes from one team member to the other from twenty three movements to only seven movements as shown in Table 5-2. The Web based management system cuts many steps from the traditional information exchange process which wastes a lot of valuable time. The designer creates a drawing after receiving a request from the client for certain requirements and/or changes. The designer then issues drawings using design software and saves the design electronic files by uploading them on the database. The system automatically sends an e-mail notice, with an attached transmittal sheet to the site engineer and any other involved party to inform them that a new drawing has been issued. The engineer can immediately view the non-editable version of this drawing on the computer screen or print it out for thorough checking if needed. This version of the drawing can be downloaded from the system and edited with any desired changes and then uploaded again on the system with another version, so that all versions are registered and saved. The transmittal sheet is also completed automatically via the web system forms. These exact forms were used previously to add the drawing on the system.

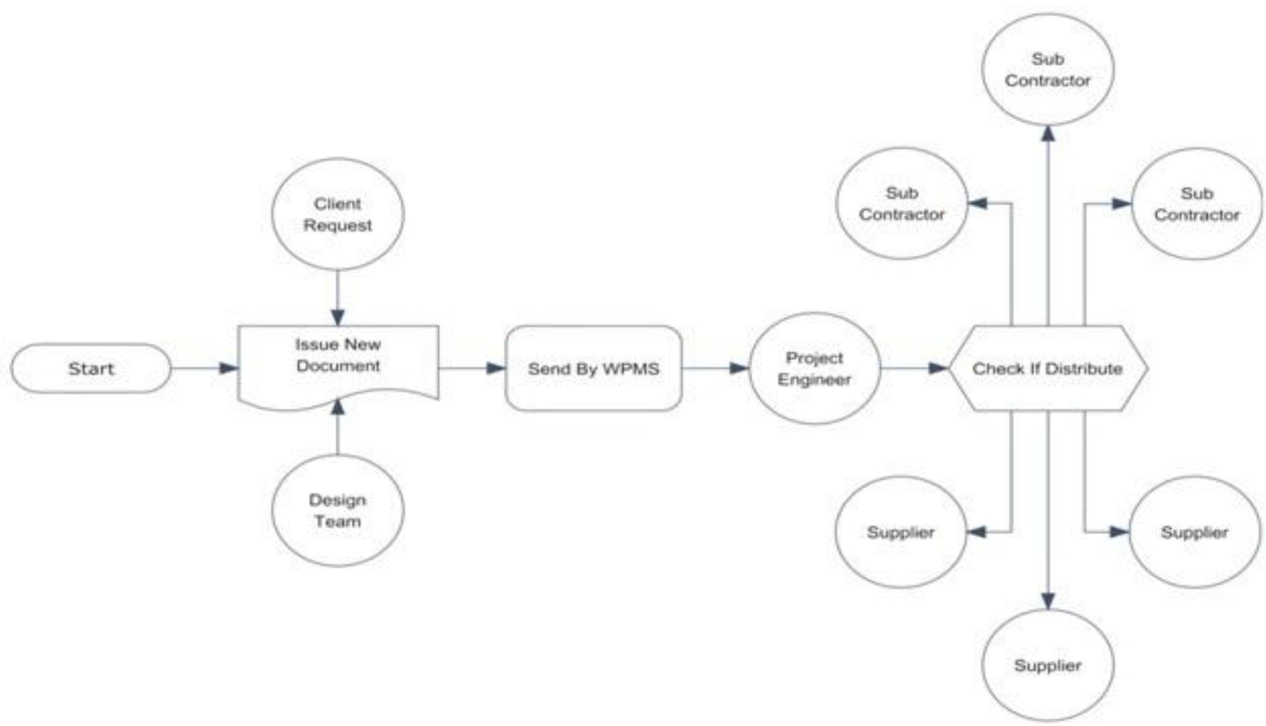

Figure 5-2: Re-Engineering Document Process Model using our Model

Any stakeholder can input comments for drawing modification directly on the same drawing document, which are being saved instantly in the system database and immediate alerts are sent to the designer for revision and resubmission. All revisions and submittal cycles for each drawing are recorded automatically in the system register for proper tracking and monitoring of each design activity. If the site engineer is completely satisfied with the drawing, he can instruct the system either to make it accessible to certain users from subcontractors or suppliers or to sent it by email using the system so that the email itself is registered and recorded as well. An acknowledgement post it document is sent to the sender once the drawings is received to make confirmation that the document is opened by the recipient.

