Performance Measurement in a Quality Management System

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ABSTRACT

Certification to quality assurance standards has become a must for many construction companies nowadays to be able to survive in highly competitive market. Companies face some difficulties while deploying a quality management system. On the other hand and from resource management point of view, resource utilization should be optimized both in company and its projects. This optimization is sought to be cost saving and time reduction while enhancing quality in many recent studies. The main challenge in resource optimization is employees' and workers' low morale and their resistance against organizational change. In order to overcome this problem and creating a motive environment in construction companies, a robust decision support tool is needed to efficiently and objectively measure and monitor employee performances.

The core research objectives of this study are to: (1) overcome main pitfalls of quality management system deployment including large amount of paperwork, unstructured documentation, improper communication, and low employee morale; (2) formulate a conceptual framework to quantify employee performances based on three management factors of time, cost, and quality to be used as a basis for motivation system; and (3) develop an online office automation system using web and database capabilities of Microsoft Visual Studio .NET 2008 that simultaneously aims to optimize resource utilization.

First, an extensive literature survey was conducted and through a questionnaire survey, the research methodology was designed.

Second, a performance measurement framework was developed to enable efficient and effective resource utilization in construction projects and companies. The framework incorporates three management factors of time, cost, and quality and objectively quantifies each employee's performance. It was aimed to reduce the subjectivity of performance calculations through quantifying work quality. The performance factors could be further employed as a motivation tool for employees while being used as a performance monitoring decision tool for manager.

Third, a prototype web-based office automation system was developed to enable the integration of the research developments of this study with information technology to facilitate its adoption in the construction companies. The system is designed to: (1) reduce paperwork and documentation problems of quality management system deployment through database management facilities of Microsoft SQL Server 2005; (2) improve communication among personnel and project participants in construction companies through the application of web facilities of Microsoft Visual Studio .NET 2008; (3) quantify employee performances on the basis of their effort to reduce time and cost while attempting to improve quality; (4) create a real-time performance tracking tool for managers; (5) Create a motive and competent environment for employees by different reward and recognition methods; and (6) develop various reports about all aspects of company and projects through different user interface modules in any time interval from system initiation.

The main research developments of this study contribute to the expansion of current practice in quality management system deployment and can lead to: (1) considerable decrease in paperwork; (2) improved communication and documentation systems; (3) increase in the efficiency of resource utilization in

construction industry; (4) highly motivated employees with a tendency to perform assigned duties to the highest quality level with the lowest cost in the shortest possible time period; and (5) enhanced company performance image in the highly competitive market.

Keywords: Quality management system, performance measurement, data warehouse, motivation, Microsoft Visual Studio .NET 2008.

ÖZ

Birçok inşaat firması yüksek rekabet koşullarında yaşayabilmek için kalite güvence sertifikası almak zorunda kalmaktadır. Firmalar kalite yönetim sistemlerini geliştirirken bazı zorluklarla karşılaşmaktadırlar. Bu kapsamdai kaynak yönetimi ve kullanımının hem firma ve hem de proje düzeyinde optimize edilmesini gerekli kılmaktadır. Böylece, hem maliyetlerin azalması hemde kalitelerin artırılması mümkün olabilecektir. Optimizasyon sürecinde çalışanların direnci ile karşılaşmak söz konusu olabileceğinden, bu darboğazı aşmak ve çalışanların performansını artırarak, motive edebilmek için ciddi bir sisteme gereksinin vardı.

Gerçekleştirlen bu araştırmanın esas amacı: (1) firmaların kalite sistemlerini oluştururken büyük miktarda bürokrasi ve kırtasiye, düzensiz dökümantasyon, uygun olmayan iletişim ve çalışanların moral bozukluğu gibi problemlere çözüm getirilmesi; (2) yönetimin üç unsuru olan zaman, maliyet ve kalite faktörlerinin somut ölçülmesi için kapsamlı çerçeve formüllerin geliştirilmesi; (3) web ve veri tabanlı otomasyon sistemleri kullanarak kaynak optimizasyonunu anında yapabilen sistemlerin geliştirilmesi olarak belirtenmıştir.

Öncelikli olarak, inşaat sektöründe kalite yönetimi sistemi, aksaklık ve sorunları, insan kaynakları yönetimi, performans yönetimi ve ölçme metodları, veri depoları ve web tabanlı sistemlerin uygulamaları üzerine kapsamlı literatür taraması yapılmıştır.

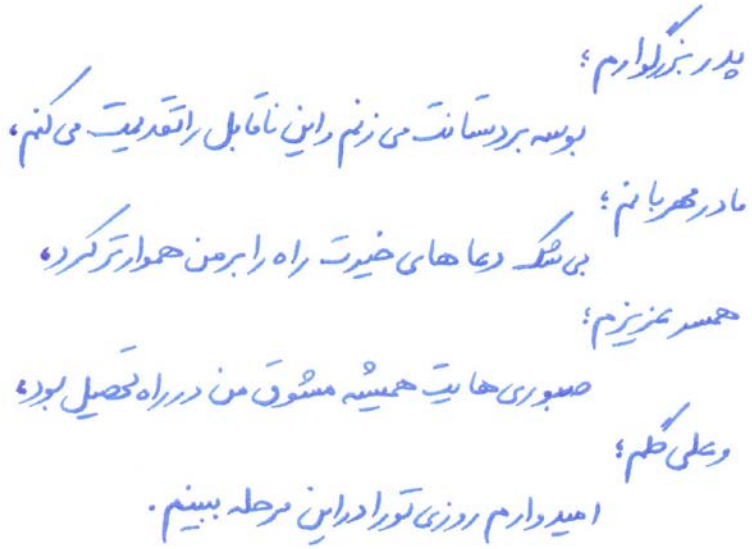
İkinci olarak, inşaat firmaları ve projelerinde etkili insan kaynağı kullanımını ölçebilecek performans ölçüm metodu geliştirilmiştir. Geliştirilen metod ile yönetimin üç unsuru, zaman, maliyet ve kalite objektif olarak değerlendirilerek çalışanların performansları ölçülmektedir. Bu model, çalışanların performanslarının

ölçülmesinde subjektifliği azaltmaktadır. Performans faktörü çalışanların performanslarını ölçerken, onları motive etmek için de kullanılmaktadır.

Üçüncü olarak, inşaat sektöründe kullanılmak üzere bu araştırmada geliştirilenler bilgi teknolojisi ile birleştirilerek web tabanlı ofis otomasyon sistemi geliştirilmiştir. Bu sistem şu işleri yapmaktadır: (1) firmalarda kalite sistemini geliştirmek için Microsoft SQL server 2005 kullanılarak kağıt ve kırtasiye işlerini azaltabilecek veri tabanı geliştirmek; (2) Microsoft Visual Studio .NET 2008 kullanılarak proje paydaşları arasında iletişimin artması sağlanmak; (3) çalışanların, kaliteyi artırarak, zaman ve maliyeti azaltan performansları objektif olarak ölçülmek; (4) yöneticiler için çalışanların performanslarını zamana bağlı olarak izleme olanağı sağlamak; (5) çalışanları ödüllendirme yöntemi ile etkili motivasyon metodu geliştirmek; (6) firma ve proje için arzu edilen zaman dilimi ve arayüz içerisinde gerekli raporlar elde edilebilmek.

Bu araştırma şu konularda katkıda bulunarak kalite yönetim sistemleri geliştirilmesine yardımcı olmaktadır: (1) kağıt ve kırtasiye işlerinin azaltılması; (2) iletişim ve dökümantasyon sistemlerinin geliştirilmesi; (3) inşaat sektöründe insan kaynaklarının verimli kullanılması; (4) çalışanların zamanı ve maliyeti azaltarak yüksek kalitede performans göstermelerinin teşvik edilmesi; (5) yüksek rekabet ortamında firmanın perfromans imajının artırılması.

Anahtar Kelimeler: Kalite yönetimi sistemi, performans ölçme, veri deposu, motivasyon, Microsoft Visual Studio .NET 2008.



To my Dad and Mom,

Whose supports and prays encouraged me not to give up,

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LIST OF ABBREVIATIONS

A/E/C ..... Architecture, Engineering and Construction

ASP ..... Active Server Pages

BI ..... Business Intelligence

BSC ..... Balanced Scorecard

C# ..... C Sharp

CPM ..... Corporate Performance Management System

DBMS ..... Database Management System

DEA ..... Data Envelopment Analysis

DSS ..... Decision Support System

DW ..... Data Warehouse

EDI ..... Electronic Data Interchange

EDMS ..... Electronic Data Management System

EIS ..... Executive Information System

ERP ..... Enterprise Resource Planning

ES ..... Expert System

GDP ..... Gross Domestic Product

GDSS ..... Group Decision Support System

GM ..... General Manager

GSS ..... Group Support System

GUI ..... Graphical User Interface

IDE ..... Integrated Development Environment

IDSS ..... Intelligent Decision Support System

IFQM ..... Internet Facilitated Quality Management

IPMS ..... Integrated Performance Measurement System

IS ..... Information System

IT ..... Information Technology

KMDSS ..... Knowledge Management-based Decision Support System

KPI ..... Key Performance Indicator

MAMB ..... Mazandaran Association of Mass Builders

NSS ..... Negotiation Support System

OBS ..... Organizational Breakdown Structure

ODBC ..... Open Database Connectivity

ODS ..... Operational Data Store

OLAP ..... On-Line Analytical Processing

OLTP ..... On-Line Transaction Processing

OS ..... Organizational Structure

PDA ..... Personal Digital Assistant

PDSS ..... Personal Decision Support System

PMBOK ..... Project Management Body of Knowledge

PMSS ..... Performance Management Support System

QA ..... Quality Assurance

QC ..... Quality Control

QM ..... Quality Management

QMS ..... Quality Management System

QS ..... Quality System

RDBMS ..... Relational Database Management System

SME ..... Small and Medium-sized Enterprises

SQL ..... Structured Query Language

TQM ..... Total Quality Management

WBS ..... Work Breakdown Structure

WPMS ..... Web-based Project Management System

WWW ..... World Wide Web

LIST OF SYMBOLS

APF .....Activity Performance Factor

C_{est} .....Estimated Cost

C_{per} .....Performed Cost

D_{est} .....Estimated Delay

D_{per} .....Performed Delay

i .....Number of Orders Coming to the Employee

j .....Number of Activities with Checklist

m .....Number of Lower Level Employees

M_{est} ..... Estimated Number of Mistakes/Errors/Deficiencies

M_{per} ..... Performed Number of Mistakes/Errors/Deficiencies

n .....Number of Total Works Performed

PC_{est} .....Estimated Percentage of Work Completed

PC_{per} .....Performed Percentage of Work Completed

PF .....Performance Factor

Q_{est} ..... Estimated Quality

Q_{per} ..... Performed Quality

T_{est} .....Estimated Time

T_{per} .....Performed Time

w .....Work Experience in Years

W_C .....Weighted Factor for Cost

W_D ..... Weighted Factor for Delay

W_M .....Weighted Factor for Number of Mistakes/Errors/Deficiencies

W_{PC} ..... Weighted Factor for Percentage of Work Completed

W_{Q} ..... Weighted Factor for Quality

W_{T} ..... Weighted Factor for Time

Chapter 1

INTRODUCTION

1.1 Background

Quality management system (QMS) certification has become a must in today's highly competitive construction market. One of the most common methods of QMS application to a construction company is ISO 9000 certification. While the reason for many companies to achieve a quality management certificate, like ISO 9000 certificate, is only being eligible to enter the tenders, some other companies seek for ISO certification to benefit genuinely from its numerous advantages. However, construction companies face a number of difficulties in certification process including increase in paperwork, improper documentation system, poor communication among personnel, and low employee morale and motivation. These problems make the certification process arduous and some companies might even relinquish.

The aforementioned problems will, on the other hand, influence company performance. Literature shows a considerable increase in the fields of supply chain performance and its effects on company performance (Allesina et al., 2010; Pero et al., 2010; Whicker et al., 2009; Kim, 2009; Craighead et al., 2009; Yeung, 2008; Cousins et al., 2008; Sharif et al., 2007; Wong and Wong, 2007; Carr and Kaynak, 2007) and company performance management and measurement (Phusavat et al., 2009b; Ho, 2008; Lin and Kuo, 2007; Rao, 2006; Saad, 2001; Kuo et al., 1999).

Majority of the researchers used structural equation modeling; and through development of a number of hypotheses, tried to prove or reject them based on a survey among different experts. However, research on performance quantification is relatively scarce and less attention has been paid to employee performance.

This research aims to fill this gap by developing a system to measure the performance of personnel that subsequently applies the obtained performance factor to motivate and appreciate the personnel which in-turn, affects employee performance and consequently company performance.

The objectives of the present research study are to overcome QMS deployment problems and create a decision tool for company managers to track employee performances. Data warehousing technique and soft computing methods were applied to develop a system called Performance Management Support System (PMSS) (Rezaei et al., 2011). PMSS is a web-based office automation system that measures the performance of employees based on three management factors of time, cost, and quality. Each of these indexes could provide useful information for managers Arjomandi et al. (2009) and were emphasized in many studies. The measured performances can further affect employees' standing in the company and their salaries as well. This is highly effective on the motivation of the personnel and as a result, creates a competitive environment among personnel and encourages them to perform their responsibilities in the shortest time, with the lowest cost and at the highest quality level. Thus, it overcomes QMS deployment difficulties and ultimately imposes continuous improvement. PMSS is principally designed and developed for construction companies due to the more complex nature and uniqueness of construction projects; however, its structure is quite general to be applicable to any organization type.

The practicability of the developed system was checked through trial runs and evaluations with skilled software developers and experienced general managers of five construction companies and ISO certification agencies. Time saving, cost reduction, less paperwork, easier communication, and more efficient documentation were affirmed to be the most important advantages of PMSS. The feedbacks approved the appropriateness and applicability of the system in construction sector.

1.2 Scope and Objectives of the Research

The scope of this study is to contribute to QMS implementation in construction companies through application of performance measurement and motivation methods. The main objectives of the research, therefore, are set up as:

1. To overcome main drawbacks of QMS deployment including large amount of paperwork, poor communication, improper documentation, and low employee morale.
2. To develop a conceptual framework for measuring employee performances based on three management factors of time, cost, and quality.
3. To develop a web-based office automation system.

1.3 Reasons for Objectives

Although PMSS is not aimed to be as an ISO certification tool, it could be used to simplify the certification process. Its aim is to revolutionize certification process from a rigid administration work procedures to an organizational culture. The main reasons for the objectives include:

1. To shorten the process of achieving ISO certificate for construction companies through:
    - Progress towards “paperless office”,

- Improving communication among different departments and levels in an organization, and
- Link the main office and project sites,

2. Little information is available on employee performance measurement and the methods to quantify it. Therefore, the framework is developed to:
    - Encourage and motivate employees in QMS implementation process,
    - Introduce continuous improvement culture through performance measurement and monitoring system,
    - Create a competitive environment among employees,
    - Develop an objective factor by using a numerical performance measurement method,
    - Ensure that the decisions are based on fact, not on emotion,
    - Enhance organization performance through improvements in employee performances, and
    - Optimize resource utilization.
3. Recent advances in information technology (IT) have provided an opportunity to use its numerous capabilities in different fields. The reasons to develop PMSS include:
    - Implementing a document transfer system to minimize paperwork and create a more systematic procedure for this purpose,
    - Providing a networked communication,
    - Improve coordination and the enhance the flow of information and work submission in the organization,
    - Establishing clear, documented, and systematic procedures and instructions that have to be followed by everyone in the organization,

- Simplifying information saving and retrieval through database management system (DBMS) application,

1.4 Work Undertaken

Despite a considerable research carried out on QMS deployment, ISO certification, performance measurement, and data warehousing, the construction industry in many countries still suffers from the difficulties and pitfalls of a systemized application of quality management. Thus, the work undertaken to solve the problem and develop PMSS were mainly:

1. An extensive literature survey on the following subjects:
    - Quality management systems and ISO standards in construction industry,
    - The pitfalls of deploying a QMS and achieving ISO certificate in construction companies,
    - Performance management and performance measurement in construction companies and projects, and
    - IT and data warehousing (DW) and their application to construction industry.
2. A questionnaire survey was conducted to find the major difficulties of construction and project management among Iranian construction companies. A set of structured interviews with 5 construction company managers supported the outcomes of the survey.
3. Based on the literature survey on performance management and performance measurement, an employee performance measurement framework was developed. The important considerations in formula development were:

- Critical management factors of time, cost, and quality considered to be the main parameters for performance evaluation,
- Subjectivity of quality grading must be minimized through considering different parameters such as number of mistakes/errors/deficiencies and employee delay in performing job,
- Employee work experience should be considered in performance calculations,
- Different weighted factors should be applied to each parameter, and
- Stipulating adequate incentive plans for employee acknowledgement, promotion, and motivation,

4. In order to develop the computer program:
    - A survey was conducted among different software development environments and programming languages,
    - Microsoft Visual Studio .NET 2008 was selected for developing the web facilities and user interfaces together with programming parts of the system,
    - Microsoft SQL Server 2005 was selected for database development,
    - PMSS was developed and checked with skilled software developers and construction managers, and
    - After revising PMSS based on the recommendations of the experts, it was installed in a construction company and the short-term feedbacks were achieved.

1.5 Achievements

After installing and running PMSS in a construction company, two types of feedbacks were expected to be achieved: short-term feedback and long-term feedback. The feedbacks proved that:

1. QMS deployment drawbacks would be overcome and reduced by:
    - Decreasing or even eliminating paperwork,
    - Improving communication through web-based application and document transfer mechanism of PMSS,
    - Enhancing documentation through DBMS facilities of PMSS, and
    - Motivating employees and imposing continuous improvement culture.
2. The developed performance evaluation framework proved to be an objective tool for performance calculation. Some of the implementation feedbacks were:
    - Sense of accountability by people for their performance and to understand their contribution importance in the organization,
    - Committed, motivated, and involved employees,
    - More productive workforce,
    - Decision making based on factual employee performances considering their workload and experience,
    - Optimized resources by reducing cost and time while improving quality.
3. The main achievements of PMSS application are, but not limited to:
    - Decision tool for managers to track employee performances,
    - A computerized system with easy installation process that will be installed on company server and can be accessed through different web browsers and via authentication page for authorized people, and

- Various reports related to different aspects of a construction company including administrative, financial, schedule, and projects.

1.6 Thesis Outline

The thesis is organized in eight chapters. In the first chapter, a general overview of the problem is discussed. The objectives of the research, reasons for objectives, work undertaken, and the achievements are discussed in this chapter.

In chapter two, an introduction to quality, history of quality, quality assurance, and quality management system will be reviewed. Construction need to quality, problems and benefits of implementing a QMS, and efforts to overcome QMS implementation difficulties will be discussed in details.

Chapter three explains human resources management, organizational structures, communication, performance measurement, and motivation aspects of project management. These factors have direct influence on QMS deployment success.

In chapter four, research efforts in decision-making and data warehousing in construction industry are reviewed. A brief review of data and information in the industry will be presented followed by the application of IT and decision support systems (DSSs) in construction industry. Finally, the concept of data warehousing, its characteristics and application to construction industry will be reviewed.

Chapter five will discuss the process and outcomes of a questionnaire survey which was conducted among 50 construction companies in Mazandaran, Iran. It aims to demonstrate the level of project and quality management awareness and IT application to regular procedures by the surveyed companies.

Chapter six will introduce the model developed to measure the performance of employees in an organization (PMSS). An office automation system developed using data warehousing and internet facilities of Microsoft Visual Studio.Net 2008 will be

completely discussed. It aims at aligning performance measures with employee development and compensation. It is developed and is based on calculating and recognizing employee performances in real time that can be used as a basis for employee motivation.

In chapter seven, the efforts for evaluating the applicability of PMSS in construction industry, from IT and performance management points of view will be discussed.

Finally, conclusions, limitations of the study, and recommendations for future work will be presented in chapter eight.

Chapter 2

QUALITY IN CONSTRUCTION

2.1 Introduction

"Quality has become one of the most important forces leading to organizational success and company growth in national and international markets. The construction industry is principally project based and quality is one of the clients' major concerns in their construction projects" (Palaneeswaran et al., 2006). Thus, construction companies have been seeking for appropriate methods of applying quality principles to their organizations, processes and projects for the last three decades. One of the most common QMSs best applied to all industries is the ISO 9000 series of standards. Although ISO 9000 application is somehow difficult due to different nature of construction industry, it became the most popular method in recent decades. However; construction companies face various problems during the process of ISO 9000 certification and thereafter, implementing the QMS.

In this chapter, an introduction to quality, history of quality, quality assurance, and quality management system will be reviewed. Construction need to quality, problems and benefits of implementing a QMS, and efforts to overcome QMS implementation difficulties will be discussed in details.

2.2 Quality

Price makes a point about quality when he states that 'the word itself must have been used more in the last ten years than in the preceding centuries, yet the more we

hear it, the more confusing its meaning seems to become'. Everything we do, everything we consume, the service we receive must have quality. But what exactly does quality mean? (Mccabe, 1998)

It is debatable whether there is an answer. Quality, like beauty, appears to be in the eye of the beholder. What constitutes quality to one person may be different to others. In an increasingly competitive market, consumer power is recognized as being a major detriment on the ability of an organization to sell its goods. Thus, the capability to provide what the customer wants is the minimum expectation (Mccabe, 1998).

Quality should no longer be considered as luxury since it is critical for company survival (Pheng and Hong, 2005). It is totally related to thoughts and is value creating tool; thus, it should be considered a primary concern in a company's strategy.

Different definitions may be found in the literature. Definitions such as "zero defects", "conformance to requirements", "customer satisfaction" and suchlike that all want to explain one word which covers a wide range of definitions.

2.3 History of Quality in Construction

Arditi and Gunaydin (1997) explained the history of quality as:

> Until the end of the 19th century, building projects were delivered by master builders, who combined architecture and building. As architects separated themselves from delivery of buildings and engineers became civil engineers first and military engineers second, methods changed. The design phase was totally controlled by engineers and architects through the first half of past century. They carried out a role described as "supervision" during construction, to insure that the owner received his money's worth in terms of quality. Control of time was limited, and often considered a function of luck. Owners became more concerned with cost and schedule in the 1950s and 1960s; areas that were not well controlled by the design professionals. The emphasis continued to be on quality.

As the role of master builders narrowed to that of designer, construction was taken over by the general contractor who had to be concerned with the realities of

maintaining a viable business. He had to spread out his management, seek new jobs and manage effectively to maintain profits. “The sealed competitive bid became popular in the private sector and, to a lower degree, the public sector. This gave the advantage of competitive pricing to the owner. General contractor was also forced to look for every advantage during construction to control cost” (O’Brien, 1997).

“Responsibility for such work was turned over to subcontractors as mechanical and electrical systems became more complex”, which even included quality control of their workmanship. When the general contractor was essentially in complete control of a project, quality control was in inherent duty. Today, with even top-notch contractors brokering out almost the entire project, who is in charge of quality control? The general contractor has delegated responsibility for quality through contract, subcontract and sub-subcontract. At best, the situation is confusing. At worst, it becomes a subject of litigation. At the extreme, it becomes the basis for building failures (Arditi and Gunaydin, 1997).

2.4 Quality Management

When offering a product or service, the minimum objective of any organization or individual is to provide what is expected. There will be a provider and a customer. Both are free to obtain what they can from the transaction and there is usually a market consisting of customers who can willingly purchase wherever they like. Providing they have choice, customers will normally seek to maximize their purchasing power. However, a purchaser has an expectation about what they desire in seeking to maximize their purchasing power. The calculation that occurs is individual and perceptive. In effect, consumers make sophisticated judgments about value. Thus the amount they are prepared to spend provides a guide to the

expectations. Normally we do it every day of our lives in order to achieve satisfaction (Mccabe, 1998).

Reputation plays its part. If you are recommended to use a particular supplier, it is usually because others who have used them think they are good. This does not mean that such suppliers are necessarily expensive. Far from it, they may be extremely cheap in comparison to others. The difference is that their product or service performs well in comparison to competitors. What is worth asking is how do good suppliers achieve their reputation? (Mccabe, 1998)

Most potential buyers rarely bother to verify how suppliers actually manage their organization. As long as buyers continue to get what they expect, they will normally continue to purchase from them. But the important point is that being able to supply what customers want is not something which can be left to chance. It requires management, and quality management is the process that any sensible organization will use in order to consistently satisfy its customers' expectations. It need not be complicated. In fact, it can be summarized as being good or sensible management (Mccabe, 1998).

Based on BS EN ISO 8402 definition, "quality management is all activities of the overall management function that determine the quality policy, objectives and responsibilities, and implement them by means such as quality planning, quality control, quality assurance, and quality improvement within the quality system" (Mccabe, 1998).

2.5 The Four Stages of Quality Management

There is a belief within many researchers that quality management (QM) includes four stages: inspection, quality control (QC), quality assurance (QA) and total quality management (TQM). Figure 2.1 shows the progression from one stage to the next.

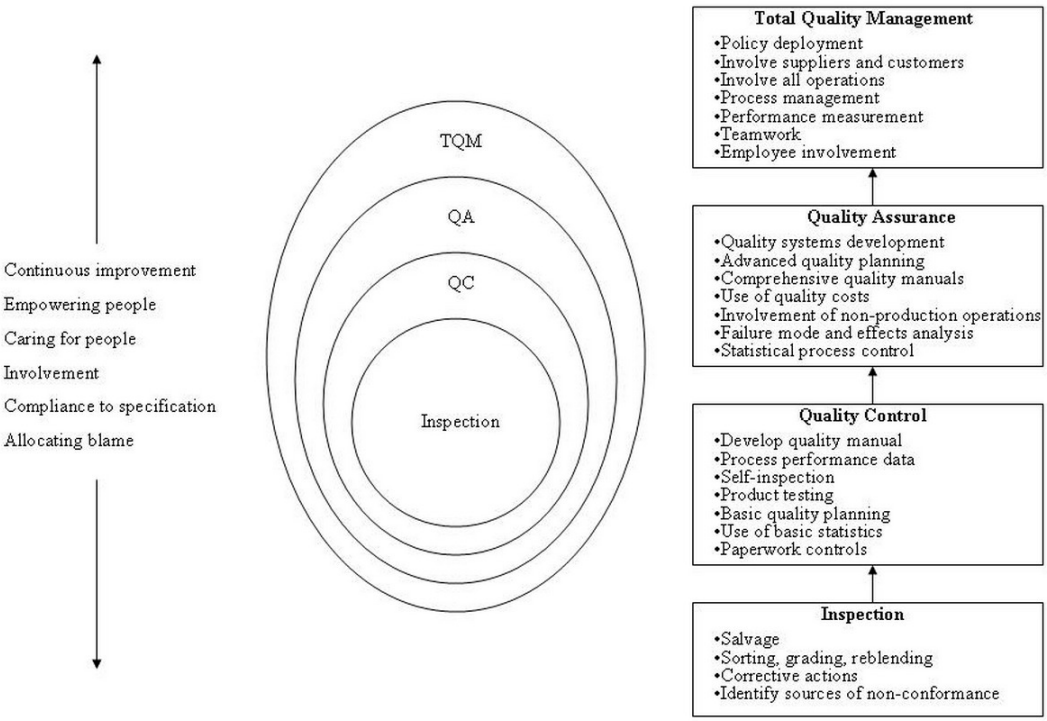

Figure 2.1 The Four Stages of Quality Management (Mccabe, 1998)

Inspection and QC are traditional; they function in a detection mode, aiming to find the occurred problems. QA and especially TQM aim to reduce and eventually to avoid problems occurring. This means they can be used to bring about improvement.

2.5.1 Inspection

BS EN ISO 8402 defines inspection as "activity such as measuring, examining, testing or gauging one or more characteristics of an entity and comparing these results with specified requirements in order to establish whether conformity is achieved for each characteristic". Using inspection to ensure conformance is still widely used in some industries, particularly construction. Much of what is built will be compared to the drawings and specifications. Unless the customer agrees otherwise, the contract requires that anything which does not conform will need to be done again until the client is satisfied that it meets the specification (Mccabe, 1998).

2.5.2 Quality Control (QC)

This stage is often considered as an extension of inspection. According to BS EN ISO 8402, it involves the “operational techniques and activities that are used to fulfil requirements for quality”. QC will require data collection for using statistical techniques. From this information, trends will often emerge which show where certain problems are occurring. This technique is used as a matter of course in manufacturing. It is much rarer in construction. Statistical analysis of concrete cube test results is the one situation where statistics are routinely used (Mccabe, 1998).

2.5.3 Quality Assurance

BS EN ISO 8402 defines quality assurance as being “all the planned activities implemented within the quality system, and demonstrated as needed, to provide adequate confidence that an entity will fulfil requirements for quality”. Essentially what is being advocated is that any organization should aim to logically ‘prevent rather than cure’ problems. In effect, using quality management should be proactive rather than reactive (Kale and Arditi, 2006). This is what QA seeks to achieve by using a recognized QMS such as ISO 9000 (Mccabe, 1998). Some benefits of quality assurance include:

- Meeting customer requirements
- Communicating customer requirements
- Staying on tender lists and getting new business
- Doing it right first time

And some pitfalls of QA:

- Bureaucracy
- Cost

2.5.4 Total Quality Management (TQM)

Although it is not a prerequisite, TQM often follows the implementation of QA. This is a normal transition and should not be interpreted as QA having failed. The change from QA to TQM will need to be carefully managed. Although it normally requires the use of procedures and may be criticized for being too formal, QA does have the advantage of being tangible. It is possible to see how well the system is being accepted by auditing. If the procedures are being adhered to, the QA system can be judged successful. If procedures are not being adhered to, then they need to be rewritten or the users need more explanation of what is required. TQM is less formal, having neither system nor procedures, but its very lack of formality makes it more difficult to describe. It is often described as a philosophy, which requires change in things like attitude, management style and culture (Mccabe, 1998).

According to BS EN ISO 8402, TQM is a "management approach of an organization, centered on quality, based on the participation of all members and aiming at long-term success through customer satisfaction, and benefits to all members of the organization and to society" (Mccabe, 1998).

Five essentials for TQM as stated by Mccabe (1998) are "intense focus on customer, concern for continual improvement, improvement in the quality of everything, accurate measurement, and empowerment of employees."

2.6 Construction Need to Quality

> The construction industry must be tuned to provide products and services that satisfy the valid requirements and expectations of its customers. Construction is a competitive business that is hurt by absenteeism, low morale and high turnover. (Lew, 1991)

During the 1980s and when government and large clients began to support quality assurance as a way of making the industry more efficient, one of the main spotlights was that it contained nothing fundamentally new. It was all about doing the best with

the single difference that conformity to procedures and methods should be documented, so that it could be assured that what a firm said was being done was in fact done. QA systems were set up to satisfy customer requirements. Many were doubtful about how useful they were going to be, and expected a considrable extra paperwork resulting from the imposed procedures (Mccabe et al., 1998).

Quality management is one of the most critical factors for successfully managing construction projects. Many recent studies have focused on Quality and quality systems (Ahmed et al., 2005; Pheng and Hong, 2005). Clients' demand is believed to be the main motivator towards this orientation. Clients are becoming ever more knowledgeable and demand higher quality levels in order to satisfy their needs.

Quality in construction might be viewed as a part of a triangle in which the contractor should accomplish the planned cost level, meet the schedule deadlines, and attain the quality level as required. An equitative balance among these three aspects is considered as ideal. However, quality may be the first of these components to be disregarded or sacrificed in favor of increased cost savings and time reductions (Chini and Valdez, 2003; Egemen and Mohamed, 2006; Turk, 2006; Roy et al., 2005; Tam et al., 2000; Rwelamila et al., 1995).

Numerous quality standards have been developed and adopted over the years (Liao et al., 2004). One of the most common QMSs applied to different industries including construction industry is ISO 9000 series of standards. "ISO 9000 quality management standards were first issued in 1987 by International Organization for Standardization which is located in Switzerland" (Khan and Hafiz, 1999). The introduction of ISO 9000 has influenced the development of organizational efforts towards quality assurance to a great extent. According to Kale and Arditi (2006), "ISO 9000 is one of the most important administrative innovations of the last two

decades." Construction companies adopt ISO 9000 as the basis for their QMSs (Turk, 2006; Ng, 2005; Love and Li, 2000; Hiyassat, 2000; Motazed-Keivani et al., 1999); however, it should be considered that "ISO certification by itself does not guarantee the quality of products or services of an organization to be better than the quality of other organizations" (Palaneeswaran et al., 2006).

"The original ISO quality standards from 1987 went through a major revision in 1994" (Sroufe and Curkovic, 2008). The prerequisite for registration to the standards is having a documented and demonstrable in place quality system to declare that what is said by an organization is consistently produced (Martinez-Costa et al., 2009; Sroufe and Curkovic, 2008; Bhuiyan and Alam, 2005). The 1994 version of the standards created widespread criticism which caused another revision in 2000 which even changed the title of the standards from "Quality Assurance" to "Quality Management". Thereafter, it was applied successfully since the latest revision was released on 2008.

ISO 9000:2000 and ISO 9000:2008 quality management standards are based on eight principles which would be applicable for organizations' performance improvement. These principles include customer focus, leadership, involvement of people, process approach, system approach to management, continual improvement, factual approach to decision making, and mutually beneficial supplier relationships

2.7 Problems, Benefits, and Objectives of Implementing the QMS

Although QMS implementation by construction companies has been emphasized by many researchers, these companies face different difficulties during QMS implementation process.

One of the most important problems in a QMS implementation is paperwork and documentation. "Managing the system documentation as a result of the extremely

arduous and bureaucratic QM documentation requirements is difficult for contractors" (Lam and Ng, 2006). This problem was mentioned in other researches carried out by Foster (2008), Sroufe and Curkovic (2008), Turk (2006), Delgao-Hernandez and Aspinwall (2005), Chin et al. (2004), Tsekouras et al., (2002) Pheng and Wee (2001), Dissanayaka et al. (2001), Love and Li (2000), and Motazed-Keivani et al. (1999). By ineffective maintaining of the QMS, companies might not be able to achieve the quality system objectives and might be directed into wrong directions such as "managing the documentation aspects of the system." Therefore, a computerized system especially a system capable of performing database management can help construction companies to overcome this problem and commit to QMS more confidently.

Studies show that many companies' reason for obtaining ISO certificate and developing a QMS has been their customers' pressure. Lack of employee interest and motivation can deter the QMS performance (Sroufe and Curkovic, 2008; Lam and Ng, 2006; Rodriguez-Escobar et al., 2006; Ng, 2005; Pheng and Wee, 2001; Dissanayaka et al., 2001; Love and Li, 2000; Kumaraswamy and Dissanayaka, 2000). Many companies apply a QMS and obtain ISO certificate since it is a mandatory requirement and prerequisite from the clients to be able to enter tenders and thus, this certification became a work permit. These companies perhaps have not correctly understood the fundamentals of quality and management which in turn, would affect the company and the personnel's morale and makes the goal difficult to achieve.

"Implementing quality management in the construction industry is complicated since it is rather less structured; therefore, a sustainable improvement in quality is hard to achieve. The construction industry has continuously been motivated for many

years for better methods of working in order to achieve quality objectives. Unfortunately, the quality of construction services and facilities is still the core cause of many problems" (Lam et al., 2008).

Other limiting factor in the application of a QMS in a construction company is the resistance of workforce. "It is difficult to force site personnel to use the system due to excessive workload" (Lam and Ng, 2006). It is very difficult to educate the employees to adopt new work procedures. "These inflexible staff may bypass the checking procedures by just signing the forms without doing the actual checking" (Lam and Ng, 2006; Serpell, 1999). On the other hand, workers possibly perceive new procedures as controlling while top management might believe that they are providing empowered jobs (Fok et al., 2000) or from the opposite view, individuals accept the concept of empowered jobs in the TQM environment, but they may not want empowered jobs.

Poor communication among project participants is another factor which can cause various problems in adopting a QMS. "Poor communication may occur in various forms among various parties in the construction process" (Pheng and Wee, 2001; Kim et al., 2008; Tam and Le, 2007; Chin et al., 2004; Motazed-Keivani et al., 1999). "QA, mainly in the common form of dictates from above, can easily become a tool for asserting the control of higher levels in the chain of command over those lower in the chain, e.g. clients over the main contractor, managers and engineers over the workers, etc. This leads to restricted communication between the various parties, a doubtful environment and additional disagreements" (Motazed-Keivani et al., 1999).

Continuous improvement is an important focus of a QMS which is also been emphasized in ISO 9000:2000 (Ng, 2005). Construction companies can only realize

continual improvement if they are aware of their deficiencies and weaknesses and try to satisfy their clients' expectations. Some features of construction industry make it different from other industries especially in achieving continuous improvement which are mentioned in a research conducted by Öztaş et al. (2007). These features are:

- Long time is required to complete a construction project;
- One time human relationships creation;
- Difficulty in defining quality standards;
- Difficulty in achieving feedback from the processes;

"Most manufacturing are systems of mass production wherein all of these factors are consistent with producing typical products over and over again, but a construction project is usually a unique collection of people, equipments, and materials brought together at a unique weather conditions under unique circumstances" (Lam et al., 2008; Öztaş et al., 2007; Turk, 2006; Landin, 2000; Motazed-Keivani et al., 1999; Serpell, 1999; Bubshait and Al-Atiq, 1999). It can also be noticed that new workers hired for a new project may not feel too responsible for the quality aspects of the project which in turn emphasizes on the need for a QMS capable of performing quality requirements in all conditions and independent to the changes in the resources. The construction end product is not a repetitive unit, but an endeavour that may be unique in its design and composition. Internal and external factors such as community response, construction cost, and time of delivery must be addressed in the design and construction of a building (Chini and Valdez, 2003). It is also pointed out by Turk (2006) that "unlike other industries, the products and services in the construction industry are unique or in other words, not repetitive."

Thus, it is difficult to apply recurring and prototype methods to construction projects and processes (Ozorhon et al., 2007).

"Temporary construction work force is rather different from the quite stable manufacturing work force. This may make it more difficult to train workers, especially skilled workers, for the construction industry" (Kazaz and Talat Birgonul, 2005; Arditi and Gunaydin, 1997; Tam and Le, 2007). It cannot be expected from the construction skilled workers to be involved to the company's QMS; however, providing a proper work procedure to the worker can lead the company to gain its aims. Some companies prefer to have their own workforce and perform all projects by them as mentioned by Pheng and Wee (2001), but this is not possible for many companies and they do not have the financial capacity to support their workforce and thus, prefer to sub-contract some activities during the construction process. On the other hand, "construction work involves several parties with different professional backgrounds" (Lai and Cheng, 2003) which will affect the construction end product if they want to apply their own procedures.

2.8 Efforts to Overcome the Difficulties of Implementing a QMS

Lam and Ng (2006) used a prototype IFQM (Internet Facilitated Quality Management) to minimize the paperwork through internet application. Each project in the system would have a specific account through a registration process. Project stakeholders would also register for accessing and authentication purposes. The system would provide different access rights and authority levels for companies since every company might require different QM information or reports. For instance, client would have access to most of the project-oriented QM data submitted by any user, and this would enable the client to monitor the project progress and performance.

The QM data entry would be performed while project proceeds through standardized QM forms. The users could login in two different ways: by project ID and password (made available by client) or their own ID and password. The forms are categorized in four stages of design, tendering, construction, and operation and the user would select the appropriate one for the specific work. The completed forms would then be online submitted to the system. The QM data would then be resided in the server-based DBMS. “Assuming the residence engineer has discovered a defective structural component during the construction stage, he/she would fill out a non-conformance form to formally record the details of nonconformity, location, date of discovery, etc. Upon receiving the engineer’s notification, the contractor might arrange a joint inspection with the resident engineer, and a corresponding form would be completed by the contractor’s representative to outline their observations, agreed remedial measures, and the responsible parties” (Lam and Ng ,2006). All documents would be saved in project database. Useful reports could further be extracted from the QM records. The reports could be used for planning the subsequent processes and inspection or testing plans and more important, the source of any possible delay would be recognized for liability establishing in case of necessity. The reports could also help client to monitor project and to facilitate him to establish contractor’s performance more objectively. The program was aimed to reduce paperwork through easier communication in QM documentation during different stages of a construction project. It mainly focused on quality inspection and cannot help projects overcome problems such as delays, defects, and cost overruns. It made the quality inspection activities and processes more structured and manageable for different parties involved in the project.

A QS (Quality System) process based on ISO 9000:2000 was modelled by Chin et al. (2004) which aimed to improve the quality management productivity in the construction industry. Three Korean general contractors involved in the study and the model was built based on these contractors' ISO 9000 documents. The model consisted of three activities: customize for a specific project, activity-based quality management, and update company-wide quality plan. Each activity was used for specific purposes such as "developing project-specific quality documents, providing quality plans and establishing collaborations among project participants, and updating standard quality information based on the feedback and as-built quality information." The system could help construction companies in overcoming heavy paperwork and communication inefficiencies and therefore the model helped improving the productivity of the process by IT implementation.

The developed system was internet-based and concentrated on inspection processes to support collaboration and communication within construction project environment. Its primary focus was on the QS process of the general contractor. It also supported documentation through integrated facility to attach photos and scanned images to reports.

Turk (2006) identified more systematic paperwork and documentation as one of ISO 9000 QMS certification results in Turkish construction industry. He emphasized on ISO 9000 application in construction industry in Turkey that other countries could achieve advantages through ISO 9000 certification. Although it is believed that ISO 9000 certification will help to create a more systematic paperwork and documentation, the survey results showed that the increase in documentation was the most important disadvantage of ISO 9000 certification among Turkish construction firms; however, no method was introduced to be as a tool to overcome this problem.

It was finally recommended that effective use of IT can help construction firms in reducing paperwork and solving the documentation problems.

Increase in paperwork was considered as one of the debates about suitability of ISO 9000 QMS to construction industry in a research carried out by Pheng and Wee (2001). They believed that this problem would reduce rather than enhancing quality. It was mentioned in their research that defective documentation and poor communication are important causes of defects in a project. Documentation defects might be due to inaccurate information, insufficient information, missing data, inaccurate drawings and such like. “When one party assumes knowledge and experience in the other and therefore fails to draw sufficient attention to certain details, poor communication arises that could be critical to proper construction” (Pheng and Wee, 2001). A main building contractor in Singapore which had implemented a quality system was considered to study the system functioning and to survey the effects of ISO 9000 QA standards on building defects control. The company had established an effective communication and documentation system to control the most detailed characteristics of every action such as “all related procedures to the detail of identifying the person involved in the particular action, from whom it is to be received, what is to be done to it and finally to whom it is to be given.” A set of detailed flowcharts were necessary to represent all activities. The study analysed the effects of ISO 9000 application on defect reduction in a construction company but it did not provide a proper solution to specific problems especially paperwork and communication.

Dissanayaka et al. (2001) found that more paperwork is the major drawback of ISO 9000-certified quality system in their survey among Hong Kong constructors. Although increased bureaucracy and more paperwork, higher project cost and more

time spent on management were negative points of ISO 9000 certification, most of the ISO 9000-certified constructors generally agreed that high net benefits were achieved. The research did not propose any solution to the negative outcomes of the certification process such as paperwork and bureaucracy.

Love and Li (2000) pointed out to the documentation requirements of ISO standards which are extremely difficult and bureaucratic. The documents should be maintained effectively, otherwise, “the organizations may find themselves being channelled into managing the documentation aspects of the certification process rather than into achieving the objectives of the quality system” Love and Li (2000). Effectiveness of quality certification in construction was studied throughout building and engineering contractors. One of the most important problems in ISO 9000 certification was observed to be documentation since almost none of the employees had experience in procedure writing. From third-party auditor view, to eliminate and overcome quality deficiencies and poor quality services and products, an organization must accept the paperwork required for certification. It was stated by one of the surveyed company managers that documentation and paperwork brought stress and workload to staff. Finally an external consultancy was inquired and they recognized that “management had not made it clear to staff that standards do not improve quality and only people do.” The management and consultant then tried to gain employee commitment by changing the way from focusing on new quality system development to integration of all necessary processes to daily works. “As a result, the quality system was no longer seen as being separate from people’s jobs. Instead of having quality built around the standard, the standard was adopted to the work that people were doing both in the office and on site.” Therefore the company

could overcome the excessive paperwork and documentation and some other problems by only a strategic change in the application method.

Kim et al. (2008) carried out a research on Korea building defect management. Due to high population density in South Korea and apartment housing demand and due to similarities in interior designs, customers claimed for changes especially in finishing materials. Therefore, quality inspection and defect management of the finished housing units attracted more attention to satisfy customers' diverse tastes. However, there were many deficiencies near the project completion time due to low number of on-site staff to survey for defects and control the quality, extra workloads for meeting deadlines, large number of documents which should be manually filled and lack of unified checklists, and poor communication between project participants. The authors therefore proposed a "Personal Digital Assistant (PDA) and wireless web-integrated Quality Inspection and Defect Management System (QIDMS) to collect defect data at a site in real time, and manage the statuses and results of the corrective works performed by crews." The system aimed to reduce paperwork and data transfer from paper to PC, create a unified data recording system, provide easier way to follow and monitor defects correction procedures, make prompt corrective actions through interaction with different professionals, strengthening communication among on-site quality managers with other participants in managing and correcting defects, and to create a repository of data and feedback system for future reference. After creating a specific project's database and introducing the project details in the main server, all processes including "data collection, exchange, and defect management" could be performed through "PDAs, wireless internet, and relational databases". Quality inspectors would receive generated e-checklists on-site through central server and PDA and the inspection results would then be submitted to

the server. The corresponding contractor would receive the list of defects with descriptive corrective actions and after correction were applied, the result would be transferred to the main server and approval or rejection of the final work would be attested by on-site staff after performing rechecks. Quality inspection and defect management would be performed in real time since all data transfer could be done through wireless internet and PDA and also all data would be saved in main server. The developed system focused on PDA and wireless internet application in defect management and quality inspection of finishing works at the completion stage of apartment housing projects and helped making communication and documentation processes of final inspection procedures easier and faster.

Motazed-Keivani et al. (1999) pointed to particular characteristics of construction industry in their study on UK construction industry and ISO 9000 standards experience. They considered design and construction separation as one of the main reasons of quality defects. They also stated that “it seems QA can easily become a tool for asserting the control of those higher up in the chain of command over those lower in the chains, e.g. clients over the main contractor, main contractor over subcontractors, managers and engineers over workers, etc.” This would undoubtedly lead to constrained communication between various parties and subsequently will limit the quality system effectiveness. The study was performed of a survey among 12 ISO 9000 certified UK construction companies to find out reasons of adopting a QA system, impacts of ISO certifications, and finally negatives outcomes of certification. They concluded that increase in paperwork and more bureaucracy, higher cost, more time consumption, and also lack of innovation were the most important negative impacts of ISO 9000 certification. The research only summarized

the experiences of a number of UK construction companies and did not provide a solution to the negative impacts of QA system implementation.

All the problems of achieving a proper QMS, together with the benefits and advantages of a QMS for a construction company were the motivators for developing a QMS using data warehousing method which could be an effective tool to overcome the difficulties and simplify the achievement of the QMS implementation advantages.

Chapter 3

HUMAN RESOURCES MANAGEMENT AND PERFORMANCE MEASUREMENT

3.1 Introduction

"Technological advancements, dynamic markets, tough global competition, and complex organizational structures" have highly influenced the survival of construction organizations. Effective management of human resources is agreed by most project management professionals as one of the toughest challenges they face (Verma, 1995).

People's role in success or failure of an organization is undeniable. "If people are committed to the organization, the way it is organized, and the organization's human resource management climate, they will turn ordinary performance to extraordinary performance" (Verma, 1995). In order for an organization to develop a successful QMS, special attention must be paid to human aspects of the organization.

This chapter aims to explain human resources management, organizational structures, communication, performance measurement, and motivation aspects of project management. These factors have direct influence on QMS deployment success and were utilized as the basis for developing an office automation system.

3.2 Human Resources Management

Managers of the organizations must understand the human side of their organizations if they want to compete and survive in highly competitive market. It is

sometimes forgotten that despite the recent information and technology revolution in project management, people are at the center of organizations and they determine the success or failure of the organization. People are the backbone of any organization and its most importance resource (Verma, 1996). Therefore, human resources management is a vital component of project management. Project Management Body of Knowledge considers human resources management as one of the eight knowledge areas (PMBOK, 2004). Kazaz and Ulubeyli (2007) conveyed in their research on productivity drivers among construction workers that human resources are recognized as vital strategic resources for any organization in ensuring improved productivity and competitiveness. They stressed that with effective utilization of human resources, the productivity of all other production inputs such as materials and equipments is simultaneously enhanced.

Most of the project management problems are of a behavioural nature; therefore, managers must understand the dynamics of human behaviour and how it influences relationships, perceptions and productivity. Better understanding of people with effective communication and interpersonal skills will help managers to influence and motivate employees and hence to optimize their performances which ultimately affects organizational performance. The most important interpersonal skills stated by Verma (1996) that a manager should acquire include effective communication, motivation, negotiation, conflict management, stress management, and leadership.

The importance of human resources management from top management workforce to the non-management workforce in establishing a QMS in organizations is emphasized in different studies such as Jiménez-Jiménez and Martinéz-Costa (2009), Martinéz-Costa et al. (2008), Tarí and Sabater (2004), Galelli (2002), Pheng and Wee (2001), Fok et al. (2000), and Serpell (1999).

The impact of human resource management on organizational performance and operational performance are also the subject of interest in different research studies (Jiménez-Jiménez and Martinéz-Costa, 2009; Ahmad and Schroeder, 2003; Jayaram et al., 1999).

3.3 Organizational Structures

The structure of an organization can positively influence projects, or lead to problems such as delays, which prove to be time consuming and costly. According to Verma (1995), “Designing an organization is the process of selecting a structure and the formal systems of communication, division of labor, coordination, control, authority, and responsibility necessary to achieve organizational goals”. An organization can improve itself through proper information flow and enhanced decision making, clarified authorities and responsibilities, and establishing the requires coordination levels through creating a good organizational structure.

Organizational structure is the pattern of formal relationships that exists among project teams and individual team members in an organization (Verma, 1995). Simply drawing an organizational chart is not enough to ensure success in an organization. Clear job descriptions, correct communication lines, and formal reporting relationships should be considered in designing the organizational structure to guarantee its applicability.

Since each employee has specific skills and each position in organization needs its appropriate expertise, individuals in the organization should be assigned responsibilities that match their abilities and skills. If clear job descriptions are not defined during organizational structure design, or if proper people are not assigned to correct positions, it will cause negative results.

Designing appropriate organizational relationships involves designing an organizational hierarchy to facilitate the execution of tasks by providing a proper arrangement of authority and responsibility to oversee the execution and completion of assignments.

“Organizational structure must comprise formal reporting relationships, including the number of levels in the hierarchy and the span of control of managers and supervisors” (Pinto, 2007). In a well-designed organizational structure, it should be identified that who reports to whom. This would assist employees to avoid many conflicts and create a trust-based environment with openness in communications within the organization.

Construction projects are very complex and require an immense amount of information to be exchanged. A proper organizational structure is a basis for identifying the channels through which the information will flow.

3.4 Types of Organizational Structure

Some common structural types that classify the majority of firms are functional organizations, project organizations, and matrix organizations.

3.4.1 Functional Organizations

The most common organizational type used in business today is probably the functional structure (Pinto, 2007). It is based on the logic that “people and departments performing similar activities should be grouped into units.” It is common in this type to create different departments such as design department, accounting department, or research and development department. The main consideration in a functional structure is the skills of the employees and labors; therefore, members might simultaneously work on multiple projects or support multiple product lines. Although efficiency is one of the most important strengths of

functional structure, slower communication, lack of direct ownership of the projects, and competing priorities among the functional departments are some of its weaknesses (Pinto, 2007).

3.4.2 Project Organizations

Project organizations are those that are set up with their exclusive focus aimed at running projects (Pinto, 2007). Within the project organization, each project is an independent business unit within the organization with a devoted project team. The firm assigns resources from functional pools directly to the project for the required time period. Project manager's sole authority, improved communication across the organization, effective and speedy decision-making, and rapid response to market opportunities are some of the advantages of this type. On the other hand, expensive setting up and maintaining teams, deploying loyalty to the project rather than to the organization by project team members, and future career of team members after project end are important disadvantages of project organization structures (Pinto, 2007).

3.4.3 Matrix Organizations

Matrix organizations are combination of functional and project structures and seek a balance between them by focusing on function and project at the same time (Pinto, 2007). It creates a dual hierarchy with a balance of authority between the project emphasis and the firm's departments. Matrix organizations are best suited to "dynamic environments, emphasize the dual importance of project management and functional efficiency, promote coordination across functional units, and maximize limited resources between competing project and functional responsibilities" (Pinto, 2007). On the other hand, dual hierarchies mean two bosses, it requires considerable time to be spent "negotiating on critical resources sharing between projects and

departments, and can be frustrating for workers caught between competing project and functional demands" (Pinto, 2007).