Table 5-2: Drawing exchange steps using Model:

Responsibility	Step Description	Counter
Client	Request a drawing	1
Design team	Create a drawing	2
Design team	Upload Drawing	3
Site Team	Writes Comment for modification	4
Design Team	Upload Revised Drawing	5
Secretary	Distribute drawings	6
All Stakeholders	Receive and comment on drawings	7

5.1.3 Comparison of the WPCS with Traditional Paper Based System

The WPCS was compared against the traditional paper-based document exchange system based on two criteria; the main process activities comprising the document exchange and the number of steps the document has to take between stakeholders to reach its final destination. The main process activities were reduced from five process activities in the traditional system to three process activities in the web-based system. The document exchange took 23 steps to reach its final destination in the traditional system compared to only seven steps to reach the same final destination with a saving of 17 steps. Without making an accurate assessment of the actual time spent during each step, it is obviously clear that the WPCS made a huge saving in regarding process activities and accordingly time and cost.

Cost savings are in directly affected by time savings however are directly affected by other expenses that are completely eliminated from the document exchange steps using web-based coordination system

5.2 Validation of the system

A system demonstration to show drawing addition and distribution is illustrated in Figures 5-3. To start using the system, the user will login to the system using his username and password.

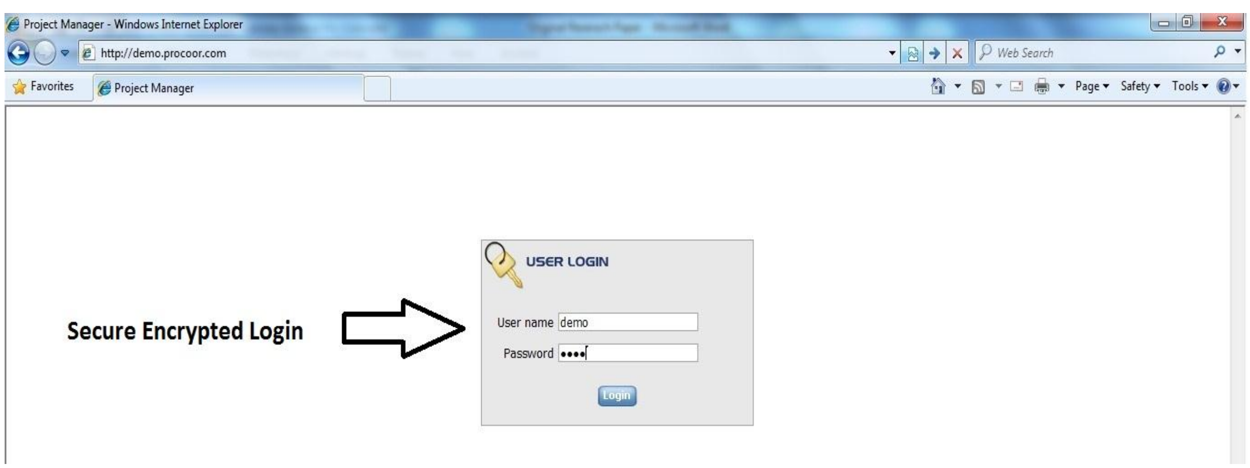

Figure 5-3: System login page

Access to the system will lead to the company home page, which is a summary dashboard of all alerts on the right hand side and all projects on the left hand side. All the menu buttons provide links to required information stored in the central database as shown in Figure 5-4