3.5 Communication

"Inadequate coordination and inefficient communication of project information and data has been the root cause of the two-thirds of the construction problems" (Dawood et al., 2002). The communication flow within an organization in the construction industry plays an important role in the success of all projects. In order for the employees to improve performance, effective communication must exist, or be implemented. Verma (1995) defines communication as "a process by which information is exchanged between individuals through a common system of symbols, signs, or behavior." Pheng and Wee (2001) overemphasized the effect of poor communication on a high percentage of worker resistances, aggravation, and inefficiencies in working relationships.

According to Verma (1996), "Project management involves formal and informal communication at different levels in the organization." Such communication includes all the activities and behavior used to transfer information or ideas between manager and individuals working in the organization.

As stated by Verma (1996), "a significant number of project problems are caused by poor and/or ineffective communications." He further stressed that "effective communication is the key to success for the individual as well as for the projects and organizations."

As a part of management communication framework, an organization must ensure that clear lines of authority exist and that every member of the organization knows what he or she must do to enhance organizational performance. This is essential for motivating all the employees. To have a balanced management communications,

adequate feedback paths through and across the organization should be provided. It allows progress monitoring, reporting back difficulties to executive management and expert specialist advice on technical or commercial problems to be required by any participant (Lock, 1996).

In a study on the "effects of communication methods and information sharing on firm performance," Carr and Kaynak (2007) grouped communication methods to traditional methods and advanced methods. Traditional communication methods mostly involve the use of written or face-to-face contact, telephone, fax, and e-mail. "Advanced communication methods refer to computer-to-computer links, electronic data interchange (EDI), and enterprise resource planning (ERP)."

"Construction is a multi-organization process" which is heavily dependent on large complex data and information exchange. Accurate and timely information exchange among project participants plays an important role in the successful completion of the project. One of the barriers to the innovative construction processes is the inefficiency of the current communication practices (Dawood et al., 2002).

Current improvements in IT help organizations to develop effective management information systems (ISs) to monitor progress and facilitate good communication. However, they should be such designed and implemented carefully to be economic, efficient, and effective. Carr and Kaynak (2007) and Arslan et al. (2006) emphasized the effect of IT on communication. They stated that due to its communication facilities, people in an organization interact more frequently when they use IT.

"With the available and rapidly evolving IT, the construction industry needs to develop an improved communication process more than ever." Several research studies focused on taking advantage of evolving computer technologies in the

construction industry through data standardization. These technologies like Internet have significantly impacted other industries such as manufacturing by improving performance and productivity.

3.6 Performance Management

Performance management is a commonly used method to measure and improve performance and to engage employees in achieving organization's goal and objectives. Organizations interested in establishing a continuous improvement culture, apply performance management concepts. Managers use performance management as a systematic method to evaluate and track employees continuously and as a decision-making tool. Galelli (2002) pointed out that systems such as performance management influence employee performance and as a consequence, the success or failure of total quality initiative.

A great deal of research has been done that look at different aspects of performance including organizational performance, project performance, supply chain performance, and subcontractor performance; however, as stated by Isik et al. (2010a), they have mostly focused on manufacturing industries and the ones in construction industry, concentrated on project performance measurement.

Literature shows a considerable increase in the fields of supply chain performance and its effects on company performance (Zelbst et al., 2009; Gulledge and Chavusholu, 2008; Koh et al., 2007; Wong and Wong, 2007; Morgan and Dewhurst, 2007; Caputo et al., 2004), and company performance management and measurement (Phusavat et al., 2009b; Ho, 2008; Velcu, 2007; Lin and Kuo, 2007; Choy et al., 2006; Rao, 2006; Liang et al., 2004; Bose, 2004; Saad, 2001; Chen et al., 2001; Kuo et al., 1999). However, little research has been conducted on employee performance and more specifically, quantifying employee performance.

People can make more effective and confident decisions if they are “well informed about their current and likely future levels of performance” throughout an organization. Management based on measurement with focus on objective factors leads to success, as employees and management are informed and allowed to take action when required. Major performance management benefits include:

- Better objectives achievement,
- Faster and quicker decision-making,
- Aligning common goals for the staff, and
- Highly motivated and more confident managers and staff.

3.7 Performance Measurement

“Measurement is considered as a key management activity which can provide decision makers with essential information for decision making, performance monitoring and effective resources allocation” (Kutucuoglu et al., 2001) and has become subject of considerable interest over the last 20 years (Isik, 2009).

Bourne et al. (2000) emphasized on the considerable interest in performance measurement. They briefly pointed to the history of performance measures that “in the late 1970s and 1980s, a general frustration was observed with traditional accounting based performance measurement systems, identifying their shortcomings and arguing for change. In the late 1980s and early 1990s, this frustration led to the development of “balanced” or “multi-dimensional” performance measurement frameworks, which placed emphasis on non-financial measures.”

Performance measurement is not simply a data collection exercise, but rather a management practice to realize, validate and improve operations. Every organization must employ performance measures to assess and monitor personnel effectiveness, efficiency and productivity.

Amaratunga and Baldry (2002) defined performance measurement as “the process of quantifying efficiency and effectiveness.” This definition was emphasized by Franco-Santos et al. (2007) and Neely et al. (2005). Performance measurement involves systematic data collection and an objective manner to determine the efficiency and effectiveness of whatever to be evaluated and decided. Performance management is the application of such data into an integrated management system to move an organization towards the achievement of strategic objectives.

Performance measurement can benefit organizations by:

- Strengthening accountability,
- Enhancing decision-making,
- Improving customer service,
- Assisting in determining effective resource use, and
- Supporting strategic planning and goal setting.

An effective system of performance measurement is an essential decision-making tool for managers. It is also an essential element in achieving the organization’s goals and objectives.

“ISO 9001:2008 clearly specifies performance measurement as part of its requirement no.8. Performance measurement could bring more scientific analysis into a decision-making process. It highlights the change from traditional management based on experiences and judgement towards management by information and knowledge” (Phusavat et al., 2009a).

According to Ukko et al. (2007), “one of the main purposes of performance measurement is to convey consistent information for effective decision-making.” They stated that performance measurement systems aim to “turn the focus of employees’ on issues that are important to the company, by relating key objectives to

the employees' jobs and continuous reviews." Performance measurement systems improve people's satisfaction and align their behavior towards continuous improvement.

As notified by Moxham (2009), Johnston and Pongatichat (2008), Smith and Smith (2007), Bititci et al. (2006), and Bititci et al. (2000), the past 15 years have seen considerable research and development in performance measurement field which resulted in the generation of different models, frameworks and methodologies by practitioners, consultants and academics. Performance measurement methods were attracted by researchers (Isik et al., 2010b; Lehtinen and Ahola, 2010; Phusavat et al., 2009a; Cousins et al., 2008; McAdam et al., 2008; Phusavat and Photaranon, 2006; Neely, 2005; Neely et al., 2005; Hudson et al., 2001; Neely et al., 2000). The factors affecting performance measurement in different research studies are based on one or a combination of some criteria like finance, operations, quality, safety, personnel, and customer satisfaction. Methods like the balanced scorecard, Malcolm Baldrige Criteria for Performance Excellence, performance prism, performance measurement matrix, lead performance measurement and benchmarking, performance pyramid, performance measurement questionnaire, data envelopment analysis (DEA), Skandia navigator, and some new methods are widely used.

The balanced scorecard (BSC) developed by Kaplan and Norton on 1992 "includes operational measures on customer satisfaction, internal processes and the organization's innovation and improvement activities, as well as financial measures. Thus, BSC provides managers with a balanced presentation of both operational and financial measures" (Neely et al., 2005).

"Malcolm Baldrige Criteria for Performance Excellence provides a somewhat different framework. It divides performance measures into customer, financial and

market, human resource, supplier and partner performance, and organizational effectiveness" (Evans, 2004).

Wang (2005) developed a knowledge-based DSS to measure the government real estate performance of investment projects in China. He used DEA to perform efficiency analysis. "DEA is a linear programming approach for measuring the relative efficiency of units in a group of units. DEA has been widely applied to different industries such as finance, universities, medical care, IT, airlines, and tourism" (Wang et al., 2008; Wang, 2005).

"The performance prism considers a five-faceted performance framework. The top facet is stakeholder satisfaction while the bottom facet is stakeholder contribution. The other three sides are strategies, processes and capabilities. On the other hand, it places emphasis on stakeholder requirements." It emphasizes the alignment of capabilities necessary for operation of the processes (Nudurupati et al., 2007).

Ho (2008) states that "performance refers to the achievement in quality and quantity of individual or group works." Employees are critical components of business success (Ho, 2008) and their performances directly influence the company performance (Green et al., 2004). Thus, effective strategies to motivate and enhance employees' competency are in urgent needs for companies. Literature does not show much work on employee performance. Medlin and Green (2009) examined the relationship between "employee engagement and employee optimism" as a tool to enhance employee performance. Kuo et al. (1999) performed a research on using productivity and attendance as evaluation criteria for employee performance. Tarng and Liu (1994) developed a document management system that creates microfilm from all documents which in turn could be used to evaluate employee performance.

Green et al. (2004) stated that methods, techniques, and processes to improve employee and organizational performance have been the focus of business managers. Laitinen (2009) emphasized on the role of management ISs in delivering information to managers. The role of ISs and database systems on performance measurement was discussed in a study conducted by Phusavat et al. (2009a). Laitinen (2009) found that almost 23 percent of CEO total working time was spent on getting information. He continued that taking informing and reviewing information into account, the information-handling could occupy 51 percent of the total working day on average. Based on an extensive literature survey on performance measurement systems and their application to construction industry, Nudurupati et al. (2007) found that performance measurement remains unexplored in construction sector due to its complex supply chain and relationships and different clients with variable needs and goals.

One of the most critical types of information necessary for monitoring employees' performance is believed to be personnel performance information. Some difficulties of managing without performance measurement are pointed out by Phusavat et al. (2009a).

Recently, "performance measurement systems research has developed outside the IS research field." A few attempts have been applied to link IS and performance measurement systems, "but these attempts have been isolated." Performance measurement systems lack the references to IS research and "these systems are not present in the mainstream of IS knowledge" (Marchand and Raymond, 2008).

3.8 Motivation

In all organizations, people use their human skills to perform the assigned jobs with the highest quality within the specified constraints. Human factors in project

management must be emphasized to create an environment in order to encourage effective and open communication and environment with motivated and committed employee to produce their best. Most employees seek for job satisfaction; a sense of accomplishment and growth; and enough financial reimbursement and other rewards (Verma, 1996). Satisfied employees do their best at work; thus, managers must understand the dynamics of human behavior in order to create an environment in which all employees feel motivated.

Motivation has been defined as “the process of inducing an individual to work toward achieving project objectives while also satisfying personal objectives. Motivation helps people energize themselves to overcome political, bureaucratic, and resource barriers to change” (Verma, 1996). Hartmann (2006) defined motivation as “the main force through which individuals allocate effort to generate and implement new ideas.” Tabassi and Bakar (2009) defined motivation as “the characteristics of an individual willing to expend effort towards a particular set of behaviors.”

Overall organizational success is dependent upon the motivation and performance of employees. While it is well known that motivated and satisfied employees always do their best and produce quality results, it is important to recognize that motivation is an internal phenomenon that causes individuals to contribute extra effort voluntarily; thus “performance is a function of ability and motivation” (Verma, 1996).

Islam and Ismail (2008) defined motivation as “what moves us from boredom to interest. Motivation is a force that energizes behavior, gives direction to behavior, and underlies the tendency to persist.” They stated that “motivation represents those psychological processes that cause the encouragement, direction, and persistence of voluntary activities that are goal oriented.”

As stated by Garcia (1997), “there is a direct correlation between motivation and productivity.” The employees must feel a sense of importance to the organization in order to be productive. They must be motivated “to feel as if they are an integral part of the organization.” The effect of motivation on performance was also emphasized by Amaratunga and Baldry (2002).

Motivation has also an undeniable effect on quality improvement. In a survey among a number of executives, American Society for Quality found that employee motivation appears in the first place among eight different methods for improving quality (Galelli, 2002). In an organizational change effort, individuals are expected to improve their particular way of doing their jobs, leading the organization to improved performance. In other words, members of an organization are supposed to change behavior, for which the issue of motivation plays a decisive role.

Verma (1996) considers “six core phases in the motivational process.” These include:

1- “Identify the person’s needs” (psychological such as the need for recognition, physiological such as food or clothes, or social affiliation like friendship),
2- “Create drives,”
3- “Select goal-directed behaviour,”
4- “Perform the task,”
5- “Receive feedback,” and
6- “Reassess needs and goals.”

This model, presented in Figure 3.1, is however oversimplified and in the real world, the process is not so clear-cut.

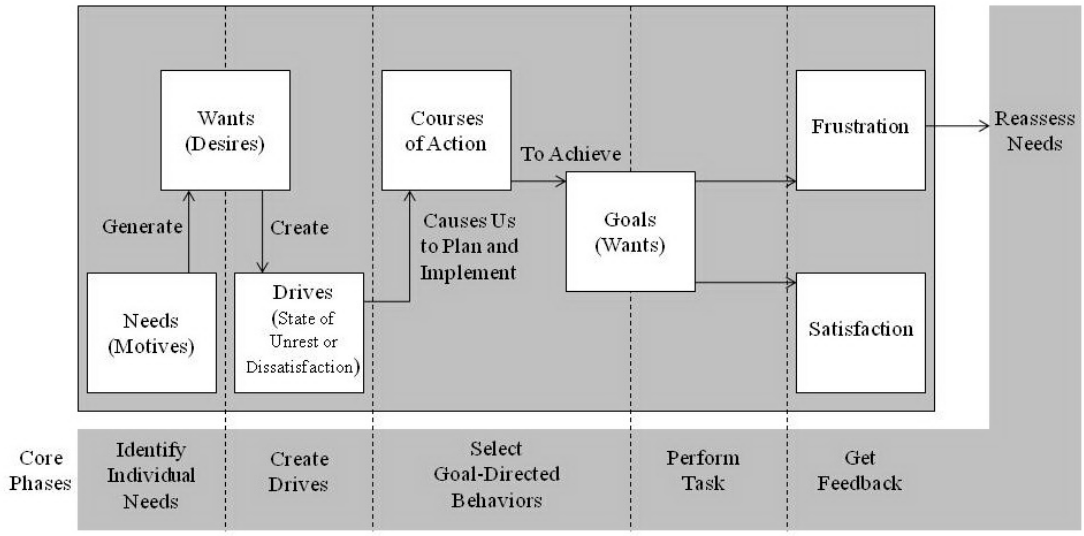

Figure 3.1 The Motivation Process (Verma, 1996)

As stated by Verma (1996), some of the most important factors that motivate people might be:

- "Good salary, working conditions and friendly co-workers;"
- "Food, clothes and shelter to satisfy basic physiological needs;"
- "Job security or working in a financially stable industry;"
- "Need for advancement and growth;" and
- "Need for achievement, power and affiliation."

There are different motivation theories that a successful manager should understand them along with their strengths and weaknesses.

Apart from these theories, some motivation methods can be:

- Monetary incentives
- Public rewards and recognition for superior performance
- Lapel pins
- Trophies
- Appreciation certificates or letters
- Adequate orientation programs

- Articles in the company newsletter
- Achievement lists on bulletin board
- Attendance at conferences and seminars
- Time off from work
- Paid vacations
- Promotion

Money seems to be the most important tool for motivation since Verma (1996) emphasized its high importance in a review of 80 studies that evaluated motivational methods and their impact on employee productivity.

Martinéz-Costa et al. (2008) studied effect of motivation on TQM and ISO 9000 implementation processes in Spanish companies and found motivation as a powerful tool in the process. Therefore, employee motivation can be a critical factor in overcoming QMS implementation.

Decoene and Bruggeman (2006) studied the effect of BSC on organizational performance by "creating positive motivation for employees."

Bendoly and Prietura (2008) studied the interaction of motivation and skill to give rise to observable levels of performance. They expressed that skill and motivation not only interact to drive performance, but also have relationship such that skill in part may drive motivation and motivation may in part be active in the development of skills.

Considering integrated performance measurement system (IPMS), a quantitative method was thus developed which calculates employee performance by using "three classic project progress factors of cost, time, and quality" (Ojiako et al., 2008). The principal idea of IPMS is that performance measurement provides the management with a comprehensive and quick view of business (Laitinen, 2009).

Chapter 4

DATA WAREHOUSING AND ITS APPLICATION TO CONSTRUCTION INDUSTRY

4.1 Introduction

Marchand and Raymond (2008) pointed out the "evolution in the definition and initiation of performance measurement systems." In conjunction with information technologies evolution including web-based technologies, these systems with their specific functionalities could be applied to enrich performance measurement systems. This would develop them from simple measurement to more extensive decision making. Performance measurement systems could play a more important role in the organization through this enrichment and impose continuous improvement culture in the organization and develop managerial decisions.

In this chapter, research efforts in decision-making and data warehousing in construction industry are reviewed. First presented is a brief review of data and information in the industry. Then, the applications of IT and DSSs in construction are presented. Finally, the concept of data warehousing, its characteristics and application to construction industry are reviewed.

4.2 Data and Information in Construction Companies and Projects

"Many organizations are in chaos due to a flood of irrelevant, too detailed, poorly integrated, and difficult to access data which is of little value for decision making" (Ma, 2005).

Every organization creates billions of bytes of its daily operations which are important for decision making and daily operations. “Construction companies generate a great amount of operational data which are distributed across various functional databases. These data play an important role in achieving construction project objectives including finishing the project on time and within budget, and meeting design specifications” (Rujirayanyong, 2004).

Construction is an industry dependent on information. Substantial amount of information would be generated and exchanged during a project lifetime. Thus, it is essential to efficiently manage the information exchange. Extensive and valuable project data created and accumulated in construction companies usually are not used effectively by the organizations for decision-making (Zhiliang et al., 2005). Construction operations and decisions are typically supported by operational databases. “The data are often non-validated, non-integrated and stored in a format that is difficult to make quick decisions. This is a typical problem in many business organizations and it is due to existing ISs data modelling limitations, inadequate IT infrastructure, and traditional organizational setup” (Ang and Teo, 2000). “Moreover, in construction organizations, the databases are likely to be functionally and/or geographically dispersed” (Arslan et al., 2008), which makes decision making a difficult task due to time shortages in accessing relevant data. “A decision maker may have to wait days or weeks for responses from subordinates to extract required information from the data. Such long waiting periods can have adverse impact on project performance and may reduce the value of information” (Ahmad and Azhar, 2005).

Information is part of an organization's intangible asset and is needed to run its business. If used properly, it helps the organization to improve its efficiency.

Information can be used several times without value loss and may even get improved in the process. Therefore, the organization should be interested to collect and store information.

Every business needs objective information to be able to check its strategy and to develop its competitive advantage. Historical data shows business success in the past; the current information demonstrates the present business situation; and the sum of past and present information helps creating the future of the business. For instance, if a many projects faced a common problem, the construction company would examine its causes and avoid it in the future.

Dawood et al. (2002) categorized construction information into "general information, organization-specific information, and project-specific information." They further define them in more details as:

> The general information category defines publicly or commercially available information concerning construction products, regulations, standard procedures, etc. Such information is generally available to interested organizations. Organization-specific information categorizes all information available to a specific organization such as standard solutions to design-construction problems, often in the form of library of previously completed projects that are used as reference cases within the organization. The project-specific information is tied to one specific construction project or project type, but shared by several organizations that make up the supply chain.

Ahmad and Azhar (2002) claimed that "the databases in most construction organizations are based on the concept of Online Transaction Processing (OLTP)." These OLTP databases support day-to-day business operations and would be updated continually on a periodic basis. "Such transactional databases are not organized to support analytical processing and decision-making and are only designed to answer who and what type questions" (Ahmad and Azhar, 2002). Quick data analysis and decision making is an important factor in successful management so that accurate and reasonable predictions and forecasts can be made in a timely manner.

Recently, some research studies have conducted to integrate transactional ISs in order to develop decision-support systems (DSS). These systems could be used for effective problem analyzing in support of decision-making process (Anumba, 2000). However, such DSSs were not very successful. Chau et al. (2002) and Watson et al. (2002) summarized the reasons in three parts: System halting or slowing down due to lack of complete separation from the transactional systems, inapplicability to establish multidimensional data relationships, and non-validated and poor quality data. These make critical decision making arduous for executives.

"The implementation of technology in businesses is commonly associated with the automation of bulk process of data management" (Inkinen et al., 2009). Managing and sharing the company's documents are what most companies expect from project management. Therefore, running core applications such as an electronic document management system (EDMS) on a server would apparently benefit companies. Specific organizational information would then be centralized and users can easily access them to quickly perform assigned duties. "In an effective EDMS, all information including reports, letters, drawings, databases, notes, etc. must be in electronic format" (Forcada et al., 2007).

EDMS is utilized by many companies for standard information access and transfer within the company. In this way, every user can easily find and access the required documents based on his authority level. An EDMS provides data security and reliability for company and relieves users for work completion. "Many of these features eventually save time, simplify work, protect the investment made in creating these documents, enforce quality standards, enable an audit trail and ensure accountability" (Forcada et al., 2007).

Al-Sabah et al. (2003) developed a DBMS using Microsoft Access. The DBMS could be used for "data management of disputes and claims on major construction projects." Additional payment and claims for completion time could be analyzed and documented for construction projects. Forcada et al. (2007) developed a "web-based tool to improve internal and external document management for small and medium-sized enterprises (SMEs) in the architecture, engineering and construction (A/E/C) sector." The system could create an organizational document structure for each specific project and users could download them to the PCs or servers. It could also be downloaded to the web-based project management system (WPMS) that is for the entire project management.

4.3 Information Technology

Computers are used for data processing, and information provision to assist managers in proper decision making. Enterprises began to take advantage of IT to store their knowledge and enhance their competitiveness (Soibelman et al., 2008; Lin and Tseng, 2005; Turban et al., 2002). IT gained considerable organizational impact due to establishing links between information and managerial decision making (Michael, 2007).

Managers rely more on management ISs nowadays as critical decision making tools (Bendoly et al., 2009). Managers on the other hand, need timely and accurate performance factors for managing and leading their organizations. Therefore, "enterprises are increasingly turning to software systems to seek support for enterprise performance measures and monitor progress" (Bose, 2006).

Using of computers for operational data processing and information providing to decision-makers started about three decades ago. IT has advanced to a stage that allows the storage of and access to timely and accurate data. Computer technology

has helped the construction industry meet increasing complex challenges. Its importance has been widely recognized and cannot be overemphasized.

"ISs in today's manufacturing enterprises are distributed. Data exchange and share can be performed by computer network systems. The internet is a large and connected network of computers and web is the fastest growing segment of the internet" (Ma, 2005).

Computer technology including both software and hardware, especially internet-based systems has recently advanced to a level that, researchers have developed on-line project management systems, 4D visualization systems, and enterprise resource planning systems.

4.4 Internet Technology and Web-based Systems

Research studies in the construction industry have proved its potential to accept web-based systems to support management decision making during the last decade. According to Arslan et al. (2008) and Nikas et al. (2007), several advantages can be achieved through online collaboration tools including:

- "Easier construction project management,"
- "Easier access to project information from anywhere at any time,"
- "Faster transaction time,"
- "Better transparency in the exchange of project information,"
- "Better collaboration between construction project partners,"
- "Time savings for communication of project information,"
- "Savings on project cost," and
- "Streamlined construction business processes.'

According to Ahuja et al. (2009):

> Internet helps in effective collaboration and coordination between project team organizations. Its use as a communication medium can help information transfer

> to occur faster and more effectively and can provide new opportunities for the development of distributed systems that can cross organizational boundaries and can offer a unique opportunity for teamwork and workflow automation.

A construction project usually involves a number of participants such as the owner, contractors and engineers. The participants are normally dispersed and a large amount of information in forms of documents, oral messages and meetings, etc. should be exchanged among them. These documents contain most important management information related to all aspects of construction project management. “Although paper-based documents are still preferred in the construction industry, electronic documents are considered to become acceptable media” (Zhiliang et al., 2005). Electronic document exchange through Web-based project management systems has become a necessity in the construction industry.

Chassiakos and Sakellaropoulos (2008) developed “a web-based system that facilitates construction information management and communication system which aims to include common information circulated within the construction process.” Abudayyeh et al. (2001) suggested the “use of an Intranet-based project management system which focused on cost control as a means for improving the timeliness and quality of information.” The Internet was used for communicating project control data and information.

Chou and O’Connor (2007) developed a “web-based application called the Preliminary Item-Level Cost Estimating System” (PILCES) for preliminary cost estimation. It was used to toggle project input information and segregate unit price of highway projects. Estimating parameters would be documented after being derived from statistical analyses and could be updated continuously. A Web-based relational DBMS was developed to store the statistical models to be then used for computation

and storing the data. PILCES also contained unit price and quantity prediction models for highway projects.

Cheung et al. (2004) developed “a web-based construction Project Performance Monitoring System (PPMS) to be as an assistant in construction project control.” Eight categories of “project performance measures including people, cost, time, quality, safety and health, environment, client satisfaction, and communication” were included in the PPMS. Performance indicators were established for each category. Database and Internet technologies were applied to automate process monitoring, data collection, and dissemination. Project performance data were stored in a centralized database that would be populated via the Internet.

Arıöz et al. (2007) developed “a web-based system for ready mixed concrete quality control.” The developed system was used to connect manufacturer and customer. The program could check the properties of the concrete production materials and fresh and hardened concrete properties, and inform the jobsite responsible persons. The results of the tests on fresh and hardened concretes would be used as a basis for corrective actions in next production batches.

Although Web-based Project Management Systems (WPMSs) provide reliable and centralized tools for easy utilization and data storage, they are quite new and need to be optimized for practical use. A/E/C firms still have doubt on permanently transfer to WPMSs (Forcada et al., 2007).

4.5 Decision Support Systems

As business grows more complex and spreads globally, surviving in the competitive environment becomes a matter of concern for business executives. Operational computer systems cannot support organizations in this problem since

they only provide information and support for day-to-day operations and lack to support strategic decision making needs of executives.

It is important to consider decision-making process in construction operations. “There are many factors involved in the decision-making process including internal factors, external information, and personnel information. The extent of these data is remarkable and DBMSs must be used to support decision-making process” (Deng, 2004).

As stated by Wang et al. (2008), “because of the complexity and importance of performance evaluation, DSSs are frequently used as effective tools in support of decision-making.” They defined DSSs as “computer-based tools that help managerial decision-making by presenting various effective alternatives.”

“DSSs are ISs that are designed to support complex decision-making and problem solving. These systems save the time and effort of experienced users in arriving at optimal decisions” (Azhar, 2005).