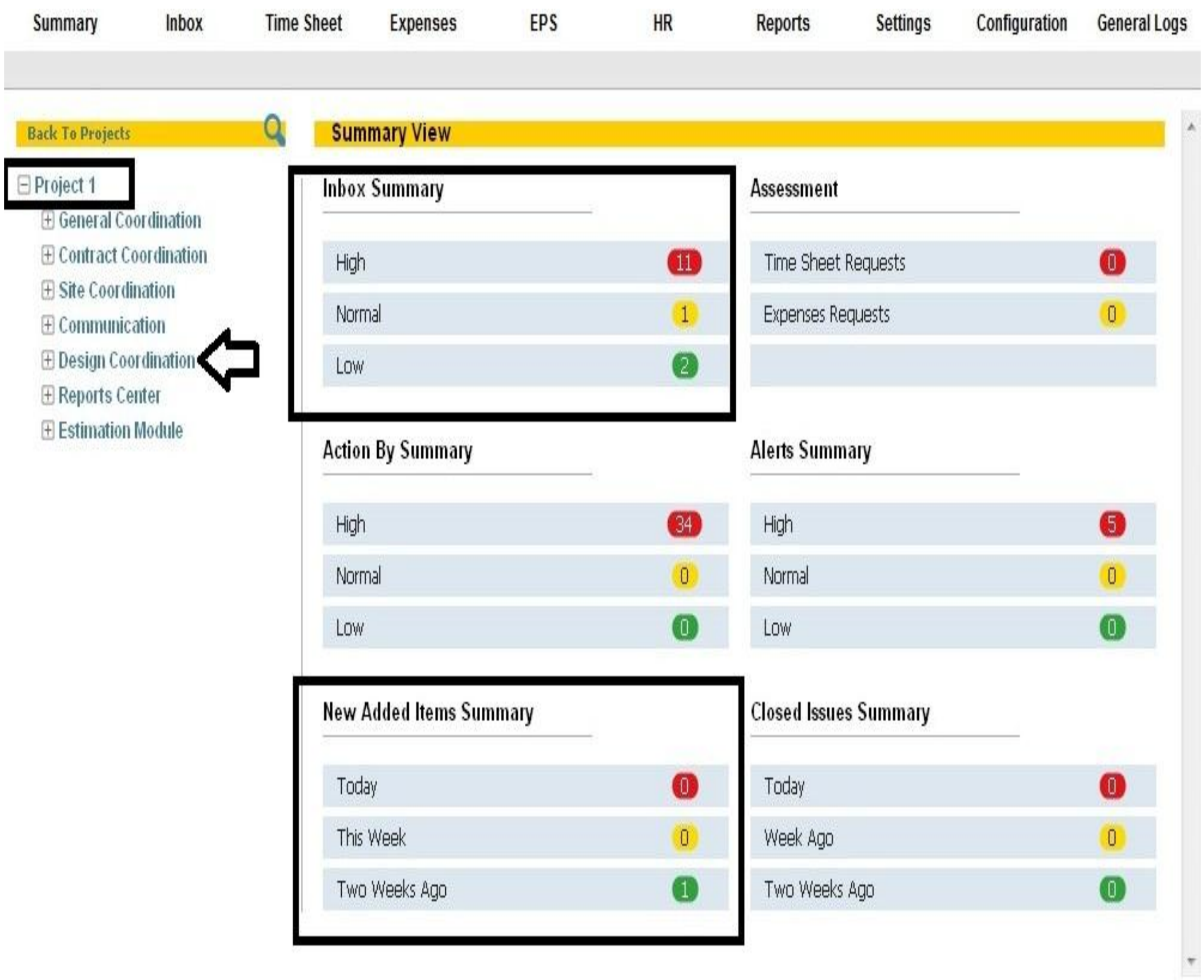

Figure 5-4: System Dashboard and Projects

A simple click on any project will open the specific project with all its technical categories as shown in figure 5-4. A simple click on the design coordination category will open all document categories inside the design category in a given project. Another click on the document category called drawing will open an automatic log of all the drawings currently issued under this project as shown in Figure 5-5.

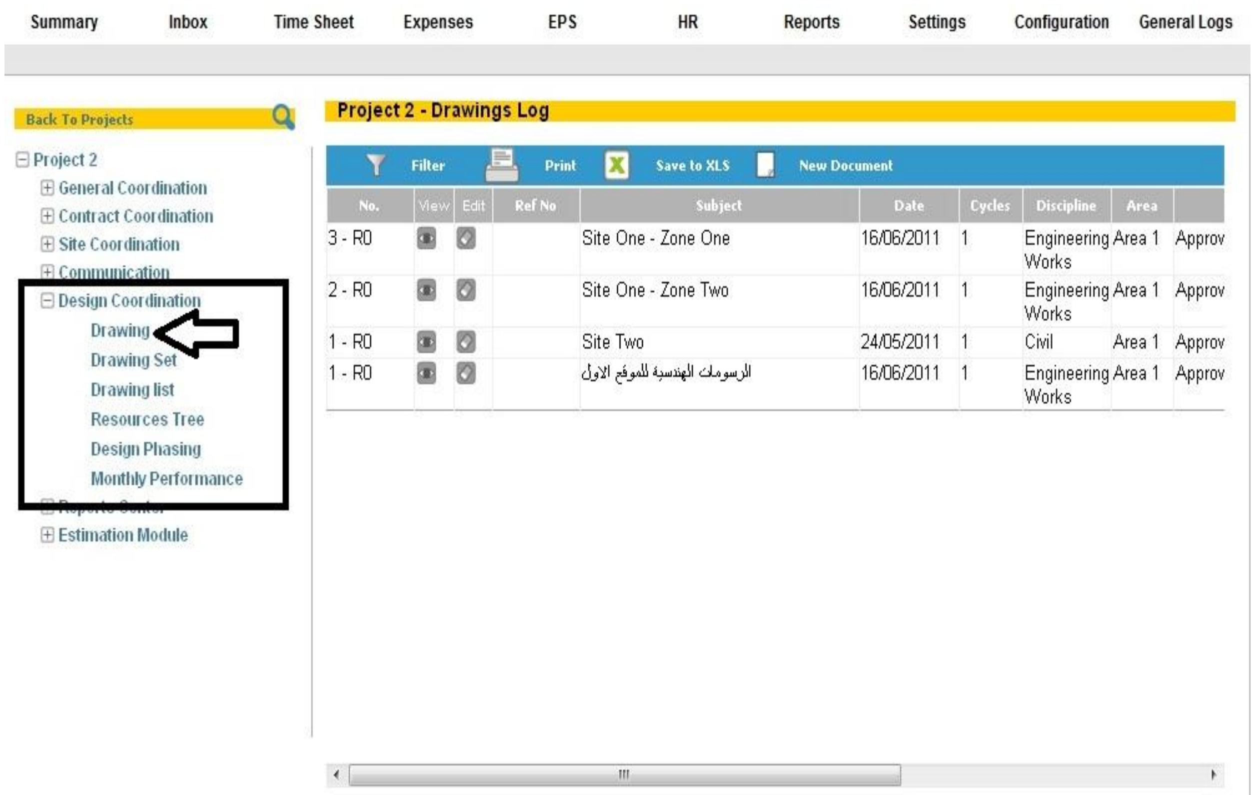

Figure 5-5: Drawing Automatic Register

This drawing register contains a lot of information such as drawing description, number, reference number, revisions, approval status, and number of cycles until approval, open date, closed date and all cycle dates, etc. Another simple click on any drawing will open the drawing to view all details and choose either to view the drawing, or edit, print, send as an email or as a task or many more actions as shown in Figure 5-6. This drawing can be distributed through the local system or to outside emails depending on which stakeholder has an access to the system and who does not, however in all cases all parties are being alerted.

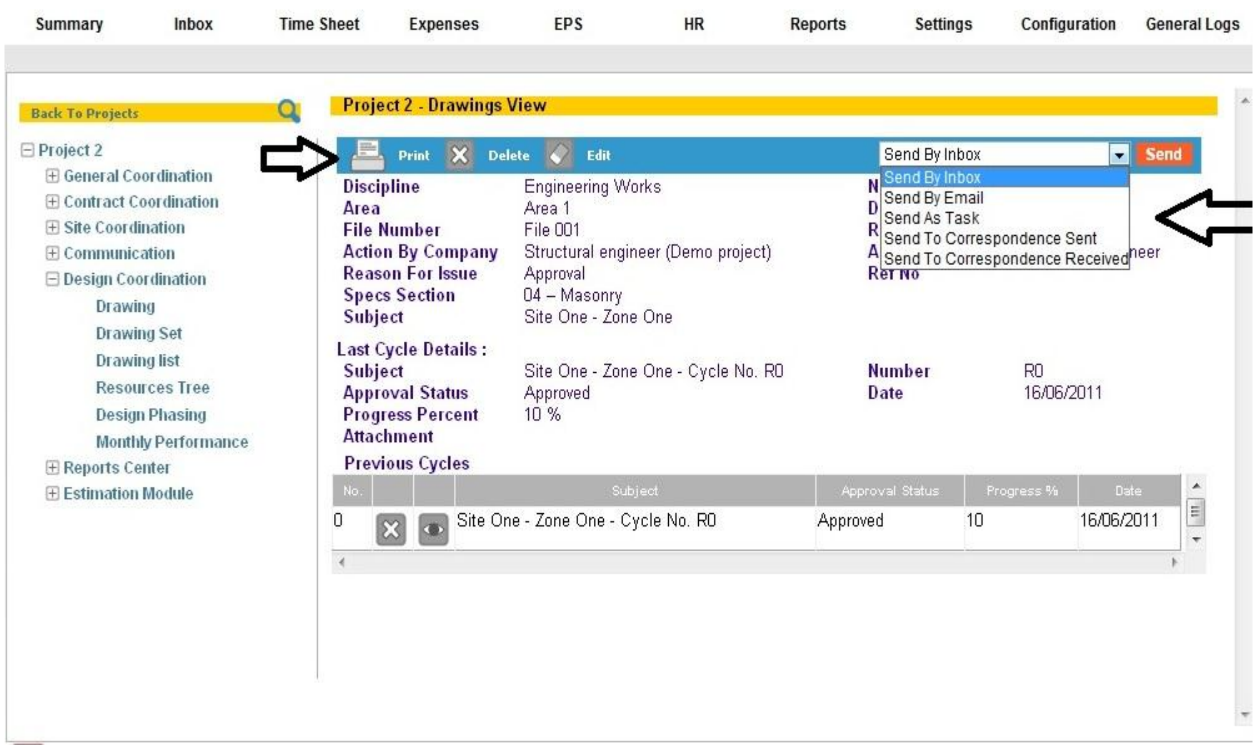

Figure 5-6: Drawing Distribution and other Actions

5.3 Evaluation of the system

In order to evaluate the proposed system, we adopted factors (technical and non-technical) that influence the performance of our developed system as well as measures that assess such performance. The main groups of factors that are thought to affect the performance of the system are; the characteristics of the project, the project team, the service provider, and the system itself. Our survey questionnaire was designed to include all these factors along with the measures that can assess such factors in simple and direct questions as shown in table 5-3