One of the objectives of a DSS is believed to be a tool for better decision making while dealing with complex situations and information (Wang, 2005).

The literature shows some efforts on DSS application in construction management. The early systems were developed using analytical and mathematical models to solve managerial problems (Azhar, 2005). DSSs for retaining wall management application, DSSs for bid/no-bid decision, DSSs for contractors prequalification, DSS for delays analysis and many more developed in 1980s and 1990s are some examples of this type.

Group decision support systems (GDSS) received its popularity over the last decade when the scope of organizational decision-making shifted from individuals to small teams. By the growth of internet technology, researchers changed their focus to

take advantage from web-based technologies for DSSs and GDSSs development. “This trend is recently shifted towards the development of knowledge-based decision support systems (KDSS) which are hybrid of DSSs and expert systems (ES) and could be utilized to solve a broad range of organizational problems using present and historical data” (Azhar, 2005).

Arnott et al. (2008) defined DSSs as “the area of the IS discipline that focused on supporting and improving managerial decision-making.” They stated that DSS has a number of distinct sub-fields including:

- “Personal Decision Support Systems (PDSS),”
- “Group Support Systems (GSS),”
- “Negotiation Support Systems (NSS),”
- “Intelligent Decision Support Systems (IDSS),”
- “Knowledge Management-based DSS (KMDSS,”
- “Data Warehousing (DW),” and
- “Enterprise Reporting and Analysis Systems including executive information systems (EIS), business intelligence (BI), and more recently, corporate performance management systems (CPM).”

Some reasons to DSS application can be considered as:

- “Decision-making is becoming more pluralistic and less hierarchical, determined not so much by position in the corporate hierarchy but much by argumentative and evidential value” (Arnott et al., 2008).
- “A target for some sort of intelligent new generation of DSS technology should be the overwhelming flow of data, information and knowledge produced for the executives from an increasing number of sources” (Arnott et al., 2008).

- “The complexities of decisions in the information age require every manager to utilize information analysis tools for supporting business decisions” (Nemati et al., 2002).

As stated by Azhar (2005), “the practical use of DSS in the construction industry is very limited due to several reasons” such as:

- “The lack of a strong database component due to limitations of transactional databases,”
- “Poor quality data due to non-validation of data, different data structures and storage formats of scattered databases,” and
- “Development of these applications by computer specialists in information centers that sometimes all the requirements of construction managers are not embodied sufficiently.”

”For effective decision-making, there is a need to develop integrated DBMSs that can organize quality data from different databases over a period of time and automatically filter and transmit them to DSSs. Recently developed data warehousing technique is a response to the limitations imposed by the lack of effective connection between conventional DBMSs and current DSSs” (Azhar, 2005).

4.6 Data Warehouse

“Successfully supporting managerial decision-making is critically dependent upon the availability of integrated, high quality information organized and presented in a timely and easily understood manner.” Data warehouses (DWs) have emerged to meet this need (March and Hevner, 2007).

As stated by Tan et al. (2003):

> Data warehousing is not a software product or application. It is a system architecture that provides end users with decision support data in a timely

> manner. The process of retrieving, sorting, storing, and analyzing information and then generating reports is the essence of data warehousing.

"Construction is an industry bound by traditions. Implementation of concepts like data warehousing is challenging in construction. The concept of data warehousing is simple, technically appealing but when taken practical issues into consideration, its implementation in construction organizations poses enormous challenges. These challenges are organizational, financial, and technical" (Azhar, 2005).

Despite the growing need for more information, organizations do not use any formalized initiative beyond the transaction level to organize the daily created data. For the most part, these data are literally locked up in many computer systems. "It is estimated that only a small fraction of the data that are captured, processed and stored in the enterprise is actually ever made available to executives and decision makers" (Ramamurthy et al., 2008). The concept of DW is part of the response by IT to meet this identified need. It is a simple concept that, over time, has the potential to contribute to the success and loyalty of an organization in the global marketplace. "Data warehousing is one of the most powerful decision-support tools that have emerged in the last decade" (Ramamurthy et al., 2008). The DW is a facility for integrating the data generated in a world of disintegrated IS. A functional DW organizes and stores all of the available data needed for informational, analytical processing over a historical time perspective. It is the goal of the DW to reintegrate the data generated by many internal and external ISs to create a sense of unity about the data without surrendering their natural complexities (Marakas, 2006). Data warehousing offers organizations the ability to quickly access and manage data that is required for reporting and administrative purposes (Garner, 2007).

"The traditional view of database management is based on the need for data to support transaction processing (therefore such systems are called Online Transaction

Processing systems). Data warehousing evolved to support analytical processing for informed decision-making." Therefore, data warehousing focuses on analytical processing rather than transaction processing (Azhar, 2005).

> A DW is defined as a structured extensible environment designed for the analysis of non-volatile data, logically and physically transformed from multiple source applications to align with business structure, updated and maintained for a long time period, expressed in simple business terms, and summarized for quick analysis (Bose, 2006).

The main concept in data warehousing is that a good DW must be extensible which means that it must be able to inquire data from various applications when demands arise. The second concept is analysis of non-volatile data since DW data comes from different operational applications which consist of volatile operational data. The third concept is "time dimension" which means that "a DW contains data over several periods of time. This feature allows users to perform extensive yearly, quarterly, and monthly analyses which would have been much more difficult (if not impossible) to glean from operational data alone" (Bose, 2006).

Zhiliang et al. (2005) defined data warehousing technique as an "extension of the transactional database technique." They considered the following unique features driven from the basic idea for data warehousing technique developed by Inmon in comparison with the transactional database technique:

- Subject oriented: data are organized based on the application programs in a transactional database; while in a DW, they are structured around a subject. A subject consists of facts and dimensions.
- Integrated: Transactional databases are normally related to specific application programs and are independent and even diverse; while a data warehousing is generated by extracting data from different databases, processing and

integrating them and thus, the data in a DW are steady and inclusive about the analyzed subject.

- Relatively stable: Transactional databases are updated with the transactions in real time; while the data will remain unchanged in a data warehouse until they are updated.
- Time variant: Transactional databases do not have the capability to store historical data, while there is no data storage time limit for a data warehouse.

The main purpose of a DW is to provide better resources for DSSs. Top managers usually require an overall view of a company. An overall view involves data from different departments in the company. Without a warehousing process, accessing data directly from the departments may result in inconsistent information (Indratmo, 2001).

Bose (2006) defined the data processing in a DW as:

> Data are obtained from different sources, manipulated into a common format for the warehouse, inserted into the warehouse with any necessary calculations or additional appended data, then loaded into appropriate reference tables or data marts for efficient query performance, analyses, reporting, or data mining by the users through the use of commercially available tools such as business objects, web intelligence, oracle crystal reports. The data from a DW is typically used for decision support rather than for operations.

Finally, it must be noted that data warehousing is not a product, but a process. During this process, data would be collected and managed from various sources to provide a detailed view of part or all of a business. Also, the "DW is a journey and not a destination, since it is constantly changing without having an end point" (Elson, 2001).

4.6.1 Reasons for Using a Data Warehouse

Bouman and Dongen (2009) listed a number of reasons why a DW is useful, from a user's perspective:

- All information is in one place: No more hunting down several disparate sources of information or trying to find older files in a cluttered e-mail system or folder structure. No need either for combining all this data yourself: it's already integrated and ready for use.
- Up-to-date information: Data in the DW is automatically loaded and updated on a regular basis, which means you are never out of date or looking at old information.
- Quick access: The DW is optimized for speedy retrieval of information. The DW answers queries a lot quicker than local file stores or e-mail archives.
- No size limits: Spreadsheets can store only a limited amount of data and often need to be split in pieces to accommodate all required information. A DW can store a virtually unlimited amount of data so no more offloading of data to a local database or yet another spreadsheet is required.
- All history available: The DW not only contains current information but also data from last week, last month, last year, and several years back as well. This means that any trend analysis or comparison over time is supported by the DW. In fact, if you never delete data from the DW, it will often contain much more historical information than the source systems. The available history is not only "older data," but offers additional value when changes are tracked as well. This allows one to look at the data as it actually was during the time it was originally processed.
- Easy to understand: The DW is modelled in business terms and reflects the way you look at your organization. You don't need to decipher three-letter acronyms that no one understands, but can have clear names for all data elements.

- Clear and uniform definitions: No more discussions about what data means or what the definition of “revenue” is. Everyone in the organization uses the same definitions, which greatly simplifies communication.
- Standardized data: All data conforms to standards, which means there is only one definition and one set of values for each piece of information. Coding of gender is good example in this case. Some systems use 0 and 1, some use male/female and other use M/F/U (for unknown). All translations into a single standardized definition have been taken care of.

4.6.2 Data Mining and On-Line Analytical Processing (OLAP)

As stated by Lau et al. (2004), “data mining is a term for describing knowledge discovery in databases, knowledge extraction, data exploration, data pattern processing and information harvesting, thereby providing sophisticated analysis for business applications to support decision making.” Data mining is a rapidly emerging field. The main motivator behind this technology is the need of new methods for analyzing, understanding or on a higher degree, visualizing the large amounts of data gathered from various applications. “It is the process of discovering interesting knowledge from large amounts of information stored in different databases, DWs, or other data repositories.” Hui and Jha (2000) classified the major data mining functions developed to date as “summarization, association, classification, prediction and clustering.”

“A typical example of data mining tool is OLAP which provides a service for accessing, viewing and analyzing large volumes of data with high flexibility and performance” (Hui and Jha, 2000). The important feature of OLAP is statistical and numerical analysis of multi-dimensional data. OLAP supports decision making

through quick responses and accurate results provision to the users to achieve almost real-time data.

Design of a DW is mainly based on multidimensional data modelling. Data models for traditional OLTP systems design seemed to be inappropriate. OLAP, as a query-based methodology, was proposed to overcome complexity and performance deficiencies of queries through supporting data analysis in multidimensional environment (Combes and Rivat, 2008).

A successful data warehousing system extracts data from operational systems without any negative impact and provides “consistent, timely, reliable, and accessible data” to decision makers. DW integrates data from different sources to describe organizational operations and the environment it operates in. OLAP provides status reports and decision support by “performing complex analysis over a DW data” (Bose, 2006).

OLAP, with its multidimensional data view characteristic, can support enterprises in data storage and analysis for effective decision. Briefly, OLAP enables data analysis “across any dimension and at any level of aggregation” from the information buried in the databases. Thus, the OLAP multidimensional database was recognized due to placing the analyst in direct contact with relevant data, appropriate models and the related analyses. “The OLAP tool is used to assist the decision-maker in creating appropriate knowledge and models by browsing the appropriate data groups, and defining the model-based relations between these data groups” (Lau et al., 2004).

DW and OLAP form the basis of modern DSSs. “They are complementary technologies because the DW makes summary data available to OLAP and ensures its timeliness, accuracy and consistency whereas OLAP focuses on the end-users’ analytical requirements.” The decision makers access the DW through OLAP queries

to analyze multi-dimensional data; view changes over a time period to obtain a general view of business operations and also to perform detailed analysis in specific sub-functions (Bose, 2006).

OLAP achieved its popularity in different application areas due to alleviating the enterprise data analyzing process. “Almost all OLAP systems are based on a dimensional view of data” in which measures or numeric values are characterized by dimensions that are descriptive values. “The values of a dimension are typically organized in a hierarchy, where an upper-level value contains several lower-level values” (Pedersen et al., 2009).

OLAP uses aggregated (multi-dimensionally organized summary) data to support decision making. Aggregated data on a specific subject are required for multidimensional data analysis to make reliable decisions. Dimension attributes could be used to analyze summary. In order to obtain a view into summary data, specific dimensions should be selected. Different views might be constructed by only changing dimensions. “OLAP queries are capable of performing such actions through multidimensional view creation from the basic views that are provided by data warehousing” (Bose, 2006).

Star schema is the most popular OLAP data model and is “based on multidimensional modelling and structures information into facts and dimensions” (Luján-Mora et al., 2006). Facts include measures about events or situations and dimensions analyze these measures through aggregation operations such as counting, summation, average, etc. (Schneider, 2008; McGuire et al., 2008). Each dimension attribute also contains a dimension table which describes the properties of the dimension. “The star schema is mainly a model for the logical structuring of multidimensional data. All multidimensional models containing fact and dimension

tables are variants of the star schema, with the snowflake schema being probably its most famous variant" (Bose, 2006). "Both the Star and the Snowflake schemata present data as a single cube, which is the basic DW structure that allows users to perform multidimensional data analyses" (Dori et al., 2008).

In a star schema, a fact table is placed in the center, surrounded by its dimensions (Figure 4.1). Fact tables contain numerical data (measures) that record past data transactions; hence the data need to be consistent. Dimension tables contain information that describes data in fact tables. This structure allows business analysts to examine and construct views from various dimensions. The reference information is more dynamic. However, because of the star schema structure, the reference information can evolve and be updated without restructuring the whole DW schema (Indratmo, 2001).

Dimensions could be represented as multilevel hierarchies since most of the decision makers prefer to group data; for instance they might consider dimensions at different detailed levels. For example, time dimension could be represented as days, weeks, months, quarters, and years; or geography dimension as cities, states, and countries. Time dimension is a regular dimension in most OLAP applications which could result in several useful outputs conducting time series analysis. It can complement DW's ability to keep historical data for efficient time series analysis (Bose, 2006).

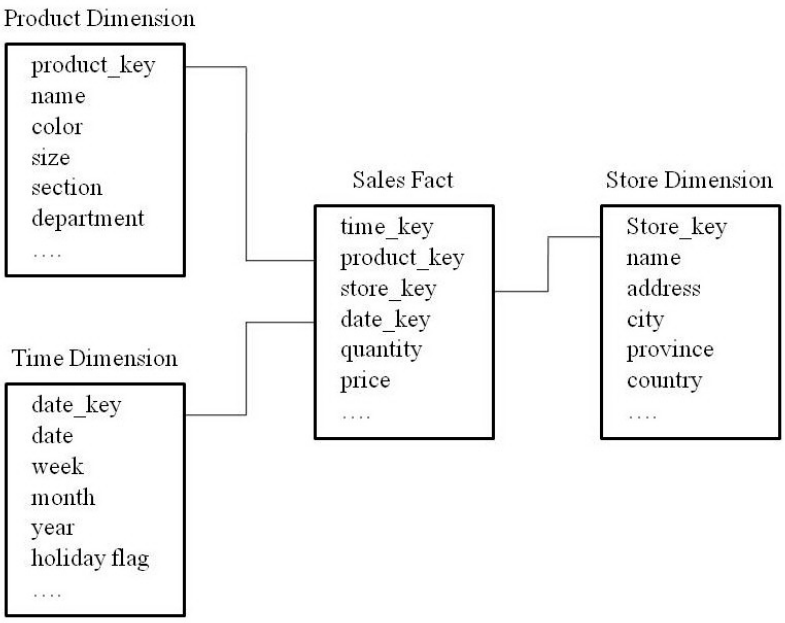

Figure 4.1 An Example of a Star Schema

Fact table has a one-to-many relationship with each dimension table. The primary keys in dimension tables are considered as foreign keys in fact tables. Dimension tables also include some nonkey attributes. “The primary key of the fact table is a composite key that consists of the concatenation of all of the foreign keys.” Querying the database could be performed easily though the relationships between dimension tables and the fact table using SQL statements. Nonkey attributes are generally called data columns (McFadden et al., 1999).

The snowflake schema has a similar structure to the star schema. It has a fact table and a set of dimension and sub-dimension tables (Figure 4.2). Sub-dimension tables are produced by normalizing dimension tables.

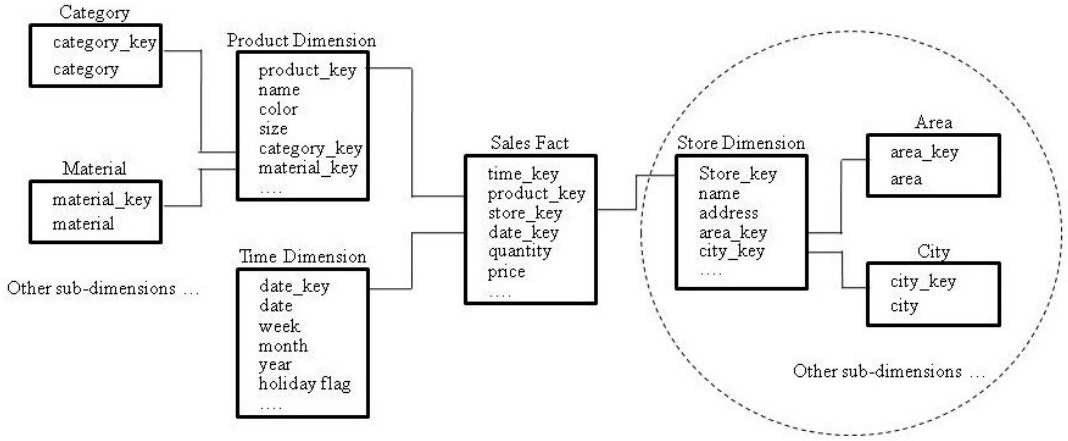

Figure 4.2 An Example of a Snowflake Schema

"Normalization usually involves dividing a database table into several tables and defining a relationship between the tables. Oppositely, denormalization is a process of aggregating data tables into larger relations for efficient analytical processing. It could be efficient in speeding up database access and query processing" (Ahmad et al., 2004).

4.6.3 Data Warehouse Architecture

According to Yi (2001) a DW system consists of data sources, data integration program, operational data store, data transformation program, DW, DW metadata and DW application system. Typical DW architecture is shown in Figure 4.3.

Data sources are the sources from which the data are integrated into operational data store. These data can be in different formats, structures, names and measurements. A typical data source that is a traditional database is called source database.

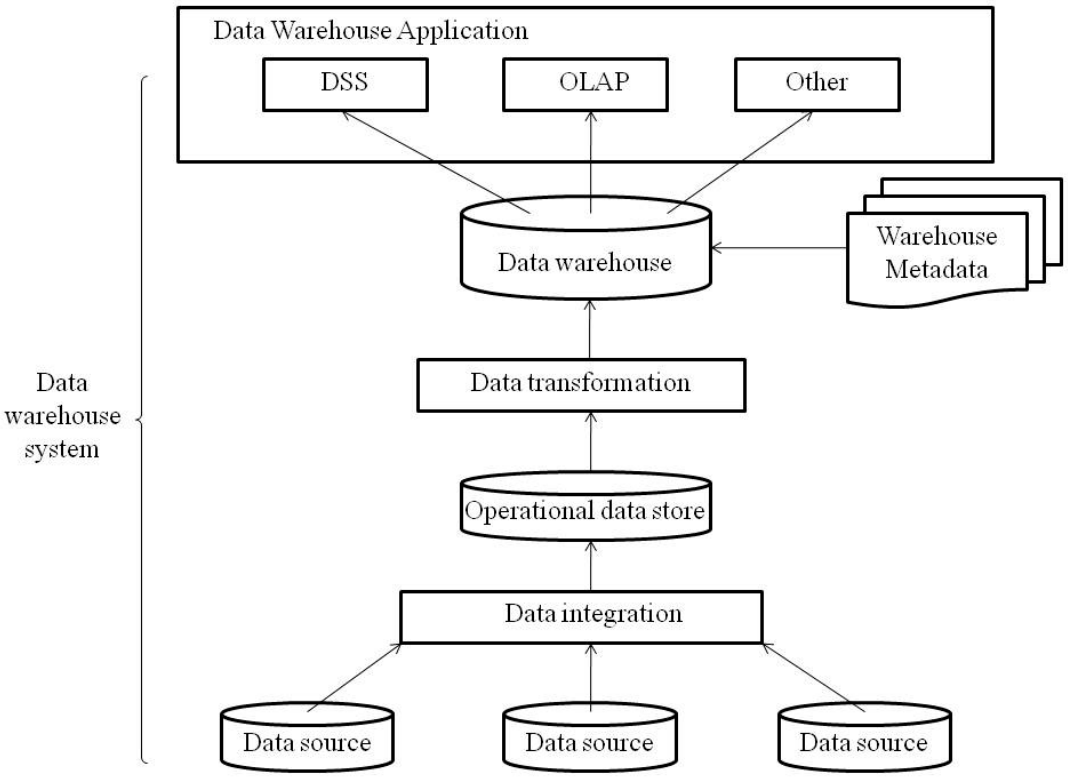

Figure 4.3 Data Warehouse System Architecture (Yi, 2002)

Data integration program is a set of programs that translate different formats of source data into the unique format of operational data store's data, remote redundancy data and non useful data, and append data into operational data store.

Operational data store (ODS) has the same table structure as DW but the data in ODS need to be validated (unified) prior to loading into the DW. Different from the data in DW, data in ODS can be inserted, updated and removed. Data are stored in ODS period time before loading into DW.

Data transformation program is a set of programs that are used for calculating aggregated values from ODS's data, updating warehouse metadata and moving valid ODS data into DW.

DW is the data store that stores the data integrated and transformed from data sources for a long period.

Warehouse Metadata is “data about data”. Warehouse Metadata describes the data in DW such as tables in DW, number of data in each table, last update time, etc.

Warehouse application is a set of systems for warehouse data mining and querying for business decision making (Yi, 2001). This is performed through the human-computer interface which is crucial to DW success from the end-user perspective. “In order to support analysis and reporting tasks, the DW must have high quality data and make these data accessible through intuitive interface technologies” (March and Hevner, 2007).

4.6.4 Data Warehouse Typology

DW might not physically be the location of the data being accessed, although it might be considered as data source in various organizational analysis initiatives and decision-making activities. Although numerous hybrid mechanisms exist in structuring a DW, three basic configurations can be identified: “virtual or point-to-point, central, and distributed DWs” (Marakas, 2006). In preface to an overview of each configuration, it must be noted that these structures would not affect DW schema configuration. “Each option fits a specific set of requirements, and a data warehousing strategy may ultimately include all three options” (Marakas, 2006).

A virtual DW or point-to-point DW configuration allows the end users to access the operational data stores directly using tools enabled at the data access layer. This approach, although providing the ultimate in flexibility, as well as the minimum amount of redundant data that must be loaded and maintained, can put the largest unplanned query load and performance degradation on operational application systems. Virtual warehousing is often an initial strategy in organizations where relatively large classes of end users have a broad but largely undefined need to get at operational data and where the likely frequency of requests is low. Virtual DWs

often provide a relatively low-cost starting point for organizations to assess what types of data end users are really looking for.

The central DW is the type that most people think of when they first are introduced to the concept of DW. The central DW is a single physical database that contains all of the data for a specific functional area, department, division, or enterprise. This warehousing approach is often selected where there is a common need for informational data and there are large numbers of end users already connected to a central computer or network. A central DW may contain data for and specific period of time and usually contains data from multiple operational applications. The central DW is real. The data stored in the DW are physically located in and accessible from one place and must be loaded and maintained on a regular basis. This configuration is the most common of the three basic types and is becoming the de facto standard for DW implementation because of the wide variety of construction and manipulation tools being offered.

The distributed DW is just what its name implies: “a DW that has its components distributed across a number of different physical databases.” Decision making is pushed to lower levels in recent large organizations. Many older DW implementations use the distributed approach because initially it was easier to create several small DW databases than to facilitate one all-encompassing one. The advent of modern DW implementation and management applications, however, has reduced the need for multiple or distributed DWs.

4.7 DW Application in Construction Management

Data warehousing can support efficient management functions and as a result, is becoming more popular for organizations. A DW by itself does not create value. The value comes from the use of the DW data in other applications. Construction industry

has lagged behind manufacturing and other business sectors in taking advantages from DWs.

4.7.1 A Project Oriented Data Warehouse for Construction

Examining the availability of project data, Rujirayanyong and Shi (2006) developed a company level DW named Project-oriented Data Warehouse (PWD). It considered the project side of the construction industry. “It was intended to provide a robust tool for collecting, storing, and utilizing historical construction project data.” PDW could serve as a business decision making tool utilizing a central data facility for users. Moreover, “the data available in the PDW would provide useful information for conducting in-depth business analyses or data mining studies” (Rujirayanyong, 2004).

4.7.2 Application of Data Warehouse and Decision Support System in Construction Management

Project managers often need real time analysis reports during the control phase for performance monitoring. These data would also be used in making long-term decisions. In order to “provide information for pattern prediction for analyzing a problem more efficiently,” Chau et al., (2002) developed an integrated DSS called “Construction Management Decision Support System (CMDSS).” The main characteristic of CMDSS was “separation of the analysis database from the operational database” in order to reduce decision support process rendering. Another advantage was the use of OLAP to change relational database into multidimensional cubes.

4.7.3 Development of a Decision Support System Using Data Warehousing to Assist Builders/Developers in Site Selection

Selection of a proper land for construction is the first and most important challenge to builders/developers. Different factors might influence residential site selection consisting “cost of the land; serviced areas; environmental regulations; characteristics of the land; demographic characteristics; closeness to hospitals, public schools and other facilities; etc.” Top executives generally prefer to select the sites based on their experience and feelings since they often need to make quick decisions. The data for making decisions on site selection are usually “very large, complex and not organized in a suitable format.” Moreover, historical data must be analyzed for strategic decision making in order to derive conclusive decisions. Ahmad et al. (2004) utilized data warehousing technology to develop a prototype DSS for selecting sites in residential housing development. The DW was developed for organizing, storing, retrieving and analyzing data during all stages of site selection process. The objective of the developed system was “to help investors or builders/developers to select the most appropriate site from a list of available ones.”

4.7.4 Construction Enterprise Project Management DW

Construction project management involves different resources including manpower, materials, machineries, equipments and money. Schedule, quality, site safety and cost of projects should be controlled at the same time. These factors bring complexities to management ability and decision making when an enterprise takes on several projects simultaneously. IT could be applied to different steps of enterprise management for improving the decision-making ability. Enterprises can accumulate precious historical data during the construction management process. The important problem is then how to organize and analyze these data for decision making

purposes. Based on the investigation among construction enterprises, a series of subjects including human resources, materials, machine, schedule, quality, safety, costs and such like were defined by Zhang et al. (2004). The developed DW system could assist decision-makers in construction project management in analysis of resources, construction schedule, quality and safety in construction.

4.7.5 EXPLYZER: Data Warehousing of Electronic Documents in Construction Projects

A large number of documents are usually exchanged among different stakeholders in construction projects. This idea encouraged Zhiliang et al. (2005) to apply data warehousing to develop a DSS to enable decision makers in a construction project to improve decision making among project participants through electronic document exchange. The developed system called EXPLYZER could "extract useful information from the accumulated documents through data warehousing application." The electronic documents were assumed to be available in the construction project management process. Script programs were developed to extract information from any Web-based project management system database. Project information was divided into four categories of payment, schedule, quality and material. The system was divided into two parts: one for documents management and the other for in-depth analysis which shared a common graphical user interface. In document management part, functions such as "importing documents from data sources, browsing, query and updating the data in the DW" were implemented. In in-depth analysis part, DW was established through star schema application which consisted payment, schedule, quality and material subjects.