Table 5-3: Performance Assessment Questionnaire:

	System Performance Perspective	Strongly Agree 5	4	Neutral 3	2	Strongly Disagree 1
Strategic	Did it help in tracking project activities					
	Did it enhance organization's image					
	Did it enhance competitive advantage					
	Did it improve computer literacy					
	Did it improve customer/supplier relations					
	Did it increase global corporation					
	Did it help in attracting more clients					
	Did it improve integration with other functions					
Time	Did it facilitate document transfer					
	Did it help in searching for files and documents					
	Did it enable immediate report and feedback					
	Did it reduce response time to answer queries					
	Did it help in preparing correspondence					
Cost	Did it reduce number of faxes					
	Did it reduce number of postage and shipping					
	Did it reduce amount of paperwork					
	Did it reduce telephone usage and expense					
	Did it reduce travel expense					
	Did it reduce number of face-to-face meetings					
Quality	Did it improve quality of documents					
	Did it facilitate task control					
	Did it reduce rework					
	Did it reduce number of design errors					
Risk	Did it improve decision making of project team					
	Did it help in conforming with contracts					
	Did it reduce number of claims					
Communication	Did it reduce number of request for information					
	Did it make Communication improvement					
	Did it enhance coordination within team					
	Did it reduce bottlenecks in communications					
	Did it reduce barriers in communications					

The questionnaire interview was conducted on an engineering consultancy group in Egypt with a number of engineers reaching almost 500 with different positions and disciplines. The head of each department was contacted to select the respondents that are most willing to participate in the questionnaire interview. The overall performance WPCS scores are rated by the respondents on a scale of 1 to 5 (1 extreme failure and 5 extreme successes). The number of the engineers that participated in the questionnaire interview was ten engineers. During each interview, the interviewee was asked to provide a general view on the use of WPCS in the organization, including the implementation setting/decision and operational issues that his team experienced. The interviewee was then presented with the set of questions that measures the intensity of the success factors. Questions were deliberately closed-ended with a number scale to avoid unstructured answers but, however, shall allow the interviewee the freedom to respond with more than merely positive or negative answers. The objective was to check for absence/presence of the assessment criteria identified in the survey, while at the same time checking whether they were fulfilled only superficially, or in a meaningful way. Each interview lasted approximately one hour and data was compiled to form results as illustrated in the following section.

5.4 Analysis of the Interviews Data

A numerical analysis was performed on the data of the interview questionnaires to show the percentage of agreement and/or disagreement of the interviewees with the system performance in their organization. The performance scores are rated on a scale of (1) to (5) with (1) showing complete disagreement implying failure and (5) showing complete agreement implying success of implementation.

As illustrated in Table 5-4 below, the number of hits for each scale number was registered at the specific column of the scale number and at the corresponding row of the question in hand. The scale numbers (5) and (4) represent agreement and (2) and (1) represent disagreements, however (3) is not included as it is considered neutral opinion. Percentage for each assessment factor was calculated by adding percentage values under scales of (5) and (4) in case of agreements and (2) and (1) in case of disagreements. Overall percentage for the whole sample was calculated by taking average of all agreements and disagreements percentages values and dividing it by the number of factors. Overall percentage was found out to be (65.5 %) agreements and (11.3%) disagreements. This means that (65.5%) of the interviewees agree that that there is an obvious improvement in the organization after implementing the system and (11.3%) of them disagree with the improvements in certain disciplines. Percentage values for each group of factors were also calculated to give an indication for which group of factors were most successful in comparison to others. And hence the time improvement scored the highest percentage of (86 %) while communication, time and quality improvements scored almost the same percentage of (70 thru 72 %). In the third place comes the risk improvements with (56.7 %) and finally comes the organization strategic improvement scoring the lowest percentage of improvement among all other improvement factors to show only (45 %). These results are all illustrated in table 5-4 hereunder.