4.7.6 Cost Data Management System (CDMS)

Historical cost databases offer more objective decisions based on the information related to past construction works performance. Analytical approaches are required for meaningful information extraction due to the large amount of data stored in cost databases. OLAP can be a proper solution to support rapid analysis in more accurate prediction of construction costs. Therefore, “a prototype of the cost data management environment” was developed by Moon et al. (2007) to apply OLAP to cost estimation. Using some probability definitions and equations and considering the relationship between the construction activities, a probability model was developed to be integrated with the cost DW system. The cost DW was able to search relevant databases for extracting appropriate data such as “project information, construction periods, work locations, and cost data.” Using SQL tables and star and snowflake schemas, the data was loaded in the DW. Required information for construction cost estimate consisting “project information, work breakdown, units and unit costs” were integrated in the schema table. The system could conduct probability analysis on cost estimate and present different standard normal distribution curves as a means to assist users in decision-making.

4.7.7 Housing and Development Board (HDB) Data Warehouse

“Housing and Development Board (HDB) is responsible for providing affordable, high-quality public housing to Singapore citizens” (Ang and Teo, 2000). Data access from HDB operational systems became time consuming and difficult for the users. Therefore, the HDB decided to build a DW aiming to facilitate users’ access to corporate information for planning and decision making (Ang and Teo, 2000). “The HDB was supported by 120 separate operational systems for managing the links in sales and rental of the flats and complexes, finance proposals, and the continual

streamlining of the HDB application procedures." Valuable information was accumulated over the years which were not easily accessible to the relevant users making it difficult to generate timely management and status reports. Therefore, they developed a DW in four years, called the Information Center Database (ICDB). "ICDB resulted in easy access to consistent and reliable data, creating new demands for new types of data, and stabilizing requests for ad hoc reports."

4.7.8 DW and DSS for Construction Equipment Management

Fan et al. (2006) developed an equipment DW and a prototype DSS. The proposed DW provided visual equipment data analysis from different perspectives and at different detail levels. The DW-based DSS facilitated "high-level, fact-based decision-making regarding equipment logistics, supplies, maintenance, repair, and replacement and had higher levels of performance and flexibility" in comparison to other equipment management systems.

4.8 DW Application in Construction Quality Management

Some research studies have been conducted in construction quality management; however, they most concentrate on the application of IT and web-based techniques in quality inspection and quality control of the projects and their focus is not on the DW itself.

4.8.1 An Internet-Facilitated Quality Management Environment for Construction

Lam and Ng (2006) developed an internet-facilitated quality management environment by the aim of examining the applicability of web-based techniques to collecting, managing, accessing and distributing quality-related data. "The conceptual framework consisted of five components. Data entry allowed registered users like clients, consultants, contactors, subcontractors and suppliers to post their

quality management documents; registered users to submit project specific QM data; accreditation bodies to enter necessary data; and organizations to register as approved users of the system." The users could enter data through internet connection with a PC or PDA and update their own data. They could also be reminded by the system through e-mail reminders if they fail to enter data promptly.

The prototype of EQUALITY was developed with different programming environments. It offered the user seven functions including "user registration, project registration, data entry, organization QM report, project QM report, sample quality system, and other information." An online account can be created for each project. Project participants can have access to specific parts of the project relative to their contribution but the project manager can access to all parts of the project profile. The participants can enter the new data or update the existing data by logging in with their personal username and password. The new data will then be saved and appropriate reports might be created and used by the project manager or others.

4.8.2 A PDA and Wireless Web-Integrated System for Quality Inspection and Defect Management of Apartment Housing Projects

A PDA and wireless web-integrated system was developed by Kim et al. (2008) which was intended to perform "quality inspection and defect management in apartment housing projects." The program could help site quality managers to assure quality by identifying and correcting "defects on finishing materials and facilities." The main aim of the developed system was "to collect defect data at a site in real time and effectively manage the statuses and results of the performed corrective actions." A structured data repository was thus developed which could be populated by project participants in real time and could be applied as a decision tool in case of defect detection to develop corrective actions and plans.

"Three types of quality inspection can generally be conducted near the project closing date including site office inspection, third party inspection, and customer oriented inspection" (Kim et al., 2008). The scope of the research was "site office and third party inspections performed by general contractors." After the project completion and when a profile was created for the project in the main office, an electronic checklist would be sent to the site office through internet to be used by site personnel. The results would be entered to a PDA and sent back to main office after performing inspection. The defects list then were created and together with the solution sent to main server and appropriate project participants. Then the defects should be corrected and the report should be returned to the main office. The first process would be performed again to check whether the defects were fixed or not. At the end, all data would be sent back to the main office to be stored and be checked by the project manager. They could be a reference for future projects together as being a tool to evaluate contractors' performances for future cooperation. The system would generate some primary outputs including "overall defect lists, quality inspection status chart, defect frequency and corrective work status tables with trade contractors and materials, defect type and its frequency chart in materials, electronic and semi automatic work order mailing service, and performance evaluation chart of trade contractors, etc." It can be noticed that this system could be used as a data source for a DW; however, it is only applicable to the completed housing projects and for quality inspection rather than creating a QMS.

4.8.3 ISO 9000 Quality Management Information System (QMIS)

"ISO 9000 quality management information system (QMIS)" developed by Chin et al. (2004) was proposed to integrate scheduling with the quality system process

during the construction phase. It was a web-based system aiming to “improve the productivity of the QS process based on the new version of ISO 9000.”

The system included four packages including “inspection request, inspection, nonconformance reporting, and status of inspection process.” The initiator would determine which activity requires quality inspection and testing. The appropriate checklists and work procedures would then be sent to responsible personnel and by performing the inspection, the feedback would be sent back to the project profile to be filed in the profile.

The system consisted of three different databases called “standard database, project database, and feedback database.” Standard database included “standard quality information such as work plans, inspection and testing plans, checklist items, and work type classification.” This information could be reused or customized based on the current project characteristics. The project database, which was generated separately for each project, contained all information about a specific project. The quality feedback database was utilized to share feedback on non-conformance reports from the project database. Microsoft Project was used for maintaining project schedule and work progress. “Direct management of activity information in the project” was therefore enabled via “Open Database Connectivity (ODBC).” Users could thus “initiate quality management according to the project schedule and progress, and subsequent inspection processes and their results represented the status of each activity” (Chin et al., 2004).

Chapter 5

RESEARCH METHODOLOGY

5.1 Introduction

Construction industry is one of the most important industries and shares significantly in Gross Domestic Product (GDP) in many countries. Enhanced share in GDP, increased number of employees, and annual investment growth are some factors which amplify the importance of building construction in many countries as well as Iran. This necessitates the application of advanced project management tools to provide a sustainable growth in the sector. A survey was conducted to delineate the application of project management principles and tools in building construction sector in Iran. A survey results performed in Iran in 2009 confirmed the instinctive implementation of fundamental management principles. It also revealed the low level of academic awareness and structured utilization of the management principles and tools.

This chapter will discuss the process and outcomes of a questionnaire survey which was conducted among 50 construction companies in Mazandaran, Iran. It aims to demonstrate the level of project and quality management awareness and IT application to regular procedures by the surveyed companies.

5.2 Iranian Construction Sector

Construction industry is one of the largest sectors in many countries. Construction industry's share in GDP increased from 4.7% to 6.1% between 2001 and 2005 in

Mazandaran province located in north of Iran (Mazandaran Housing Master Plan, 2008). The number of employees in construction sector increased by 215% and construction employment share rose from 9.7% to 15% form1996 to 2006. During this period, the annual capital investment increased from 50 million Dollars to 400 million Dollars. These figures highlight the crucial role of the construction industry to enhance the overall economy of Mazandaran and consequently the national economy of Iran. Mazandaran construction industry is labeled as being backward because of its relative lack of use of the latest advances in technology, management styles, and procedures. A questionnaire survey was therefore conducted to analyze the sector, and find out the potential problems in Mazandaran province together with suggestions for overcoming the problems.

Mazandaran is a province located in the north of Iran with a population of more than 3 million (Mazandaran Housing Master Plan, 2008). Its capital city is Sari which has the largest share in the population. Residential building construction in Mazandaran is mainly undertaken by private sector and NGOs. The most important NGO is called “Mazandaran Association of Mass Builders (MAMB)”. MAMB was established in 2002, and initiated its professional career by focusing on the followings (Mazandaran Association of Mass Builders, 2002):

- Promoting members to apply professional construction and management methods, and establishing proper policies for investment in mass building,
- Managing unskilled constructors operating in construction sector in order to improve construction quality and to save national resources,
- Exploiting national policies on resource optimization, expanding mass building, reducing construction costs, expanding new technologies, and enhancing construction process quality,

- Exchanging experiences among MAMB members,
- Developing building and construction databases,
- Protecting members' social rights and professional credibility and addressing their problems and difficulties, and
- Establishing relations with other local, national, and international societies.

MAMB has over 270 members which almost 50 members are construction companies and the remaining are individual builders. Important criteria for a company or a person to apply for membership are the number and quality of completed projects or the number of projects under construction. The majority of private construction has recently been undertaken by MAMB members.

Although "the nature of construction industry resists the adoption of management techniques that were successful in other disciplines" (Mohamed, 2001), there are methods to enhance utilization of decision tools in construction industry. Organizing appropriate workshops, expanding new technologies and industrialized construction methods, and applying IT and web-based technologies to management processes are few possible methods for this purpose.

It was obtained from the survey that, most of the companies consider some management principles within their company and projects instinctively. However, they generally use traditional methods based on their experiences. In other words, they lack structured and scientific management procedures and tools. This deficiency could result in project delays, cost overruns, conflicts, and customer dissatisfaction. Thus, a cultural and behavioral shift in the mind-set of all participants in the construction process especially top management is necessary if the construction industry is to improve its performance and competitiveness.

5.3 Questionnaire Survey

A questionnaire was prepared after a thorough literature survey on construction management and quality management together with the comments and recommendations of MAMB Education and Training Committee and submitted to the MAMB Board of Directors for approval. The purpose of the questionnaire was to collect data for analyzing the construction sector and investigate the level of construction management principles application and as a result, applicability of new computerized methods and decision tools. A sample questionnaire is attached in appendix A.

The questionnaire consisted of three parts. The first part included general questions about the company, its field of operation, number of employees, annual turnover, number of projects in a year, etc. The second part of the questionnaire was about fundamental management principles. The third part included ISO 9000 certification, its application difficulties, ISO certification advantages, etc. All contributors were asked to respond the first and second parts. The third part was asked to be filled only by the companies who had already been ISO certified or were in the certification process.

The questionnaire was administered to the company members of MAMB. The general managers of all companies were contacted by telephone to ensure the receipt of questionnaires and also encouraging them to respond. Out of 50 questionnaires, 28 companies responded which provided a response rate of 56%.

5.4 Data Analysis and Results

Analysis process was initiated by first categorizing the data with the intention of discovering patterns and concepts related to different management knowledge areas. The data were analyzed by SPSS software.

5.4.1 General Information

Regarding the companies participated to the survey, the following aspects must be noted for clarification purposes:

- The majority of respondents were from Sari (53.6%) following by Amol (25%), Babol (14.3%), Ghaemshahr (3.6%), and Behshahr (3.6%).
- 20% of the companies have been operating since less than 10 years, 32% between 10 and 20 years, 24% between 20 and 30 years, and 24% more than 30 years.
- 40.7% of the companies undertook only private projects and 51.9% performed in both private and public projects.
- 96.3% of the companies were contractors and the rest were designers.
- 76% of the companies had grades from Management and Planning Organization (MPO) of Iran. These grades can be obtained based on the financial situation, available equipment and machinery, number of personnel and their academic certificates, and company work experience. A newly established company can apply for grade 5 and it can be upgraded up to grade 1 after performing specific number of projects together with developments in financial and other characteristics of the company. Company grade governs the type and price of projects it is allowed to undertake. 46.7% of the surveyed companies possessed grade 5, 13.3% grade 4, 26.7% grade 3, 6.7% grade 2, and 6.7% grade 1.
- 82.1% of the companies had less than 10 permanent employees.
- 24% of the companies had less than 10 and 48% had from 10 to 50 temporary employees.

- The majority of the companies (71.4%) had annual financial volume from $100,000 to $1,000,000 undertaking 2 to 5 projects per year.

5.4.2 Management Knowledge Areas

The companies were asked different questions about various knowledge areas in construction management, Since the main focus of the present study is on QMS and ISO 9000 certification, the other knowledge areas are out of scope and only a brief summary is notified.

Lack of awareness about OBS, different levels and positions in an OBS, job descriptions, and responsibilities; having project schedules and cost analysis for the projects; considering teamwork in their projects; conducting periodic jobsite meetings; and criteria for selecting designers and material suppliers were only a small fraction of the survey outcomes.

76.9% of the respondents stated that they have some criteria for personnel performance measurement. The question was continued with an open-ended part to list the major criteria for performance measurement which resulted in criteria like commitment, timeliness, interest, creativity, client satisfaction, attendance, trust, proficiency, accuracy, and cost saving. The respondents were asked whether they have a motivation system for their personnel or not. 89.3% replied that they have. Although the main criterion for most of the companies is financial reward, some used other criteria including promotion, assigning jobs which they are more interested in, employ in future projects, vacations and travels with family, and introducing to others.

5.4.3 Quality Management

Quality management related questions were more included in the questionnaire comparing to other management knowledge areas.

44.4% of the respondents stated that they have quality department in their companies. Remarkable response was that quality department is only responsible for testing some materials and checking their conformance to standards in the companies.

Project supervisor was denoted as the most important person (64.3%) to perform quality controls in projects, followed by client (50%), and finally quality department (25%). Although 44.4% of the respondents declared that they have quality departments in their companies, only 25% affirmed that quality department undertakes quality related activities within the projects.

Respondents were asked to profess the method of ensuring materials' quality in their projects. The majority of companies preferred their experiences in previous projects (67.9%) as the main decision criteria for selecting materials. Almost 60% of the respondents stated that their computer utilization in daily activities is medium and lower.

Finally, the respondents were asked about ISO 9000 standards awareness. Only 46.4% of companies knew what ISO 9000 is and more interestingly, 50% of this 46.6% stated that it is a quality control system. Notably, 36% of the companies which claimed they have quality department, did not answer to this question.

5.5 Discussions

Different criteria used by companies for performance evaluation were praiseworthy, however, they did not have a proper structured method for performance measurement and their decisions were mostly subjective. On the other hand, a unified method could be established using the combination of motivation criteria to provide a basis for employee motivation for construction companies. 15 managers stated that a computerized system to objectively measure employee and

worker performances would help them in overcoming many difficulties. IT can also help companies to establish correct and reliable organizational structures with proper lines of communications which supports companies and employees through better management of projects. It can also create a more systematic and structured communication among employees and projects.

Chapter 6

DEVELOPED SYSTEM

6.1 Introduction

In today's highly competitive market, traditional organizational management methods cannot be considered as appropriate strategies. Recent developments in DBMSs, internet technology, and office automation systems encourage managers to apply these methods to their companies in order to survive and compete with their competitors.

This chapter will introduce the model developed to measure the performance of employees in an organization. According to Neely et al. (1997), "a system measuring human behaviour will eventually change the behavior, often positively;" thus, an office automation system named Performance Management Support System (PMSS) is developed to provide a low-cost high-tech approach to performance measurement. It aims at aligning performance measures with employee development and compensation. It is developed using data warehousing and internet facilities of Microsoft Visual Studio.Net 2008 and is based on calculating and recognizing employee performances in real time that can be used as a basis for employee motivation (Rezaei et al., 2011).

6.2 PMSS Development Procedure

PMSS is principally an office automation system with the aim of overcoming paperwork, documentation, and communication of QMS deployment in

organizations. PMSS mainly focuses on construction companies since its nature is more complex and different with other industries. Another pitfall of QMS implementation was proved to be employee low morale; thus, data warehousing technology is deployed in PMSS to create a motivation system through employee performance measurement. Following works were undertaken to develop PMSS:

- Performing a thorough and comprehensive literature survey on QMSs, their benefits and shortcomings, and their implementation drawbacks; human resources management, performance management, performance measurement systems, motivation systems and theories; computerized systems on DBMSs, web-based systems, and data warehousing.
- Proposing the prototype model of the system applying database management and web facilities of Microsoft Visual Studio .NET 2008 and Microsoft SQL Server 2005.
- Preliminary testing and getting feedback from a number of programming experts and experienced managers.
- Revising the system, modifying it according to the recommendations and feedbacks, and adjusting the shortcomings.
- Installing PMSS in a construction company and running to receive feedbacks from the practical application.

The PMSS development procedure is presented in Figure 6.1.

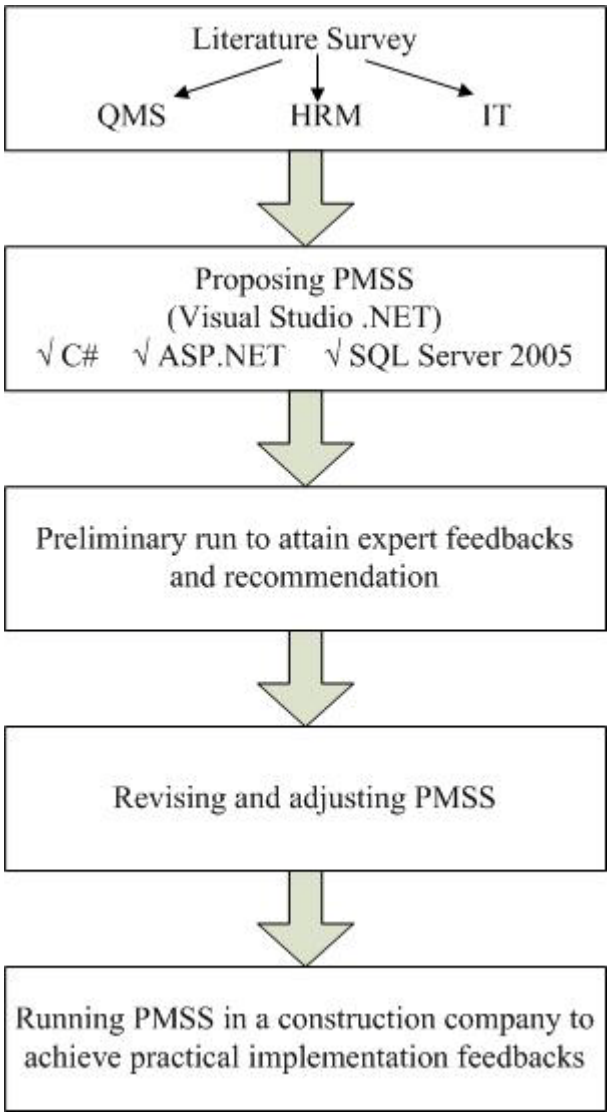

Figure 6.1PMSS Development Procedure

6.2.1 Office Automation System

A number of office automation systems are currently being used such as Autodesk Constructware, Business Collaborator, and e.Build.ca. Autodesk Constructware creates a centralized database from all project documents which can be accessed by all project participants. It is capable to perform “document management, design management, bid management, cost management, construction management, and operations management.” Business Collaborator “facilitates collaboration across teams, automates processes and enables access to project information.” It is only aimed to automate traditional paper-base processes to “improve response times,

reduce errors, and cut costs." The Collaborative Business Platform from e.Build.ca is an online collaboration and project management tool designed for planning, design, and implementation of construction projects. However, these programs were not designed for measuring employee performance which provides a decision tool for managers to monitor employees, developing organizational structure (OS) with appropriate lines of communications for easier communication, and alerting mechanism for time saving and enhancing performance.

6.2.2 Programming Environment

According to Nudurupati et al. (2007), "concluded that performance measurement systems, if appropriately designed, implemented and used with appropriate management IS, would result in a more dynamic and pro-active management style leading to improvements in business performance."

Most DW modelling techniques refer mainly to the user requirements. Based on the DBMS, communication, and performance measurement system requirements of PMSS and after discussions with expert IT programmers, Microsoft Visual Studio .NET 2008 and Microsoft SQL Server 2005 were considered for system development.

PMSS consists of three major modules including databases, user interfaces, and web applications. Microsoft Visual Studio .NET 2008 forms the main structure of the system.

Microsoft Visual Studio .NET Framework is "an Integrated Development Environment (IDE) which can be used to develop console and graphical user interface applications along with web sites, web applications, and web services" (Lair, 2008; Watson et al., 2008). Its architecture allows code sharing among software languages to "provide developers with the advanced tools necessary to build

the next generation of desktop and Internet-enabled applications. Microsoft's Visual Studio .NET product includes new versions of their brand new language called C# (pronounced "C-sharp") and ASP.NET" (Ferguson at al., 2002).

The .NET Framework was designed with one thing in mind: to fuel Internet development. This new fuel to add to Internet development is called Web Services. The Internet was originally intended to deliver static content to Web browsers. These Web pages never changed and were the same for every user that surfed to their location. Active Server Pages .NET (ASP.NET) was "released by Microsoft to enable the creation of dynamic pages based on user input and interaction with a Web site" (Watson et al., 2008; Ferguson et al., 2002). User interfaces and web pages of PMSS were designed and developed using ASP.NET.

Databases of PMSS were developed using Microsoft SQL Server 2005. According to Vaswani (2005):

> A database fundamentally is a collection of data organized and classified according to some criteria. The traditional analogy is that of a filing cabinet containing many drawers, with each drawer holding files related to a particular subject. This organization of information into drawers and files makes it easy to retrieve specific bits of information quickly. An electronic DBMS helps in organizing information and provides a framework to access it quickly and efficiently. The drawers that contain the files in databases are referred to as tables, while the files themselves are called records. The act of pulling out information is referred to as a query, and it's usually expressed using Structured Query Language (SQL). The resulting data is referred to as a result set. A relational database management system (RDBMS) like SQL Server 2005 takes things one step further by creating relationships among the tables that make up a database. These relationships can then be used to combine data from multiple tables, allowing different perspectives and more useful reports.

"SQL Server 2005 is the latest version of a database server product that has been evolving since the late 1980s" (Otey and Otey, 2006). It is the best among the recent environments for developing databases (Dewson, 2006) and is designed for heavy loads and processing of complex queries (Naramore et al., 2005). Microsoft SQL Server is a scalable database system whose primary purpose is to serve as a back-end

database for a client program, such as a Web browser, an accounting program, or a human resources application - anything that makes use of the data. Unlike text editors or games, which do not require any additional components in order to be useful, MS SQL Server does not make much sense as a stand-alone program or as a program that runs on a stand-alone computer. SQL Server is meant to be part of a network to serve more than one user. Advanced features of SQL Server 2005 include OLAP and Data Mining, which enables to analyze huge amounts of data to discover hidden trends (Kriegel, 2001).

C# is one of the available programming languages that target the .NET Framework (Pelland, 2006). “C# is just one of the languages available for .NET development, but it is certainly the best. It has the advantage of being the only language designed from the ground up for the .NET Framework and may be the principal language used in versions of .NET that are ported to other operating systems” (Watson et al., 2008). Like any spoken/written language, C# has syntax rules and a series of valid words that can be used to create applications. C# is an object-oriented programming language which is a programming style (Pelland, 2006).

The user interface must be designed such that knowledgeable users in the application domain can easily use the system (Terwilliger et al., 2007). Graphical user interface (GUI) development is one of the areas where object-oriented programming has already been applied. GUIs are important tools for users from beginners to more experienced users to access computers. C# was used to connect database, user interfaces, and web applications.

6.2.3 General Overview of PMSS

Organizational Structure (OS) of the company will be developed by PMSS and an employee will be assigned to each position in OS. Personnel profiles and login accounts will then be created. The users can access the system through an authentication page. Different departments, projects, activities, and their related data will then be defined. Users can use message transfer mechanism of PMSS to send and receive the works. The performance of each performed work is measured in three dimensions, namely, time, cost, and quality and the performance of the employee will be calculated using proposed formulas (Rezaei et al., 2011; Çelik and Rezaei, 2009). A sample application diagram of PMSS is shown in Figure 6.2.

Various databases and tables are used to develop the system. Organization structure table is used to develop OS of the company. The departments and profiles of company employees are defined in the profile table. Projects and their related data are entered to the system through the tables named project, activity type, activity code (group), activity, and resource. The heart of the system is the message table which has the capability of transferring data, sending and receiving the messages, measuring the performances and organizing all the reports. The DW then uses the databases from different departments and projects for extracting the necessary data to perform the required queries. The message table can also be used by external users like clients, consultants, contractors, and material suppliers which are not placed in the organizational structure of the company.

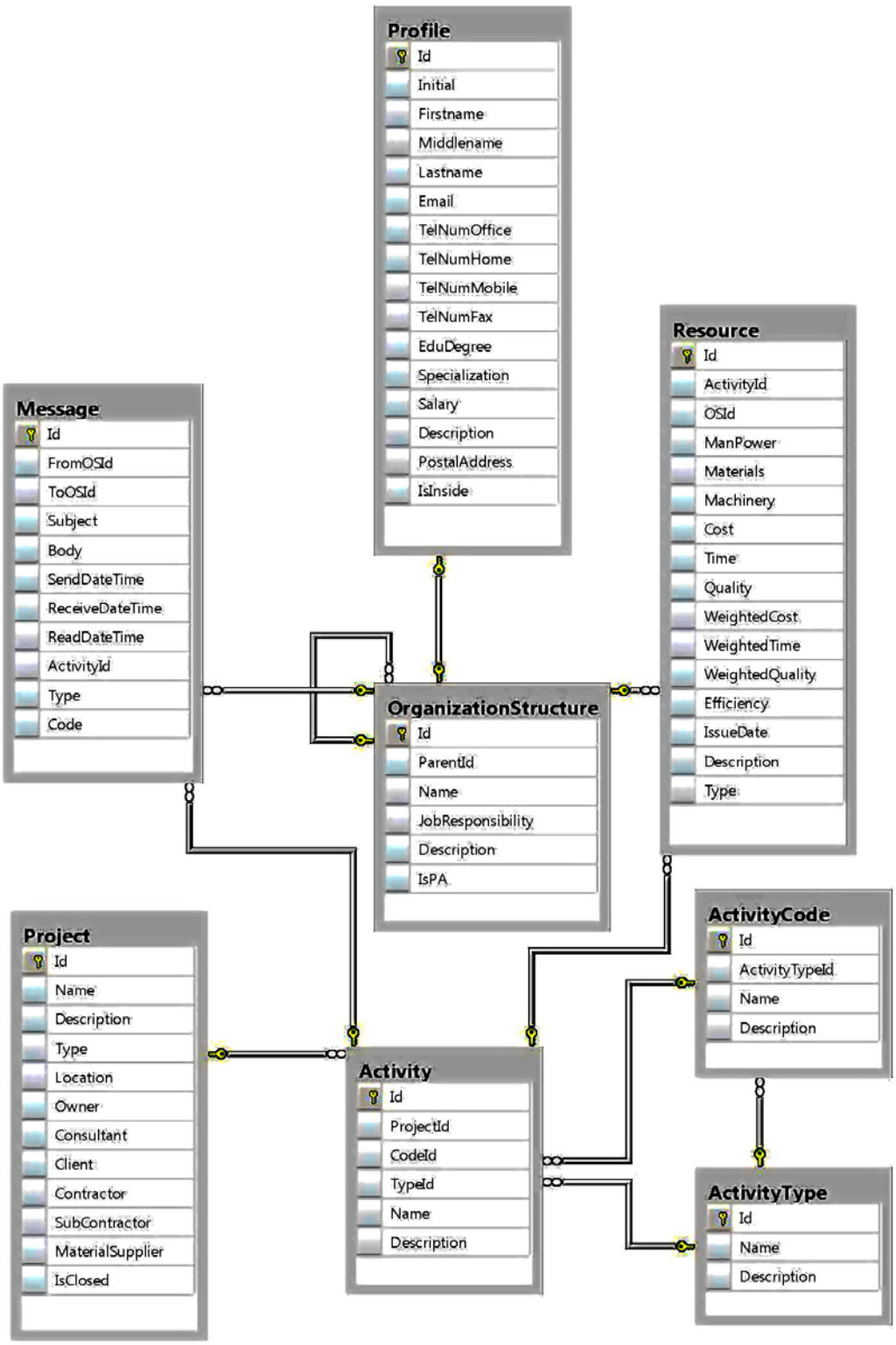

Figure 6.2 PMSS General Application Diagram

"Every database consists of tables or data files. These tables and files follow a certain structure based on a data model that has been found useful for a specific purpose" (Brazhnik, 2007).

Organization structure table includes parameters related to the organizational breakdown structure (OBS). PMSS only considers functional organizational structure since most of the companies prefer it nowadays (Pinto, 2007) among the different organizational structures. Each position in the OS is assigned an *Id*, a *ParentId*, a *Name*, a *JobResponsibility*, a *Description*, and an *IsPA* dimension. *Id* refers to the position's abbreviation (i.e. Des. Dep. for Designing Department). *Id* will be used in the back end of the system for communication purposes. *ParentId* refers to the higher level in the OS to logically form the OS. *Name* is the complete name of the position to be used in the program where appropriate. *JobResponsibility* is to define the responsibilities and span of control for each position. *Description* would be used for extra definitions and explanations necessary for each position. *IsPA* field is used to give different authority levels to different positions for accessing and being eligible to define or modify secured data. Organization structure table has a "one to many" relation which means each position in the OS can have several positions under it (Çelik and Rezaei, 2009).

After defining the general structure of the company, a person should be assigned to each position. Each individual's private and personal information will be entered using profile table. This information includes initial, first name, middle name, last name, e-mail address, various telephone numbers, educational degree, specialization, salary, postal address, and any necessary description. These data would be used for personnel identification together with different functions of the system including message sending alert, salary bonuses, etc.

Each project of the company together with all of its participants and related data will be defined to the system through project table. Each project will then have and *Id*, a *Name*, a *Description*, a *Type*, its *Location*, the *Owner*, *Consultant* (if any),

Contractor, different *Subcontractors*, and various *Material Suppliers*. Project table includes an *IsClosed* item at the end which would be used for the completed projects so that they can be archived to enhance the system performance and response times.

Each project consists of a number of activities which form the work breakdown structure (WBS) of that project. Each activity would be defined to the system through activity table. These activities will be categorized into different activity types according to their type such as earth work, concrete work, etc. which is supported by activity type table. Different projects might share a common activity; thus, activity code table should be used to group similar activities in different projects. This categorization would be later used in the system for work submission and reporting purposes.

Every activity needs specific resources for its execution including money, minute, material, manpower, and machinery (5Ms). By creating each activity in the system, its resources should also be assigned. These resources called “estimated resources” in PMSS are required resources based on the quantity takeoff calculations. The resources will be defined through resource table. Another important resource for each activity is its quality (estimated quality) which is considered to be %100 as planned for all activities.

Performance calculation is performed using three resources of time, cost, and quality; thus, a weighted factor is assigned for each of these resources based on their importance. These weighted factors are unique for each activity and even might vary for one activity type in different projects. For example, concreting of a normal building project might have to be performed with lower cost due to financial limits, where for the same concreting activity in a dam project, time might be more

important due to project deadlines. In the former, weighted factor for cost will be higher than that of time but in the dam project, it would be vice versa.

Estimated resources defined when setting up a project in the system would be used together with actual resources after performing an activity, called “performed resources” in PMSS, for calculating performances. Therefore, different resource types will be utilized and saved in the system which would be verified by *Type* dimension.

The heart of PMSS which controls all transactions and calculations is message table. All message transfers and communications between company personnel and also project stakeholders would be performed through a user interface which is directly connected to message table. Each message or work has two contributors, a sender who submits the job and a recipient who should perform it. Sender and recipient will be assigned to the message through *FromOSId* and *ToOSId* dimensions. Message subject and body will be added to the message and by selecting a project and an activity, it could be sent to the recipient. There might also be some negotiations between the sender and the recipient prior to performing the job. Therefore, a message could have different types including submitted, negotiated, and performed which will be verified by *Type* dimension.

6.3 PMSS Environment

PMSS is a web-based system which can be accessed through different web browsers such as “Mozilla Firefox, Microsoft Internet Explorer, Google Chrome, Opera, etc.” Users of the system can be anyone who is assigned a username and a password.

Some of the characteristics of PMSS are:

- Web-based data transfer

- Grant access to multiple users with different authority levels
- Complete the job on-line
- Real time performance calculation
- Performance to reward linkages

PMSS also offers its participants access to information through an easy-to-use, password-protected Web site. This Web site includes:

- Electronic discussion
- Participant rosters searchable in several ways
- Access to electronic reports about all aspects of organization
- Performance tracking tools

It affords the participants the opportunity to send and receive the assigned jobs on-line and negotiate on the resources required to perform the job. They can improve their performance through faster response time, earlier job submission, lower cost, and higher quality jobs.

General PMSS operation procedure is shown in Figure 6.3. The first step for PMSS operation is setting up. It is not necessary for all computer systems intending to use PMSS to have it installed on them. Main program and databases will be installed on company's web server and database server and published through the Internet. The authorized users would then be required only to install a Web browser on their computers and connect to Internet to be able to contribute to the system and perform their assigned jobs.

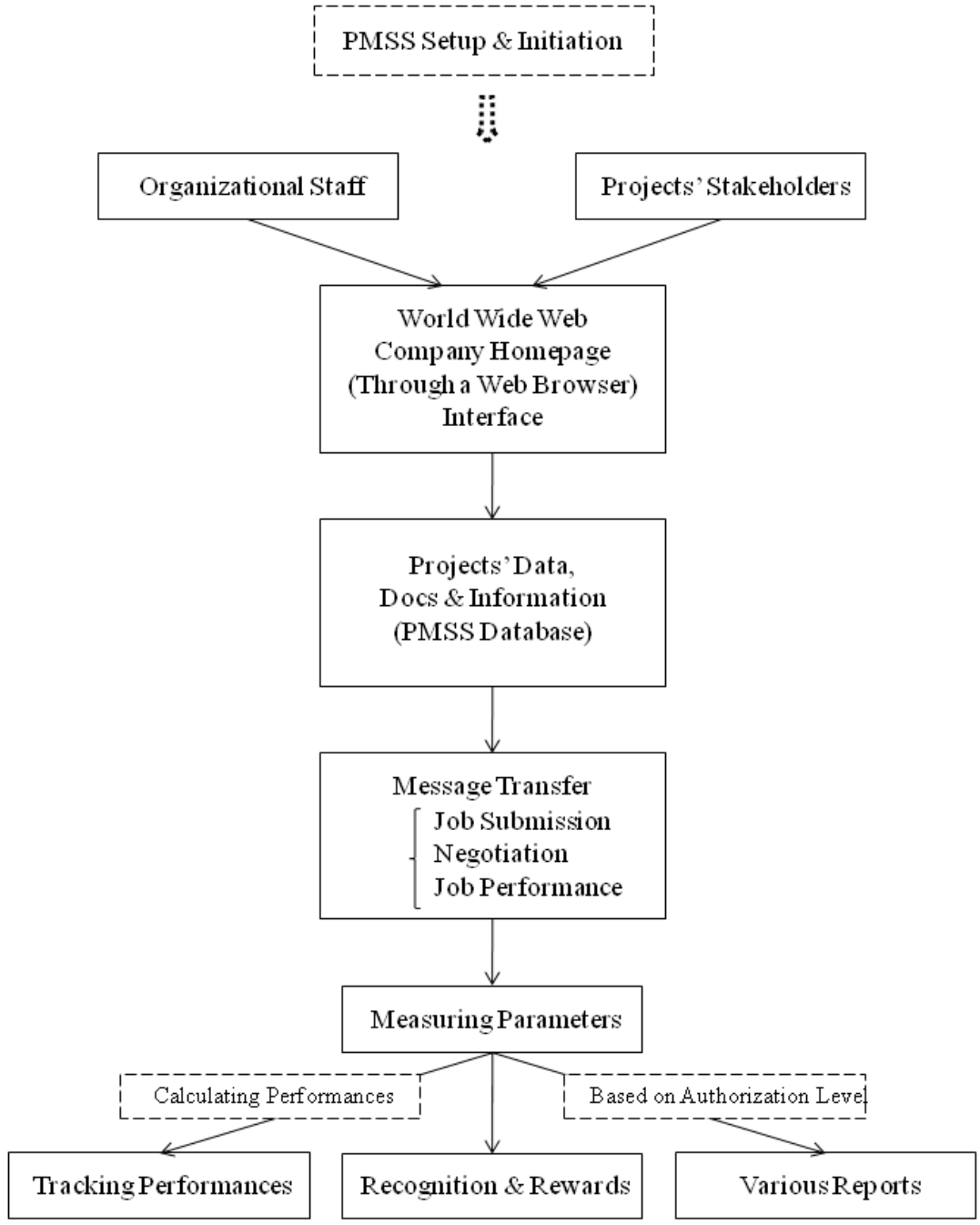

Figure 6.3 PMSS Operation Procedure

In order for the system to be successfully implemented in the organization and the proposed benefits to be achieved:

- Clear job descriptions must be developed,
- Appropriate people should be selected based on certain circumstances,
- Explicit recognition and compensation systems should be designed, and

- Career development opportunities must be provided for employees.

6.3.1 Installation, Setting Up and OS Creation

Although according to Evans (2004), the "discipline required to establish and maintain effective performance measurement system is viewed as an arduous task by many organizations," the developed system is such designed to be easy to setup and initiate. Setup and installation authority is given to the company's general manager (GM) to define company's OS. Among the different organizational structures, functional organizational structure is used in PMSS. OBS creation has a dynamic structure which means there is no limit in the number of horizontal and vertical levels; thus, each company can create its own OBS structure. One of the weaknesses of functional structure is its low team member motivation (Pinto, 2007). PMSS with its performance measurement feature and motivation system is deemed to overcome this problem and make the functional structure more efficient. GM can delegate his authority to other high level personnel, such as head of estimating and tendering department or head of design department for creating, define, or modify projects, activities, and resources. Other users have only access to the data for their works. A sample page of OBS creation is shown in Figure 6.4.

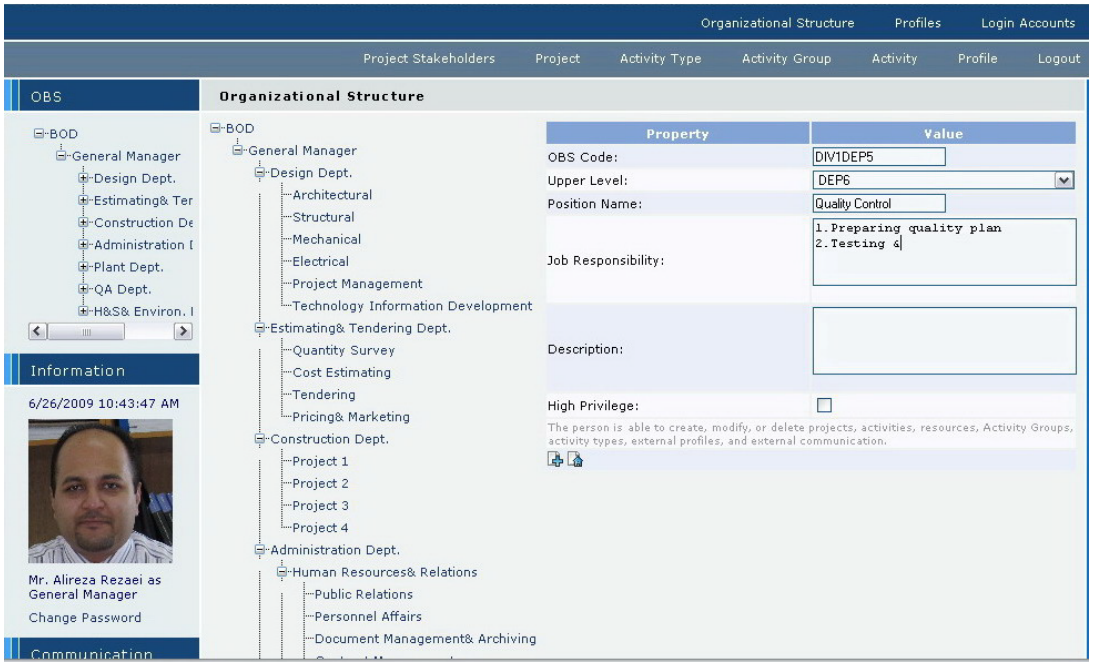

Figure 6.4 OBS Creation in PMSS

6.3.2 Employee Profile and Authorization Details Definition

Based on the defined OS, each position can communicate with specific positions which include all horizontal positions in the same department and one top position. After defining the company's OS, an employee will be assigned to each position and his/her personal details together with contact information, educational details, salary, specialization and such like will be defined to the system. A sample profile creation is shown in Figure 6.5.

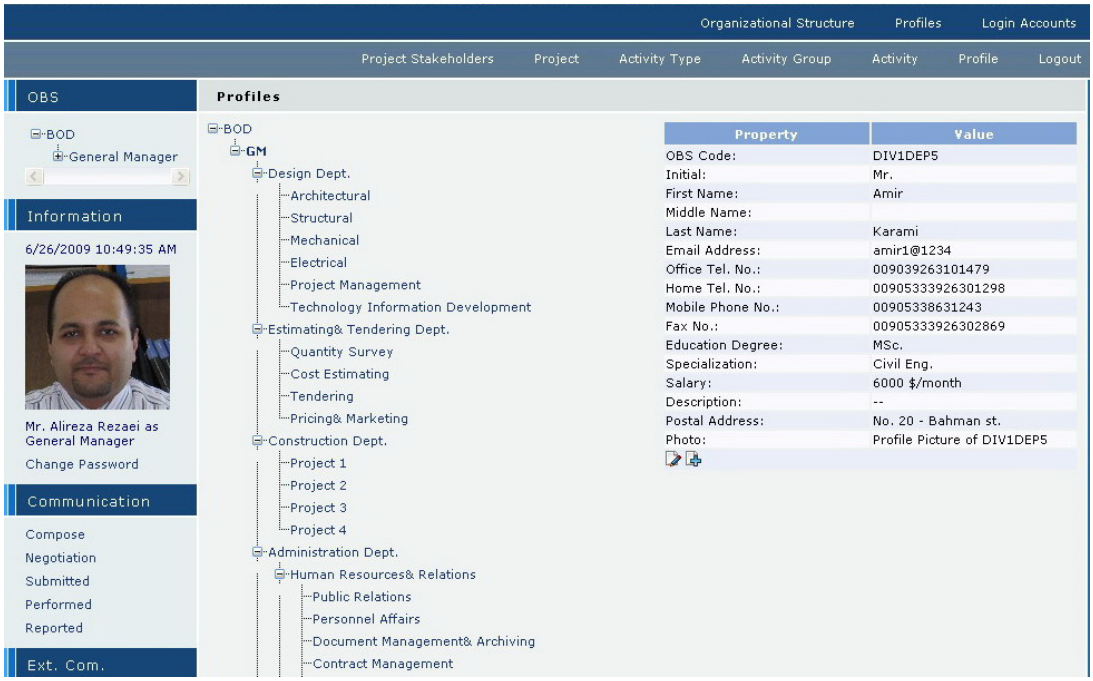

Figure 6.5 Profile Creation in PMSS

Thereafter, each user will be granted an authorization level to have access to certain information in the system. Access to the system is controlled through authorization and is a basis for determining the authority level to access particular information and the operations one is allowed to perform. The authorization details would be sent to the employee through a message on mobile phone and an e-mail to the defined address in the profile. Sample login page is shown in Figure 6.6.

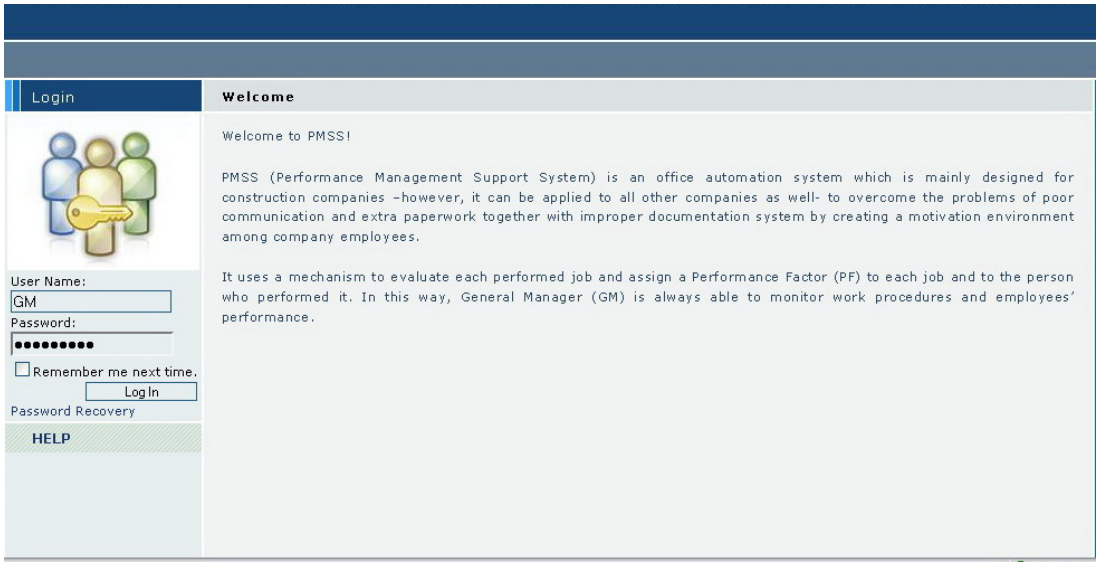

Figure 6.6 PMSS Login Page

Other stakeholders will also be defined to the system when they join any project. The main stakeholders of the projects might include external clients, external designers, consultants, contractors, sub-contractors, and material suppliers.

6.3.3 Project, Activity and Resource Creation

As the company gets involved in a project, one the authorized personnel like GM, head of estimating and tendering department, or head of design department develops a database for it. The database can be defined and created through an interface as shown in Figure 6.7.

Figure 6.7 Project Definition in PMSS

All involved stakeholders -who are already defined to the system-, will then be assigned to the project and project details will be entered in the system. Project documents such as architectural drawings, structural drawings, mechanical and electrical drawings, bills of quantities, contracts, planning and budgeting documents, etc. would be uploaded to the main company server. These documents will later be used as message attachments in work submissions. Other documents that will be created after project creation and during the project performance are primarily located on different users' computers. Once these documents are attached to a

message, they will be saved in a subfolder named “message attachments” which is created in the project folder.

Different activity groups and types will be defined according to activity categorization. Activities will then be created based on Projects’ WBS. Each activity requires specific resources to be performed. All five different resources together with importance weights which are estimated and calculated by estimating and tendering department will finally be allocated to each activity. After defining the projects, their related activities and resources, the system would be ready to be implemented. Activity creation and resource allocation procedures in PMSS are shown in Figures 6.8 and 6.9.

The system might seem to be inconvenient for general companies with a few numbers of employees. However, its advantages will be more realized for larger companies with more projects -especially construction projects with different and more dynamic nature. In such companies, hundreds of administrative and construction activities should be performed every day and in a specific time period, they cannot be controlled and evaluated manually. Melnyk et al. (2004) emphasized that “as the volume of inputs increases, through greater span of control or growing complexity of an operation, data management becomes increasingly difficult.” The ability to gather and assess relevant data is an essential property for project management (Lock, 1996). A successful manager needs to have access and be informed of all information and data continually. It is more critical for the organizations with international projects geographically dispersed.

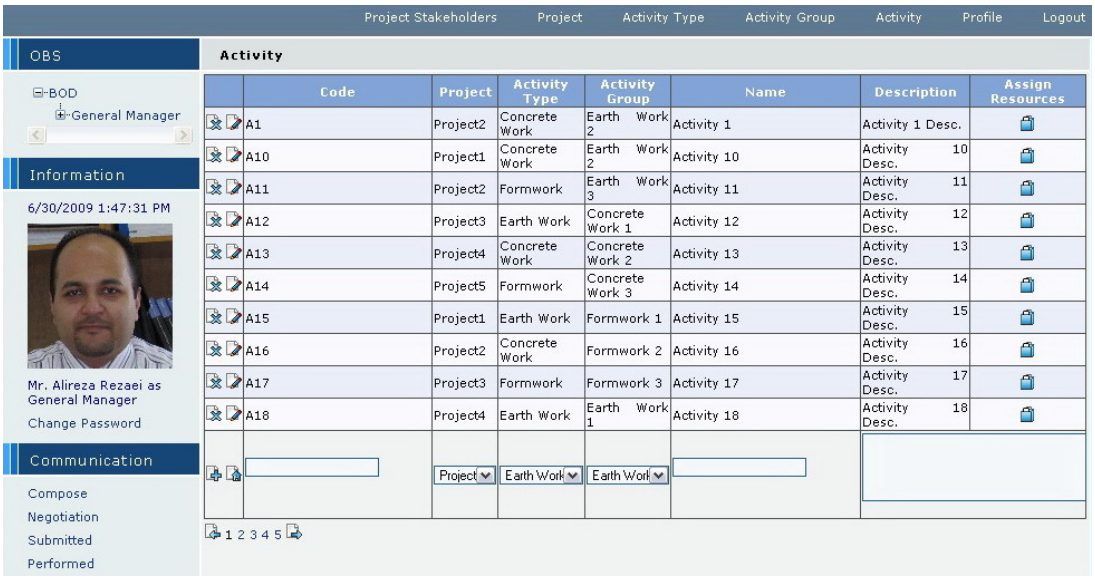

Figure 6.8 Activity Creation in PMSS

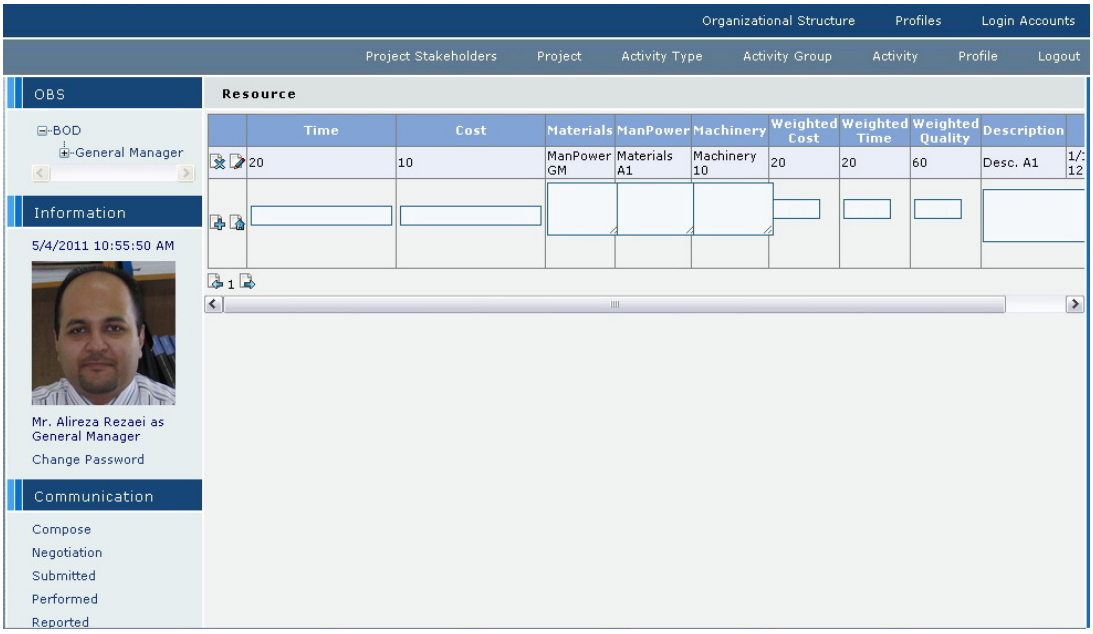

Figure 6.9 Resources Allocation to Activities in PMSS

6.3.4 Message Transfer System

The electronic data exchange is allowed through a number of web pages designed for this purpose. As the users perform their tasks with the system, the database would be populated and its data would be updated.

All sending and receiving of the works in PMSS and job submissions are done using the message transaction mechanism and through predefined lines of

communication. Each user has a panel including “communication” and “report” facilities. Communication is further divided into “communication” and “external communication”. Communication would be used to communicate with the company personnel and external communication for project stakeholders who are not in company OBS. Report could be used for retrieving appropriate reports. Report is divided to two sub-divisions named “company reports” and “position reports”. Company reports refer to the various performance, financial, cash flow, work progress, planning related, or resource related reports that only some personnel that are delegated higher authority level can access them. Position reports are position related reports that each employee can create for his/her own position in OBS.