Table 5-4: Performance Assessment of Proposed WPCS

Numerical Analysis For the Interview Questionnaire

		System Performance Perspective	Number of hits for Each Score: Agreement 5	Agreement 4	Neutral 3	Disagreement 2	Disagreement 1	% of Agreement		% of Disagreement	
Strategic	1	Did it help in tracking project activities	3	5	1	1	0	45	80	26.3	10
	2	Did it enhance organization's image	2	1	6	1	0		30		10
	3	Did it enhance competitive advantage	1	1	4	4	0		20		40
	4	Did it improve computer literacy	1	6	3	0	0		70		0
	5	Did it improve customer/supplier relations	2	0	1	7	0		20		70
	6	Did it increase global corporation	2	0	5	3	0		20		30
	7	Did it help in attracting more clients	2	1	2	5	0		30		50
	8	Did it improve integration with other functions	6	3	1	0	0		90		0
Time	9	Did it facilitate document transfer	6	4	0	0	0	86	100	4	0
	10	Did it help in searching for files and documents	6	4	0	0	0		100		0
	11	Did it enable immediate report and feedback	4	3	2	1	0		70		10
	12	Did it reduce response time to answer queries	2	6	2	0	0		80		0
	13	Did it help in preparing correspondence	6	2	1	1	0		80		10
Cost	14	Did it reduce number of faxes	5	5	0	0	0	71.7	100	10	0
	15	Did it reduce number of postage and shipping	6	3	1	0	0		90		0
	16	Did it reduce amount of paperwork	8	2	0	0	0		100		0
	17	Did it reduce telephone usage and expense	7	1	1	1	0		80		10
	18	Did it reduce travel expense	2	1	4	3	0		30		30
	19	Did it reduce number of face-to-face meetings	2	1	5	2	0		30		20
Quality	20	Did it improve quality of documents	4	6	0	0	0	70	100	10	0
	21	Did it facilitate task control	4	4	2	0	0		80		0
	22	Did it reduce rework	2	6	1	1	0		80		10
	23	Did it reduce number of design errors	0	2	5	3	0		20		30
Risk	24	Did it improve decision making of project team	4	5	1	0	0	56.7	90	6.67	0
	25	Did it help in conforming with contracts	3	2	5	0	0		50		0
	26	Did it reduce number of claims	2	1	5	2	0		30		20
Communication	27	Did it reduce number of request for information (RFIs	3	1	6	0	0	72	40	0	0
	28	Did it make Communication improvement	7	2	1	0	0		90		0
	29	Did it enhance coordination within team	7	2	1	0	0		90		0
	30	Did it reduce bottlenecks in communications	7	0	3	0	0		70		0
	31	Did it reduce barriers in communications	7	0	3	0	0		70		0
						Over All Percentage		65.5		11.3	

5.5 Results of Questionnaire Interview

. The analysis revealed that there was a big improvement in all performance perspective items as all items showed scores ranging from the highest number (5) going down to the medium low number (2). An overall implementation pure success factor of 65.5 % without adding the neutral scores of (23.2%), which if added will bring the overall score to (88.7 %). The weakness of the system appeared in the comparable poor improvement within the organization strategic factors and the risk improvement factors. However there is a very noticeable improvement in organization time, cost, quality and communication levels.

The comments in the questionnaire interview showed that the decision to employ WPCS in the organization originated from their need to monitor their projects costs, particularly those associated with the engineers' hours for design work. It was also stated that all contract drawings and specifications were put available on the WPCS, which saved a lot of time for all projects' team members. All drawings issued by the design engineers and all RFIs or change orders by other stakeholders were available digitally on the central database, which reduced errors of design and the need to rework. Similarly, drawings and documents submitted by the contractor were usually in electronic format, even the shop drawings improving communication between all parties. The WPCS was extremely efficient at logging and transferring information for RFIs, supplemental instructions, change orders, meeting minutes, and related correspondence reducing risk and improving decision making process. A transmittal system was also fully integrated with the WPCS to track all documents sent electronically. Files that was too large to be transmitted through e-mail messages before using the WPCS could now be uploaded to the WPCS and downloaded at the other end reducing cost of printing, shipping and postage. Finally, all the interviewees agreed that the organization enhanced its quality and image by the use of the WPCS.

5.6 Factors Affecting Results of the Questionnaire Interviews

Although not all the WPCS features were fully developed and utilized at the start of the implementation, there were surprisingly no major problems encountered mainly because of the client's involvement in the system customization and having sufficient knowledge to deal with minor problems as they arose. The system's ease of use was also critical to the implementation success. The WPCS was carefully customized with significant input from the actual users. Various features were based on a similar template, reducing the learning time required to become comfortable with the system. Although the majority of members were new to the system, most had sufficient computer experience. The provider could also be reached easily by regular e-mail or telephone, enabling minor issues to be characteristically addressed within minutes, with larger issues always resolved on a same-day basis.

The client also had in-house IT staff who were particularly helpful in sorting out problems with the WPCS utilization, especially at the early stages. High-speed connections were available and utilized by all major participants. The system and data connections were also extremely reliable with no significant downtime. The system also had a fully developed security system that allowed the team to create security levels, decide what information would be available at each level, and assign security levels to individuals or groups. For accountability, a record was kept of when documents were accessed and by whom. All construction specifications and drawings were kept in the central database using versioning techniques to ensure that they could not be altered. Other project information, such as schedule information could also be shared easily through the system integration features with different software packages.