“Negotiation”, “Submitted”, and “Performed” inboxes under communication panel allow composing a message, negotiating on a received work, submitting a work, or performing a work. Each message has two parties: a sender and a recipient. Sender of the message has alternatives of “Negotiate” on resources of the work or “Submit” it directly to the recipient. If the message came to the recipient through “Negotiate”, he has the right to send back his opinion to the sender. This process can continue until both parties come to an agreement on the estimated resources required for the work. In a typical compose page as shown in Figure 6.10, GM prepared a message to the head of design department for estimating the required amount of concrete for first floor beams and slabs considering the changes made in the structural drawings.

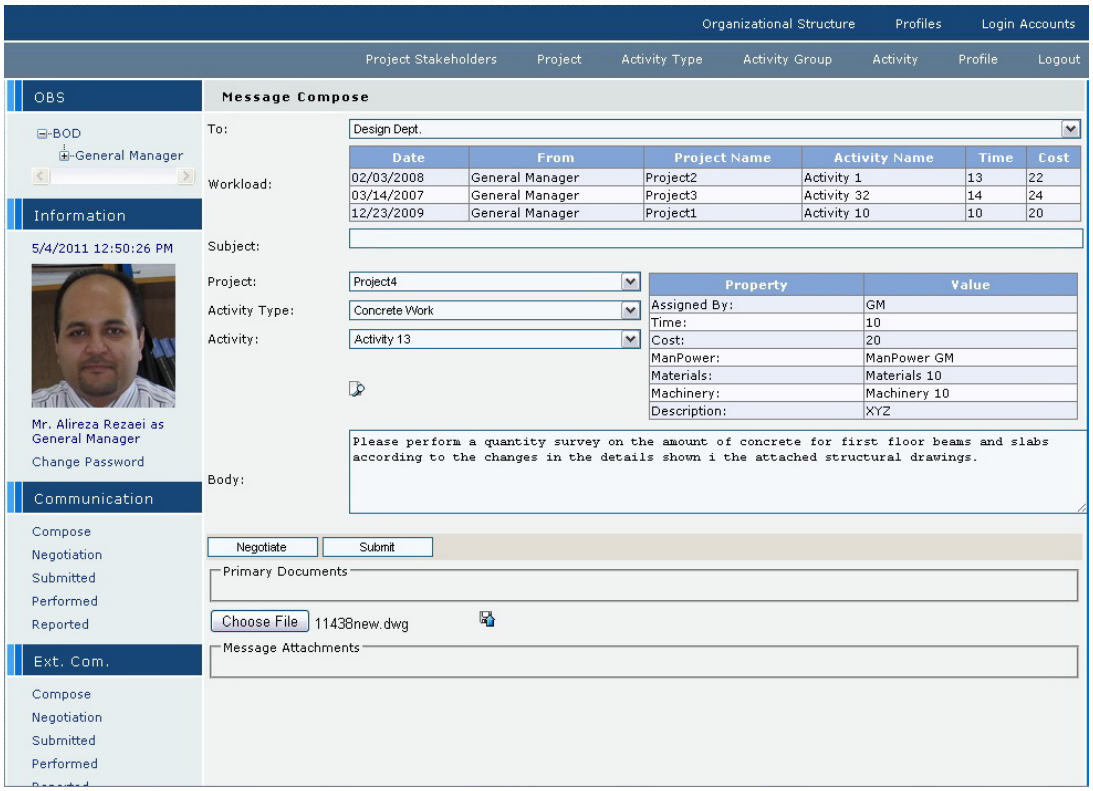

Figure 6.10 Compose Message Page in PMSS

If the work came from the sender through “Submit”, or after negotiation, while the sender submits the job to the recipient, then recipient has no right to object the estimated resources, but just perform the work and send it back. The resources can be time, money, machinery, material, and manpower. The sender is capable to check the workload of the recipient to fix the duration of the work accordingly. A typical submitted messages inbox of the head of design department is shown in Figure 6.11.

The recipient of any message will be informed by a short message through his mobile phone as soon as receiving a message in his inboxes. Documents and messages will be transferred rapidly, thus, the send and receive times are assumed to be the same. Each user has a time limit after receiving a message to open it, otherwise, the extra time than the limit will be counted as delay and would have a negative effect in his/her performance. After opening the message, delays in performing the assigned job will be considered as time resource usage which will

affect the performance as well. All of these delays could be tracked by GM or any authorized employee through specific reports.

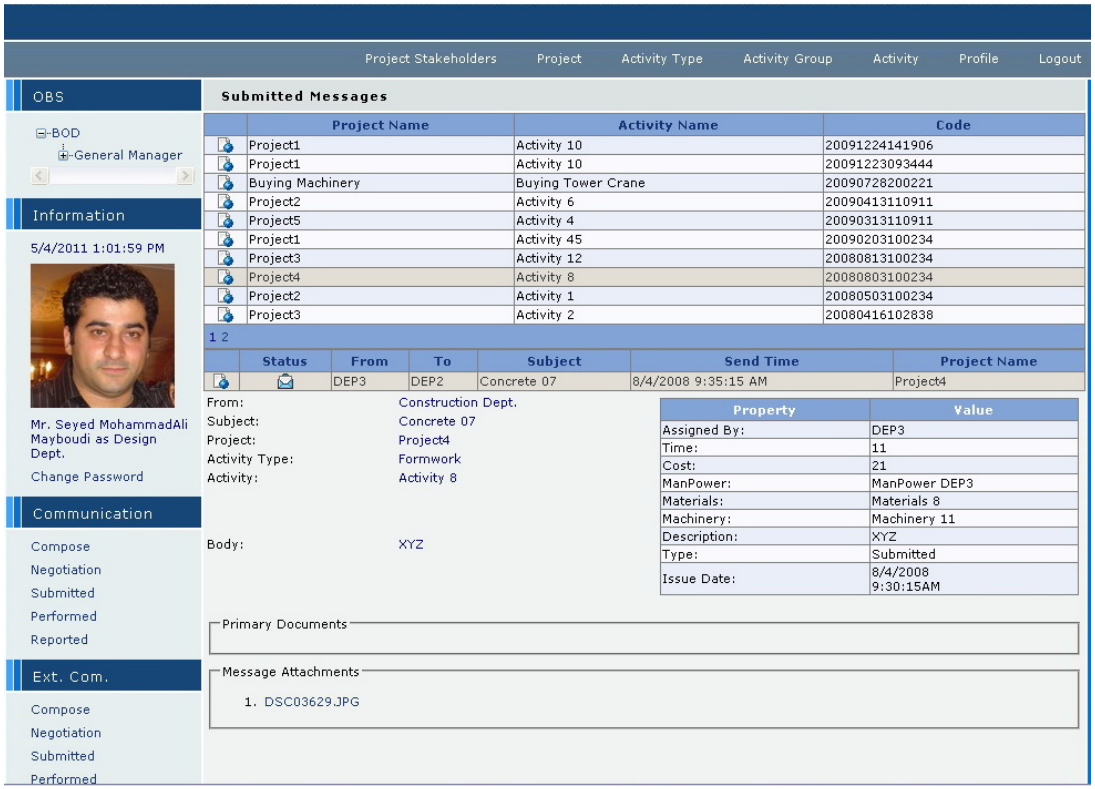

Figure 6.11 Submitted Messages Page in PMSS

Once the work is completed by the recipient it will be sent back to the "Performed" inbox of the original sender. Performed resources fields will be filled by the recipient based on the actual resources used. A sample of the performed message from the head of estimating and tendering department to the head of design department is shown in Figure 6.12.

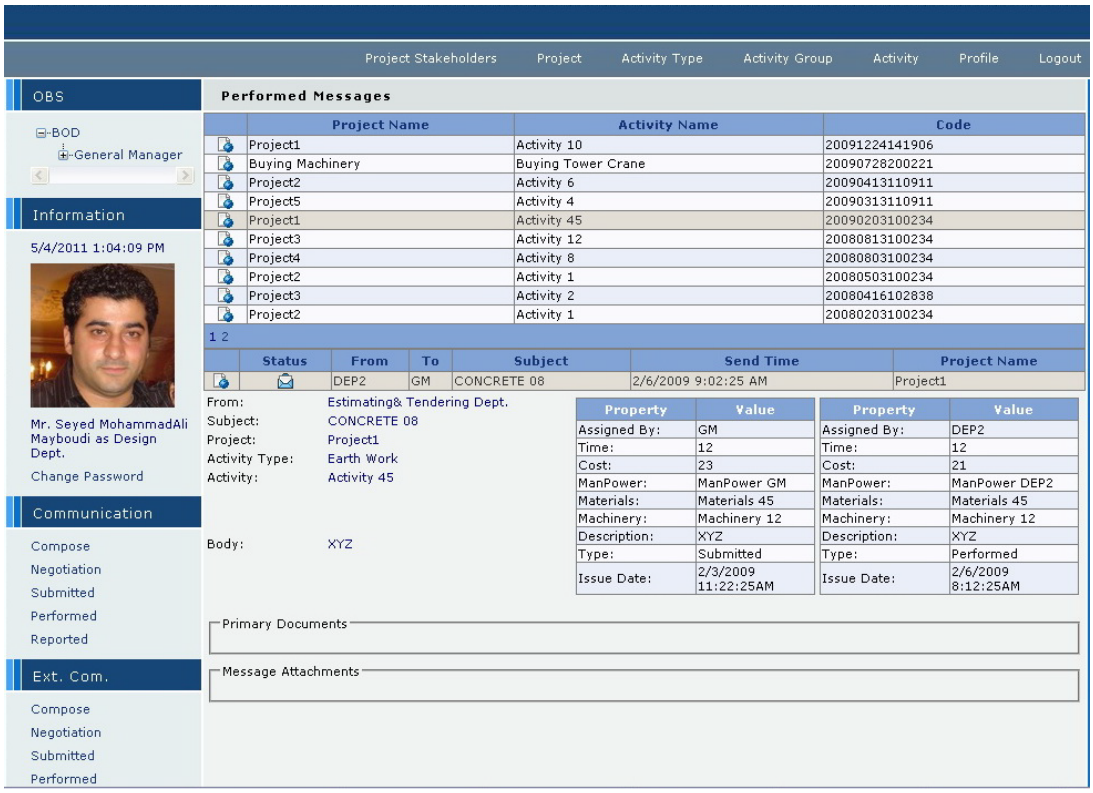

Figure 6.12 Performed Messages Page in PMSS

6.4 Performance Measurement Framework

As stated by Isik (2009), "performance measurement system refers to the measurement system implemented by a company, where performance measurement framework is general theoretical framework developed in a research that can act as a basis for the company's performance measurement system."

The most important part of developing a performance measurement framework is deciding on what to measure. Once the parameters have been selected, people will focus their efforts on those aspects of their work to receive more credit. "Performance criteria and ratings can contribute to a positive, powerfully motivating experience for organization members" (Kutucuoglu et al., 2001).

Kutucuoglu et al. (2001) proposed the following questions and their subsequent answers for effective performance measurement system development:

- "Why measurement is required? (Purpose)"

- “What should be measured? (Finding factors that are important)”
- “How it should be measured? (Methods)”
- “When should it be measured? (Timing and time frame)”
- “Who should measure it? (Owner of the process versus independent party)”
- “How should the result be used? (Assessment, improvement purposes)”

What to be measured and how to measure form the basis of measurement framework. The measures for performance calculation in PMSS were selected considering that they should be improvement rather than control measures.

Najmi and Kehoe (2001) believed that “there is no universal performance measurement system which is appropriate to all organizations;” however, according to Neely et al. (2005), “all performance measurement systems consist of a number of individual performance measures.” Based on the definition of Melnyk et al. (2004), “metrics and performance measurement are the critical elements in formulating an organization’s strategy into reality.” Neely et al. (2005) stated that “performance measure can be defined as a metric used to quantify efficiency and/or effectiveness of an action”. Every firm, every activity, and every employee needs metrics. Green et al. (2004) emphasized on the unavailability of suitable measurement scales for individual performance.

According to Bose (2006), developing measures for providing a balanced view of the business is a challenging task. Faced with a number of candidate metrics, how does one select those that are most meaningful? “Different businesses would have their own specific dimensions and related measures.” For example, the dimensions and their related measures could be:

- Productivity,
- Quality,

- Profitability,
- Timeliness,
- Process efficiency,
- Cycle time,
- Resource utilization,
- Cost savings,
- Innovation, and
- Technology management.

Most of the organizations measure their performance based on financial factors such as profitability, gross revenues, return on capital, etc. Unfortunately, “if senior management only focuses on the financial health of the organization, several unfortunate consequences arise. One of these is that financial measures are “lagging indicators” of success” (Shakoorian, 2006). “This means that how high or low these numbers go depends on a wide variety of events that may have happened months or years before and that you have no immediate control of in the present.” However, according to Garengo and Bititci (2007), performance measures’ focus changed from pure financial measures to a “combination of financial and non-financial measures” since 1980s.

To be useful, performance measurement must include time. Time is the framework in which decisions are made. It is an essential performance metric. Jiang (2005) considered a set of cost-based and non-cost-based performance measures within a DSS developed for performance measurement in steel construction. Response time minimization and lead time minimization were deemed as important non-cost-based performance measures.

Therefore, based on a thorough literature survey, the criteria to measure employee performance across the organization were considered to be time, cost, and quality (Rezaei et al., 2011), since each of these factors gives some useful information about the employee performance (Arjomandi et al., 2009). It is mentioned by De Toni and Tonchia (2001) that the logic of "trade-off" between performance measures has been more or less abandoned. New performance measures relating to quality, time, cost and flexibility are being used in recent research studies (Seyedhoseini and Hatefi, 2009; Luu et al., 2008; Jariri and Zegordi, 2008; Ozorhon et al., 2007; Nudurupati et al., 2007; Shakoorian, 2006; Neely et al., 2005; Ahmad and Schroeder, 2003; Nahm et al., 2003; De Toni and Tonchia, 2001; Najmi and Kehoe, 2001; Neely et al., 2000; Jayaram et al., 1999).

Once the original sender receives a performed work, he will compare the estimated resources with the actual resources used, check the accuracy of the work and assign a grade for its quality. For every performed work, an Activity Performance Factor (APF) will automatically be calculated by the system using the formula (1). Formula (1) was initially considered as a basic equation (x=a+b+c) and it was then improved to its final form through extensive discussions and tests. Specific issues such as optimizing resources and using different weights were considered to improve its applicability and effectiveness.

$$\mathrm{APF} = \frac{\mathrm{T_{est}}}{\mathrm{T_{per}}} \times \mathrm{W_T} + \frac{\mathrm{C_{est}}}{\mathrm{C_{per}}} \times \mathrm{W_C} + \frac{\mathrm{Q_{per}}}{\mathrm{Q_{est}}} \times \mathrm{W_Q} \qquad (1)$$

T_{est} and C_{est} are the estimated time, and cost for activities and would be calculated while performing quantity survey and costing of a project. Q_{est} of all activities is always assumed to be 100 at the beginning and is not negotiable. Different weights should be applied to different factors when measuring performance. W_T, W_C, and W_Q represent the weighted factors of time, cost, and quality respectively. These factors

are defined for every single activity while specifying its resources by estimating and tendering department. They explain the importance of each parameter. W_T, W_C, and W_Q are considered as percentages and their sum is always equal to 100%.

T_{per} and C_{per} represent the actual utilized time and cost. Q_{per} is the quality grade and is assigned by the original sender on the basis of 0 to 100 measures. Input-to-output ratios might create problem such as reduction in the quality of the output to improve the overall performance. Subjectivity of Q_{per} is believed to be minimized by considering the number of mistakes/errors/deficiencies produced, delay in reading messages caused by recipient, and percentage of work actually completed with T_{per} and C_{per} . One higher level authority will also be informed about the assigned Q_{per}. Q_{per} will be calculated by formula (2):

$$Q_{per} = \sum_1^i \frac{D_{est}}{D_{per}} \times W_D + \sum_1^j (1 - \frac{M_{per}}{M_{est}}) \times W_M + \frac{PC_{per}}{PC_{est}} \times W_{PC} \quad (2)$$

Where D_{est} is acceptable delay time for the company and is assigned by estimating and tendering department; D_{per} is recipient's delay time in reading the message which is a percentage of D_{est}; *i* is the number of orders coming to the employee; M_{est} is the number of allowed mistakes/errors/deficiencies for a specific activity and varies for different activities and is assigned by estimating and tendering department; M_{per} is the number of mistakes/errors/deficiencies occurred in a performed work; *j* is the number of activities with checklist; and PC_{per} is the percentage of work completed. PC_{est} is the estimated percentage of work completion within the assigned time (T_{est}) and by default is assumed to be 100%. W_D, W_M, and W_{PC} are weighted factors of delay, mistakes/errors/deficiencies, and percent complete respectively. W_D, W_M, and W_{PC} are considered as percentages and defined by estimating and tendering department for each activity and their sum is always equal to 100%.

Delay in reading the message would have special cases as follows:

If $D_{est} = 0$ & $D_{per} = 0 \rightarrow \frac{D_{est}}{D_{per}} = 1$

If $D_{est} = 0$ & $D_{per} \neq 0 \rightarrow \frac{D_{est}}{D_{per}} = -\frac{D_{per}}{duration}$, where *duration* is activities T_{est}.

If $D_{est} \neq 0$ & $D_{per} = 0 \rightarrow \frac{D_{est}}{D_{per}} = (1 + \frac{D_{est}}{D_{per}})$

If $D_{est} \neq 0$ & $D_{per} \neq 0 \rightarrow \frac{D_{est}}{D_{per}} = \frac{D_{est}}{D_{per}}$

APF may be equal, less or more than 100%. If it is less than 100%, it means that the submitted work was performed with lower level than expected. If it is equal to 100%, it means that it was performed as expected. If it is greater than 100%, it means that it is performed with a higher level than expected.

Every employee has a performance factor (PF) in the company. PF is updated based on the OBS level by using the formulas (3) or (4).

If employee is at the lowest level in OBS so nobody gives reports to him:

$$PF = \frac{\sum_1^n APF_i}{n} \times (1 - 0.005w) \quad (3)$$

Where APF_i is the work performance obtained from a specific work and n is the number of the total works performed so far, and w is the work experience of the employee in years. Other factors like salary and education of an employee could also impact PF; however, only work experience was considered due to its higher importance.

If there are lower positions in OBS to give reports to him:

$$PF = \frac{\frac{\sum_1^n APF_i}{n} \times (1 - 0.005w) + \frac{\sum_1^m PF_j}{m}}{2} \quad (4)$$

Where PF_j is the performance factor of every lower level employee and m is the number of the lower level employees that so far give reports to him.

6.5 Motivation

Motivation can be called a “central element within the process of human learning.” The organization must be able to use effective methods to motivate its employees so that they use their knowledge and ability to a maximum. Therefore, every organization has to “find the factors that enable it to motivate its employees” (Islam and Ismail, 2008). As stated by De Toni and Tonchia (2001), the aim of performance measurement system must be to motivate and involve employees. An essential way to motivating employees is to satisfy their needs in proper ways. Each individual has different needs; thus, different motivation methods are designed such as financial rewards like increments in the salaries; recognition through announcing the best employee of the day, month, and year in company news boards; and bonus holidays in PMSS.

Obviously, an employee with a higher PF will have better standing in the company. Besides, depending on the policy of the company, these factors can be effective in determining an increment to the salary or other types of rewards to be as supports for effectiveness of the performance measurement system. Rewards can have an underpinning and supportive role in promoting employees in their careers (Govindarajulu and Daily, 2004). This is also emphasized by Pheng and Chuan (2006) and Kuwaiti (2004) that reward system will lead to satisfaction and will increase the effectiveness of performance measurement. Performance measurement can considerably affect the lives of people if implemented and used properly; thus, it is expected that such an application will strongly motivate employees for a better performance.

On the other hand, an employee with continuous low PF will be replaced. The substitute employee might also gain low PFs that it could then be a good basis for

manager to revise job responsibilities. The position might need more than one employee or the span of control might need to be narrowed.

6.6 PMSS Reports

According to Gulledge and Chavusholu (2008):

> Effective organizational management requires data to support decision making. Managers need data for measurement and control, similar to an aircraft pilot monitoring the cockpit displays (command, control and communications center for that unit). The pilot needs controls to navigate safely and efficiently.

PMSS can support real-time report provision. Real-time reports enable employees to continuously improve their productivity (Green et al., 2004). GM can use this capability to regularly tracking employee performances.

The system is designed such that to raise warning and action signals when certain performance limits are reached. Different PF limits can be defined to the system based on various conditions. When an employee's performance (PF) drops under a certain limit, if the manager is online, he will be notified by a message in his inbox and a flashing signal to check the performances and if he is offline, he will be informed through a short message on his mobile phone.

PFs can be shown dynamically and accurately on organizational chart as one of the reports of the system as shown in Figure 6.13. The reports are online and updated automatically as any change occurs in works and databases.

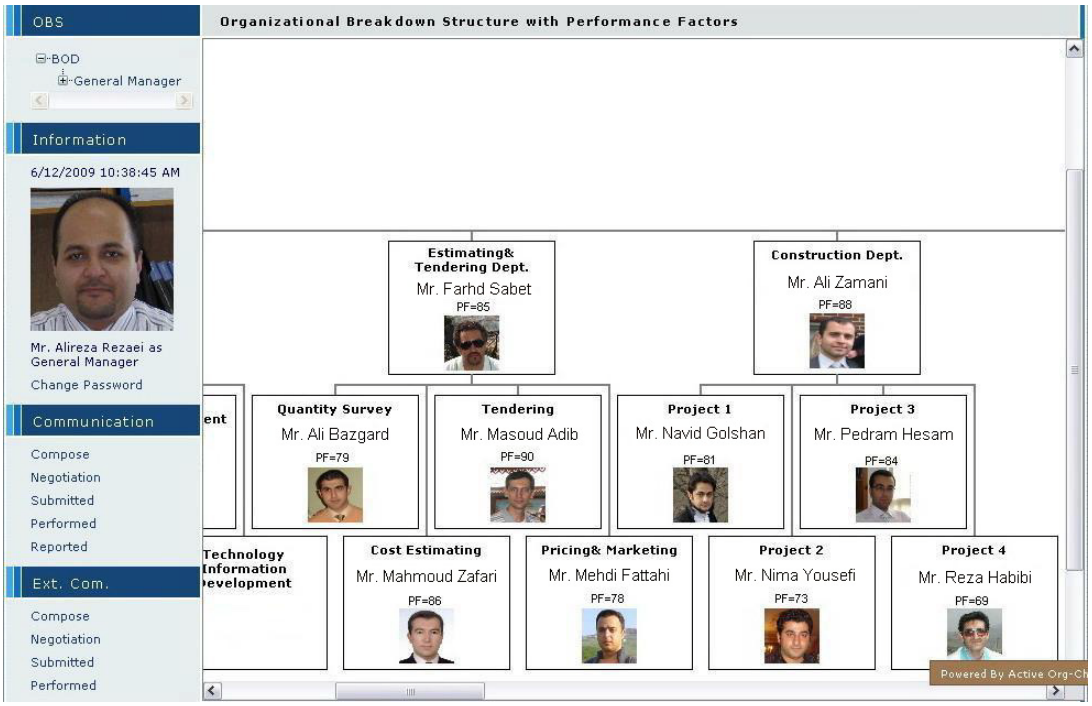

Figure 6.13 Organization Structure with Performance Factors

Another report PMSS provides is the amount of delay each person caused in message reading. The difference of receiving and reading times of all received messages will be calculated and accumulated for each person. These delays could be shown both in tabular format and graphically and could also be shown on OBS chart.

On the other hand, DW can extract the necessary data from different departments and projects and after cleansing, use them to provide various reports. It can also keep them as historical data for future use and reference.

Different report types developed by PMSS range from various financial reports about different projects and the company, resources related reports, time related reports, activity related reports, delay reports, performance reports, and organizational position reports. Such reports can be characterized in different formats such as Microsoft Excel sheets and graphs or Adobe Acrobat pdf files and also can be represented in tabular, graphical, or chart formats in different interfaces.

One of the reports created by PMSS is daily report on performed activities with estimated and performed resources. It will be automatically created everyday and sent to GM or whoever authorized to receive it. This report can be a basis for resource monitoring.

Another report could be cash flow reports that also prints s-curve based on the items and time interval selected by the user. Two sample diagrams in Figures 6.14 and 6.15 represent tabular cost report and graphical cash flow report in PMSS respectively.