Chapter (6)

6. Conclusions and Recommendations

6.1 Conclusions

There is a need for integration of information processes within the construction industry. It can now be realistically achieved using the evolving information technology, especially the capability of web technology. A model was developed in this research addressing the challenges facing information transfer in the construction industry as well as the problems that might appear in system implementation in an organization. The research has described and tackled all the research objectives and developed an advanced Web-IT coordination tool that improves communication and information sharing in a project. The easy, accurate and timeless exchange of documents during the construction of any given project, no matter its size, duration and complexity was achieved. The development and implementation of the system on the basis of the created model was achieved and described in details. The system was tested through an illustrated example for one document, the engineering drawing in our case. The illustrated example compared the paper-based system, with the developed coordination system and a considerable cut in the activities process and savings in time and cost was recorded. It also made obvious the main benefits of web-based coordination model compared to the conventional methods such as the following:

- The system provides a lot of storage space and immediate access to any project for viewing, editing, printing or downloading for modifications and/or changes.

- New documents are made available to all project members without delay, which provide clear evidence of time and cost savings.

The evaluation of the system was done through a questionnaire interview made in a large consultancy organization in Cairo, Egypt. The analysis of the data coming from the interviewed sample revealed that the organization improved noticeably in terms of time, cost, quality and communication and improved slowly on the strategic and the risks levels.

This evaluation showed the importance of implementing the web-based coordination system in all engineering firms for many reasons most importantly are the following:

- The quality of documents and tasks improved from the system implementation.
- The time involved in all engineering activities was reduced tremendously
- The cost was reduced due to the reduction in the number of faxes, postage, paperwork, telephone usage, travel expenses and face to face meeting.
- Communication was enhanced through the system and better coordination between the project team members was maintained

Based on the previous discussion the developed web coordination system can be exploited to improve communication within the construction industry.

6.2 Recommendations and Future Research

The work described in this research could be extended to include all aspects of the construction industry and the following items can be an example of future research points:

- Integrate planning, project performance indicators and estimation activities in the web-bases systems modeling.
- Explore compatibility of the system with the ISO standards
- Broader coordination model can be created to address the most complicated relations between construction documents
- Build a complete comprehensive model and develop a system that includes other aspects of the construction industry

References

AIA. 1994. *The Architect's Handbook of Professional Practice*. USA: The American Institute of Architects (AIA).

AIA California Council. 2007. *A Working Definition – Integrated Project Delivery*. New York, NY: McGraw Hill Construction.

Allen, R.K., B. Becerik, S.N. Pollalis, and B.R. Schwegler. 2005. "Promise and barriers to technology enabled and open project team collaboration." *Journal of Professional Issues in Engineering Education and Practice* 131(No. 4):301-11.

Alshawi, M. 2000. "Future IT Challenges in Project Management." *The 7th Annual Conference of the Project Management Institute: Gulf Branch, Bahrain* A1–A19.

Andresen, J., K. Christensen, R. Howard, and R. Howard. 2003. "Project management with a project web." *Journal of Information Technology in Construction* 8:29-41.

Anumba, C.J., J. Pan, R.R.A Issa, and I. Mutis. 2007. "Collaborative Project Information Management in a Semantic Web Environment." *Engineering, Construction and Architectural Management* 15(1):78-94.

Aouad, G., P. Brandon, F. Brown, T. Child, and G. Cooper. 1995. "The conceptual modelling of construction management." *Automation in Construction* 3:267–282.

Attaran, M. and S. Attaran. 2002. "Collaborative computing technology: the hot new managing tool." *Team Performance Management,* 8(1/2):13-20.

Baldwin, N. A. 2004. "Overcoming the barriers to the successful introduction of collaborative technologies in construction." *Designing, managing and supporting construction projects through innovation and IT solutions*, pp. 319–326.

Bentley, K. 1998. "Freeway to the future." *Civil Engineering Magazine* 10(2):12-16.

Chan, S.L. and N.N. Leung. 2004. "Protype Web-based Construction Project Management System." *Journal of Construction Engineering and Management* 130(6):935-943.

Chan, E.H.W. and C. Liu. 2007. "Corporate portals as extranets support for the construction industry in Hong Kong and nearby regions of China." *Journal of Information Technology in Construction* 12:180-92.

Chassiakos, A.P. and S.P. Sakellaropoulos. 2008. "A Web-Based System for Managing Construction Information." *Advances in Engineering Software* 39(11):865-876.

Chim, M.Y., C.J. Anumba, P.M. Carrillo, and P.M. Carrillo. 2004. "Internet-based collaborative decision-making system for construction." *Advances in Engineering Software* 25:357-71.