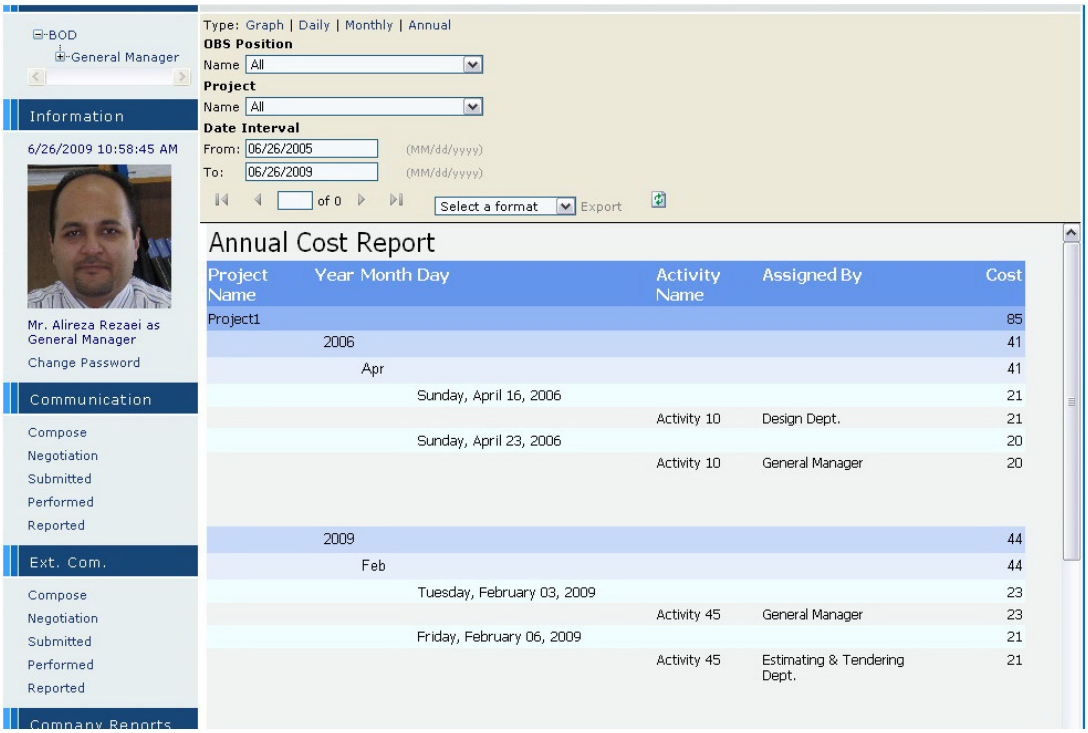

Figure 6.14 Tabular Cost Report in PMSS

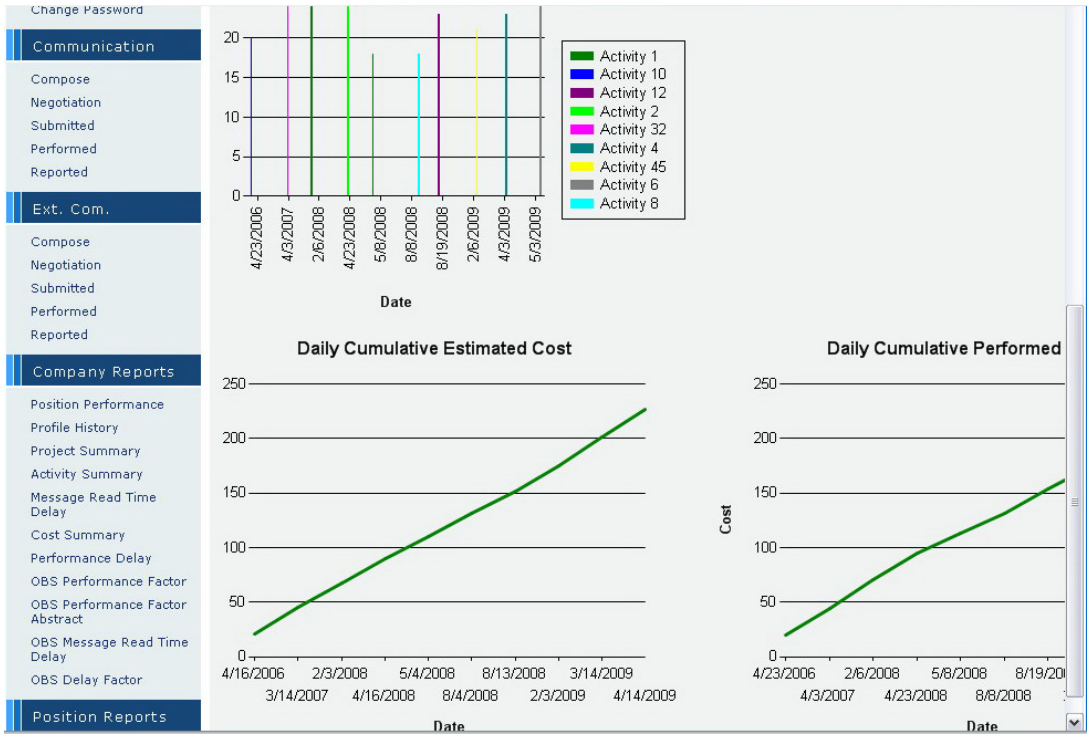

Figure 6.15 Cash Flow Report in PMSS (Bar Chart and S-curve)

Chapter 7

SYSTEM EVALUATION

7.1 Introduction

Recently, as stated by Bourne et al. (2000), "the focus has been on the early stages of the development of the performance measurement system, the conceptual frameworks and processes for designing the performance measures." There are few longitudinal studies of the practical application of performance measurement systems.

In order for an IS to be practically applicable and reliable, its functionality should be checked through different procedures. On the other hand, the reliability and positive effect of a performance measurement system should also be checked to avoid possible drawbacks of its practical implementation.

In this chapter, the efforts for evaluating the applicability of PMSS in construction industry, from IT and performance management points of view will be discussed.

7.2 System Evaluation

As stated by Ketokivi and Schroeder, (2004):

> All measurement instruments must satisfy the criteria of reliability and validity. A reliable instrument measures with consistency that is with little random measurement error (yet it may or may not measure the right thing). A valid instrument, in turn, measured what it is theoretically purported to measure (but it can do this with either high or low consistency). The distinction is fundamental and both criteria must be satisfied.

Palvia et al. (2001) defined the evaluation of an IS as “an exercise in determining its implementation success.” They further stated that “IS implementation success is a multidimensional concept” and needs some standard measures. Without a set of standards, it would be difficult to evaluate implementation success. Hartono et al. (2007) emphasized that “evaluation is the most difficult aspect of IS development since such systems lack a defined completion date.” They also pointed to the lack of clear criteria for assessing the IS performance and stated that the effectiveness of these systems depends on their evolving usage.

Bose (2006) identified several “critical implementation factors (CIFs)” categorized in two groups of technical and organizational challenges which could have impact on the success or failure of DW implementation. These include “technical, management sponsorship, goals and objectives of an organization, user-related issues, Organizational factors, and system-growth-related factors.”

Hartono et al. (2007) considered success antecedent constructs as “degree of management support, nature of organizational attitudes and commitment, perceived user friendliness of the system, degree of developed skills, task characteristics such as degree of problem difficulty supported by the system, level of user experience, level of user participation, degree of perceived value, and level of training.”

Hong et al. (2008) considered software quality, meeting targets, maintenance complexity, and user satisfaction as highest priorities for a software project development. Palvia et al. (2001) considered the main factors in the evaluation process as outcome accuracy, ease of use, positive effect on performances, manager’s decision making, and overall company performance.

Chen et al. (2000) classified IS success factors under six major categories including “system quality, information quality, use, user satisfaction, individual impact, and organizational impact.”

On the other hand, Standing et al. (2006) highlighted the main reasons for IT project failure as:

- “Insufficient awareness of organizational issues,”
- “Insufficient involvement of users,”
- “Inadequate training of users,” and
- “Poor alignment of IT adoption to the business strategy.”

Palvia et al. (2001) divided IS evaluation process to two parts: pre-implementation process and post-implementation process. On the other hand, “the concept of implementation success varies according to different perspectives.” Thus, the variation among stakeholder groups (users, developers, and mangers) perspectives must be taken into account. PMSS was evaluated based on these ideas. In the pre-implementation evaluation, it was run with a number of skilled software developers and construction managers to find its operability and deficiencies. Then, it was run in a construction company to determine its implementation success.

According to Palvia et al. (2001), one single solution method cannot be applied to different systems; therefore, since the main users of PMSS aim to be company employees, the best method for its evaluation was believed to be user feedbacks.

7.2.1 Pre-Implementation Evaluation

The developed system was run and checked by three skilled software developers. They found it acceptable; however, they suggested making some minor changes in specific parts of the system. One main criticism was about system security to be improved in certain features. The other important comment was related to the

adaptability with two more web browsers other than the ones embedded in the system. There were also minor corrections in the back-end database programming of PMSS which would not affect the operability; however, all suggestions were analyzed in more details and were applied in PMSS.

Since the main focus of PMSS is construction companies, the pilot model was run with the managers of five construction companies in the Northern Cyprus and Iran and ISO 9000 certification agencies in Iran.

The primary feedbacks attested that PMSS will provide a competitive environment among employees and thus can help companies in overcoming the difficulties of QMS implementation and ISO certification. Managers pointed out some benefits provided by PMSS including time saving; cost and expense reduction as a result of decreasing paperwork, reducing administrative staff, decreasing office expenses, decreasing archiving space, etc.; accuracy increase; easier and faster performance measurement and calculation; and communication improvement. However, there were some recommendations for improving the practicality of the system including:

- Allowing time extension after initial submission of the work;
- Considering other OS models such as matrix OS;
- Considering other three resources (material, manpower, and machinery) in performance calculation as separate parameters; and
- Checking the recipient's workload before submitting new works.

The feedbacks of the managers were then analyzed and most of them were applied to the system. Time extension after fixing the estimated resources was added to the system so that it is possible to bargain and change the resources after work submission. Matrix OBS could not be considered in the system since it is considered

as a limitation. Material, manpower, and machinery were already considered to affect the cost and their effects were included in the C_{est} and C_{per}. The recipient's existing workload consideration was also included as shown in Figure 6.10. The modified PMSS was run again with the same managers and they found it satisfactory and recommendable.

7.2.2 Post-Implementation Evaluation

The final revision of PMSS was installed in a construction company in Iran in mid 2010. The company has five departments including design & tendering, construction, accounting, quality, and administration departments. It has 35 permanent employees in main office and 50-100 temporary personnel and workers in 3 different construction projects.

After almost one month of initiating the system and training employees in main office, it was implemented in the company. Training seemed to be necessary since it helps the users better understand and be proficient in system use. The authors planned for two different feedbacks including short-term and long-term; the former from manager and department heads and the latter from both manager and all employees. Short-term feedback was attained after four months of practical implementation. The summary of the short-term feedback from manager and department heads of the company is as follows:

7.2.2.1 Cost Reduction

One of the main advantages of PMSS was stated to be cost reduction. The managers believed that they needed lower number of administrative personnel through PMSS application which would lead the company to cost savings including salaries, office space, furniture, indirect costs, food, etc. Another benefit of reducing number of employees was stated to be making management more straightforward. It

is obvious that managing a company with less number of employees is much easier. Cost saving and streamlining management would be more tangible for large companies.

7.2.2.2 Time Saving

Another advantage was reported as time saving. As declared by a company manager, average delivery time for different works would be minimized by message transfer system. It was also highlighted by ISO certification agencies that, according to their experience with other IT systems, the administrative time would reduce and according to an ISO certified company manager, this reduction could be up to 60%.

7.2.2.3 Other Benefits

Less paperwork, proper documentation and archiving and easier communication were also emphasized by managers as a result of DW and IT usage. A manager from a different company expressed that archiving space after ISO 9000 certification was expanded to 4 times bigger than what it was before certification. They had to extend the buildings for administrative and archiving purposes. This imposed a considerable expense to the company, need for new personnel, and also caused some difficulties in communication and data access. He claimed that using a system like PMSS would help the companies to prevent such extra expenses and efforts. On the other hand, an important issue for a manager is fast and easy access to required information which can be achieved easily by utilizing a system like PMSS.

Managers also revealed that more accuracy would be attained by using PMSS. Almost 100% accuracy would be provided and 15% to 20% human errors faced by companies as stated by some managers would be avoided.

7.2.2.4 Application Difficulties

The only difficulty of PMSS application was believed to be resistance of personnel. Clearly, every new system faces some resistance and adaptation difficulties. Millar (1999) defines the change cycle in his study of performance improvement. The developed transition curve in Figure 7.1 can be applied to any IS implementation process. The stages show the importance of manager commitment and user training. If the manager and users do not believe on what they are doing, they might give up and as a result, the system will fail.

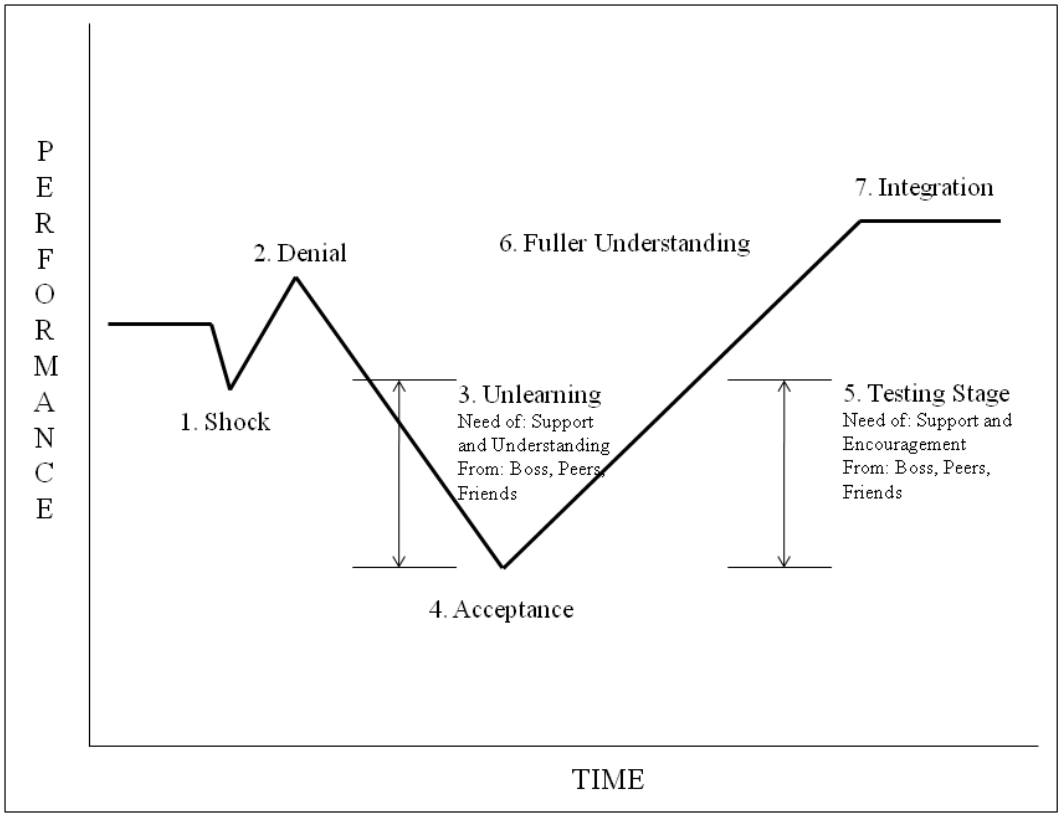

Figure 7.1 Transition Curve (Millar, 1999)

Long-term feedback was expected to be obtained after longer time usage of PMSS. The authors expect to achieve both managers and employees feedbacks after at least one year of PMSS practical implementation. As short-term feedbacks demonstrated the practicality and advantages of PMSS and positive view of the managers, it is anticipated that long-term feedbacks would also prove its

appropriateness and ease of use. Motivation could not be measured yet since it requires employees' performance to be observed and evaluated at least after PMSS implementation during a complete project. However; with effects of PFs on salaries and recognition, motivation will undoubtedly be imposed to employees. Therefore, PMSS advantages will be more documented with the long-term feedback results.

7.3 Practical Implications

Performance measurement systems and ISs are of a considerable attention nowadays; thus, it is expected that PMSS with both characteristics, provides numerous and important advantages for its users. Although PMSS is still running in two construction companies and long-term feedbacks are not received yet, it is believed and somehow proved with short-term feedback results that some main practical and managerial implications of PMSS are:

- It will have positive effects on working behavior of employees and managers.
- It will create a competitive environment among employees to perform their works in the shortest time, with the lowest cost, and to the highest quality level.
- It will provide a decision tool for managers to have quick and reliable access to employee performances and monitor the overall performance of their organization.
- It will motivate employees for better performance as a human resource management tool.
- It will encourage the companies that are seeking for ISO 9000 certification or QMS deployment to start and continue the process and overcome the implementation difficulties.

- It will reduce costs through reduction in the number of administrative personnel, office space and equipments, archiving spaces, etc.
- It will assist the organizations to make best use of the resources such as time, cost, manpower, machinery, and materials.

Chapter 8

CONCLUSIONS AND FUTURE WORK RECOMMENDATIONS

8.1 Conclusions

Companies seeking QMS deployment like ISO 9000 certification face numerous discouraging difficulties. Major difficulties are paperwork, documentation, communication, and lack of motivation.

Using web-based office automation system called Performance Management Support System (PMSS) managers would be supported by accurate information about their business promptly. Users can access the system through usernames and passwords. PMSS uses a set of web-based user interfaces to transfer messages for submitting works and performing the assigned jobs. Real-time employee performances will be calculated during message transfer system. PMSS reduces the paperwork through appropriate IT utilization, decreases documentation problems by the use of DW, overcomes communication problems by using internet and mobile phone facilities, and finally contributes to ISO certification for the company as a part of its QMS.

On the other hand, PMSS encourages employees to perform their jobs in the possible shortest time, with the lowest cost, and at the highest quality level to gain higher performance factors (PFs). Obtaining higher PFs will provide a better standing of the employee in the company and contribute to earn more perquisites.

Employing hypothesis and real data from different construction projects, the system was tested and its operability was validated through case studies. Hypothesis project was used to check system reliability and bugs were removed and fixed. Real data were then employed to check system validity. The data was acquired from a construction company in Iran. The system was successfully implemented for the case studies and proper functioning of the web pages, accurate calculations, information consistency, ease of use, and user friendliness were attested. PMSS was installed in a construction company in Iran and short-term feedbacks approved its applicability and reliability.

8.2 Limitations

While it is believed that the purpose of the study is successfully achieved, there are some limitations to the study that should be considered. PMSS only considers functional OS and the other types are not supported. It also only takes cost, time, and quality in performance calculations. Although other resources including manpower, machinery, and material will affect the cost, they are not directly considered in the developed formulas since PMSS was considered as a general system to be applicable to all companies and all activity types. If PMSS would be applied to a specific industry, it could be modified to be applicable to that industry.

8.3 Future Work Recommendations

We recommend that future research aim to consider the other three types of resources including machinery, manpower, and materials in performance measurement framework.

Further studies can also be conducted on other types of OS to enrich the applicability of PMSS.

PMSS can also be integrated to scheduling and costing software programs to connect different projects and offices for performance monitoring.

Different rewarding and recognition systems can be defined and integrated with PMSS to be used as motivation systems.

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APPENDICES

Appendix A: Sample Questionnaire

Quality of construction questionnaire

Dear manager of ……..

Mazandaran Association of Mass Builders is planning to organize seminars and workshops in order to improve the quality level of the construction industry in your province. MAMB requests your kind assistance to collect information through a survey questionnaire targeted at construction companies regarding the actual situation of the quality of construction in Mazandaran province.

Your cooperation and prompt action on this survey will be highly appreciated. Please keep the deadline of 29 September 2009 as we intend to collect the responses for analysis and planning. The results of the analysis will be structures as a technical paper if appropriate and will be sent to an international journal for publication.

Thanks you in advance for completing this questionnaire. Your views will be treated with confidence, and opinions of individuals will not be revealed without seeking prior approval.

Akbar Zoraghchian (MAMB Secretariat)

Tel: +98 151 22 11 611

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Questionnaire

Date: …….

This questionnaire is designed in three parts. First part is about your company's general information which the answers will not be revealed or published in any form. The only purpose of this part is for categorizing the companies and the answers. You are requested to correctly complete the first part. The second part related to the administration and project control in your company. This part also should be answered by all companies. The third part of the questionnaire is about ISO 9000 certification and should be filled only by the companies who are ISO 9000 certified. Please answer all questions especially open-ended questions so that the results will be reliable. Thanks for your patience.

Part one: General questions (All companies are requested to answer this part)

1. Company's name: ……...…….
2. Company's address:
   …….....
   …… Tel.: 0…..-……...
3. General Manager's Name: ……. Mobile: 09……..
4. Company's scope of work: Private Public
   If your scope is public, which type of projects?

   ☐ Building ☐ Road ☐ Water Projects ☐Others (Please specify)
   ……
5. Field of specialization:
   ☐ Consultant ☐Contractor ☐Design ☐Others (Please specify)
   ……...
6. Do you have grade from Management and Planning Organization?
   ☐ Yes ☐ No

   If yes, which grade and in which field?
   ……...
7. Number of personnel:
   a. Permanent:
   ☐ Less than 10 ☐ 10 – 50 ☐ 50 – 100 ☐ More than 100
   b. Temporary:
   ☐ Less than 10 ☐ 10 – 50 ☐ 50 – 100 ☐ More than 100
8. Annual volume:
   ☐ Less than 100,000 $ ☐ 100,000 – 1,000,000 $

   ☐ 1,000000 – 10,000000 $ ☐ More than 10,000,000 $
9. Number of project per year:
   ☐ 1 Project ☐2 – 5 Projects ☐ 5 – 10 Projects ☐ More than 10 Projects
10. Name and OBS position of the respondent:
    ……
    Mobile: 09……
    E-mail: ……..

Part two: Administration and control procedures in the company and the projects (All companies are requested to answer this part)

1. Do you have a proper organizational breakdown structure and clear job responsibilities for your company?
   ☐ Yes ☐ No
2. Do you have an appropriate contract form for designers, contractors, etc.?
   ☐ Yes ☐ No
   If yes, do you revise the contract after each project to update based on the problems faced during the project?
   ☐ Yes ☐ No
3. Do you have any criteria for selecting designers for your projects?
   ☐ Yes ☐ No
   If yes, rank the following items numerically based on their level of importance from 1 to 5, with 1 being the most important)
   ….. Least cost ….. Friendship ….. Friends' recommendation

   ….. Success in previous projects ….. Others (Please specify) ……
4. Do you have any criteria for selecting contractors?
   ☐ Yes ☐ No
   If yes, rank the following items numerically based on their level of importance from 1 to 5, with 1 being the most important)
   ….. Least cost ….. Friendship ….. Friends' recommendation

   ….. Success in previous projects ….. Others (Please specify) ……
5. Do you have proper project schedules?
   ☐ Yes ☐ No
   If yes, do you regularly review and update project schedules?
   ☐ Yes ☐ No
6. Would you please write your projects' OBS in order? (i.e. Project manager, Site engineer, Contractors, …)
   ……

   ……..
7. Do you have any form or informal inspection method for your projects?
   ☐ Yes ☐ No
   If yes, who performs quality inspection of the projects?
   ☐ Client ☐Project manager ☐ Site engineer ☐Others (Please specify) ……
8. Do you have quality control department in your company?
   ☐ Yes ☐ No
   If yes, what do they perform in the company and the projects?
   ……..
   ……..
9. How do you perform quality control actions in your company?
   ☐ Oral ☐ Documented
10. Do you consider teamwork in your company and projects?
    ☐ Yes ☐ No

11. Do you have a feedback system for your customers and clients?
☐ Yes ☐ No
If yes, do you consider the problems in the future projects?
☐ Yes ☐ No
In case of problems, do you prepare a report to be archived?
☐ Yes ☐ No
12. Do you document and file the feedbacks, corrective actions, etc. for future reference?
☐ Yes ☐ No
13. Do you document the construction with digital photographs?
☐ Yes ☐ No
14. Do you conduct periodic jobsite meetings?
☐ Yes ☐ No
15. Do you prepare as-built drawings?
☐ Yes ☐ No
16. Do you create and maintain daily log of construction operations?
☐ Yes ☐ No
17. Do you prepare weekly construction reports?
☐ Yes ☐ No
18. Do you prepare monthly payment vouchers?
☐ Yes ☐ No
19. What is the level of computer usage in your activities?
☐ Very high ☐ High ☐ Medium ☐ Low ☐ Never
20. Do you attend seminars, workshops, or fairs to be up to date with the recent construction technologies and improvements?
☐ Yes ☐ No
If yes, do you consider them in your projects?
☐ Yes ☐ No
21. Do you have a performance measurement system for your personnel?
☐ Yes ☐ No
If yes, how do you measure your workers' performances?
……..

……..

22. Do you have a motivation system in your company?
☐ Yes ☐ No
If yes, would you please explain your motivation system?
……..

……..

23. Do you know what ISO is?
☐ Yes ☐ No
If yes, what is ISO 9000 about?
☐ Financial control system ☐ Quality control system
☐ Quality management system ☐ Financial management system
☐ Others (Please specify) ……..

Part three: ISO 9000 registration and certification (ISO certified companied are requested to answer this part)

1. What initially motivated your company to become ISO certified? (Please rank the following items numerically from 1 to 5, with 1 being the most important)
   ….. Being a compulsory requirement from government
   ….. Access to foreign market
   ….. Being able to enter public tenders
   ….. Improve company and the projects' quality

   ….. Others (Please specify) …….
2. How long was the duration of certification for your company?
   ☐ Less than 6 months ☐ 6 months – 1 year ☐ 1 – 2 years ☐ More than 2 years
3. How much was the approximate cost of ISO certification for your company?
   ☐ Less than 50,000 $ ☐ 50,000 – 100,000 $
   ☐ 100,000 – 250,000 $ ☐ More than 250,000 $
4. Has ISO provided any specific advantage to your company?
   ☐ Yes ☐ No
   If yes, list the advantages of ISO certification to your company.
   ……..
   ……..
   ……..
5. List the disadvantages of ISO to your company after certification (If any).
   ……
   ……..
   ……..
6. What were your company's major difficulties for certification?
   ……..
   ……
   ……..
7. Do you consider ISO an appropriate tool for construction companies in general?
   ☐ Yes ☐ No
8. What are the barriers to ISO certification? (Please rank the following items numerically from 1 to 11, with 1 being the most important)
   ….. High cost of certification
   ….. Length of registration period
   ….. Low application to construction industry
   ….. Not enough information provided to construction companies
   ….. High level of involvement of personnel in the certification process
   ….. Low management commitment
   ….. ISO 9000 being requires only for international projects
   ….. Not needed from clients and customers
   ….. Low level of training on certification process
   ….. Personnel resistance against extra workload imposed by certification process
   ….. Others (Please specify) …….

Appendix B: Recommendation Letter for PMSS Pre-Implementation Evaluation

شرکت ساختمانی و راه سازی کیمه ساز

Based on the trial run of a web-based office automation system called Performance Management Support System, it seems interesting and most probably applicable and reliable for my company.

I faced many difficulties during ISO certification process and I had to hire more employees for documentation and administration purposes. The number of administrative personnel might reduce to 50% by using this system.

I had also problems in archiving and paperwork which forced me to expand the administrative and archiving spaces to 4 times more than what I had in the company. I had to build a new building in ready-mixed concrete site for archiving and documentation purposes.

Administrative time spent for paperwork and documentation has increased in my company up to 60% more than before ISO certification and it is possible to reduce this time between 40% to 60%. On the other hand, human errors that I almost have found it to be 15% to 20% would be minimized or even completely overcome through such computer application.

However, the real outcomes of the system should be evaluated and

Appendix C: Recommendation Letter for PMSS Evaluation

بسمه تعالی تاریخ: .....

شرکت ساختمانی ساری آرمه (با مسئولیت محدود) شماره ثبت ۷۶۹

This is to certify that Mr. Alireza Rezaei has installed an office automation system in Sari Armeh main office web server. It is a web-based system that helped our employees to communicate through internet much like an instant messaging system. Although our company employees refused to implement the new system at the beginning, we tried to train and convince them about the probable benefits and outcomes of the system like less paperwork, easier communication, and objective performance measurement together with its motivation system.

According to the feedbacks of the employees, they were unhappy with the system during the first three months; however, they became more comfortable with it afterwards.

Outcomes of system implementation proved its applicability and user friendliness. The motivation system seems to be practical and performance measurement to be reliable. There was a considerable decrease in paperwork and reduction in work performance delays. Also some reductions in costs were observed.

شرکت ساختمانی ساری آرمه (با مسئولیت محدود)

آدرس: ساری – خیابان قارن – مجامع پزشکی کسری – طبقه سوم

تلفن: ۲۲۱۲۰۱۸ – ۰۱۵۱ فاکس: ۲۲۲۶۷۹۸ - ۰۱۵۱