Dawood, N. and S. Sikka 2008. “Measuring the effectiveness of 4D planning as a valuable communication tool.” P. 13

Deng, Z.M., H. Li, C.M. Tam, Q.P. Shen, and P.E.D. Love. 2001. “An application of the Internet-based project management system.” *Automation in Construction* 10:239–246.

Erdogan, B., C.J. Anumba, D. Bouchlaghem, and Y. Nielsen. 2008. “Collaboration Environments for Construction: Implementation Case Studies.” *Journal of Management in Engineering* 24(4):234-244.

Fisher, M and J Kunz. 1995. “The Circle: Architecture for Integrating Software.” *Journal of Computing in Civil Engineering, ASCE* 2:122-133.

Han, CS, JC Kunz, KH. Law, and KH. Law. 1998. “Client/Server Framework for On-line Building Code Checking.” *Journal of Computing in Civil Engineering* 1(1):181-194.

Hjelt, M. and B.C. Bjork. 2007. “End-user attitudes toward EDM use in construction project work: case study.” *Journal of Computing in Civil Engineering,* 21(4):289-300.

Laudon, K. C. . L. J. P. 2000. *Management information systems*. Upper Saddle River, N.J.: Prentice-Hall.

Li, W.D., Y.J.H. Fuh, Y.S. Wong, and Y.S. Wong. 2004. “An internet-enabled integrated system for co-design and concurrent engineering.” *Computers in Industry* 55(a):87-103.

Mead, SP. 1997. “Project-specific Intranets for Construction Teams.” *Project Management Journal* 3(1):28.

Merrit, F.S and J.T Riicketts. 1994. *Building Design anf Construction Handbook*. 5th ed. USA: McGraw-Hill Inc.

Mitchell, A. and P. Demian 2008. “Barriers that influence the implementation of UK construction project extranets.” Beijing, China.

NIBS, National I. o. B. S. 2007. *National Building Information Modeling Standard*. Washington, DC: National Institute of Building Sciences NIBS, Washington, DC.

Nitithamyong, P. and M.J. Skibniewski. 2004. “Web-based construction project management systems: how to make them successful?” *Automation in Construction* 13(4):491-506.

Nitithamyong, P and M Skibniewski. 2006. “Success/failure factors and performance measures of web-based construction project management systems: professionals’ viewpoint.” *Journal of Construction Engineering and Management* 132(1):80-7.

Nitithamyong, P and M Skibniewski. 2007. “Key success/failure factors and their impacts on system performance of web-based project management systems in construction.” *Journal of Information Technology in Construction* 12:39-59.

O’Brien, W.J. 2000. “Implementation Issues In Project Websites: A Practitioner’s Viewpoint.” *Journal of Management in Engineering* 16(3):34-39.

Rezgui, Y, G Cooper, J Yip, P Branddon, and J Kirkham. 1996. “An Information Management Model for Concurrent Construction Engineering.” *Journal of Automation In Construction* 3(2):343-355.

Rojas, EM and AD. Songer. 1999. “Web-centric systems: a new paradigm for collaborative engineering.” *Journal of Management in Engineering* 2(1):39-45.

Ruikar, K., C.J. Anumba, P.M. Carrillo, and P.M. Carrillo. 2005. “End-user perspectives on use of project extranets in construction organisations.” *Engineering, Construction and Architectural Management* 12(3):222-35.

Sebastian, R., W. Haak, E.J. Vos, and E.J. Vos 2009. “BIM application for integrated design and engineering in small-scale housing development: a pilot project in The Netherlands.” National Cheng Kung University, Tainan.

Seesing, PR. 1996. “Distributing project control database information on the World Wide Web.” *PM Network*.

Sriprasert, E. and N. Dawood 2005. “Multi-constraint information management and visualisation for collaborative planning and control in construction”.” Pp. 341-66

Suchanic, G. 2001. *Computer Aided Project Management.* New York, p. 3-25: Oxford University Press.

Tam, CM. 1999. “Use of the Internet to enhance Construction Communication Total Information Transfer System.” *International Journal of Project Management* 17(2):20-25.

Underwood, J. and M Alshawi. 1997. “Data and Process Models for the Integration of Estimating and Valuation.” *Microcomputers in Civil Engineering, Blackwell 12* 393– 405.

Wills, N. 1998. “Project Management and the Internet.” *IEE Review*.

Zhu, Y. 1999. “Web-based construction document processing through a malleable Frame.” *PhD thesis Univ. of Florida Univ. of Michigan, Ann Arbor, Mich.*

Zhu, Yimin, Raja, R. A. Issa, Robert F. Cox, and Robert F. Cox. 2001. “Web Based Construction Document Processing via Malleable Frame.” *Journal of Computing in Civil Enginering, ASCE, USA* 15(3):157-238.