

AUTOMATED CONSTRUCTION PROJECT
PROGRESS MONITORING SYSTEM

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A thesis submitted in fulfilment of the
requirements for the award of the degree of
Doctor of Philosophy (Civil Engineering)

Faculty of Civil Engineering
Universiti Teknologi Malaysia

FEBRUARY 2007

Dedicated to my Sweet-Heart and Beloved Wife

Dr. Nuzhat Zubair (Rahi)

who I owe her so much for her

Everlasting Love, Inspiration, and Encouragement

and My Beloved Son

Muhammed Faseeh

who I had to turn down his entertainment just to find more time for this research.

And also dedicated to

My Parents, Sister, Brother and

Especially to

My Mother-in-Law.

ACKNOWLEDGMENT

Thanks to **ALLAH** for every thing I was able to achieve and for every thing I tried but I was not able to achieve.

I would like to express my profound gratitude to my supervisors Dr. Muhd Zaimi Abd.Majid and Dr. Mushairry Mustaffar for their invaluable guidance, constructive advice, thoughtful comments, inspiration, encouragement and good friendship, which have been all greatly appreciated. Without their continue support and interest, this thesis would not have been the same as presented here.

My sincere appreciation to my friends in Malaysia and Pakistan especially Mr. Imran Aness, and Mr. Muhammad Ibrahim, for their continue support and assistance especially during the difficult times. I also indebted to the professionals who shared their time and experience by responding the questionnaire form.

I would like to thanks MUET, Jamshoro, for granting me without pay leave, also HEC, Pakistan, to award me partial funding support. Especial thanks to MOSTI, for providing the funding source. Thanks to Managing Directors for the selected projects to permit me to visit site and providing required information.

Finally I wish to express special thanks and appreciation to my beloved wife for her perpetual love, sacrifice, and patience during the period of research. Also special thanks to my father, mother, sister, brother and mother-in-law for every kind of support. Finally I would like to thanks to my three years beloved son who contribute by providing innocent moments, which were useful at the time of stress to get relax. Atlas, without their sacrifices and understanding I could never have reached where I am today.

ABSTRACT

Monitoring and controlling the project progress is gaining an increasing interest in the construction industry. Manual monitoring and control of project activities have not yielded the expected results. Therefore, monitoring the project progress together with the rapid use of information technology has prompted to change the practice in the construction industry. Additionally, manual monitoring is labor-intensive, because construction managers have to spend a lot of time on data collection and processing. Due to the problems in gathering of data, there is a need for having an automated project progress monitoring and evaluation system. Therefore, this study focuses on automation of project progress and evaluation system by developing a model which can measure and determine the project progress. Existing visual technologies and computer vision can achieve aforementioned aim by providing construction professionals 3-Dimensional types of models for user interface. Knowledge-based Expert system and software integrating techniques are employed in this research for achieving the objective of automation and the monitoring process. Digital photographs captured from the project site, AutoCAD drawings of the project and planned schedule of work in Microsoft Project are the fundamental building blocks for the development of the proposed model. Once the system is browsed, it automatically interprets the detail about the structural elements from planned schedule, 3D co-ordinate values from 3DCAD drawing and 3D model of digital images. To achieve the objective of developing the automated system, a simple rectangular section was selected. The 3DCAD model developed for that section and similarly the 3D model was developed by marking and referencing on digital photographs into Photomodeler. Microsoft Visual Basic 6 programming language is used to develop the user interface and for the integration of the information with Microsoft Project as well. Finally, the percentage progress of the project is calculated and can be viewed in Microsoft project. The development of such a model called Automated Construction PROject Monitoring (ACPROM[®]) may appear to be an interactive system and its feasibility and usefulness were demonstrated, tested and validated within the Malaysian Construction Industry. The ACPROM[®] system was validated by collecting data from projects in progress which include the planned schedule of work in Microsoft Project, AutoCAD drawings and digital photographs as progress continues. The result of the verification and validation showed that the ACPROM[®] system is feasible to be used in determining the actual physical progress reports by integrating digital photos and drawings. In this study ACPROM[®] system has been successfully developed which can be used as a vehicle for monitoring and controlling the physical progress by using computer-based applications.

ABSTRAK

Minat dalam aktiviti pengawalan dan pengawasan kemajuan projek pembinaan kian meningkat di dalam industri pembinaan. Namun kawalan dan pengawasan aktiviti projek secara manual ini tidak dapat menghasilkan keputusan seperti yang diharapkan. Oleh itu, pengawasan kemajuan projek yang digabungkan bersama dengan teknologi maklumat telah mengubah amalan dalam industri pembinaan dengan pantas. Tambahan, pengawasan secara manual memerlukan tenaga buruh yang intensif menyebabkan pengurus pembinaan perlu meluangkan banyak masa untuk mengumpul dan memproses data. Disebabkan oleh masalah yang wujud di dalam pengumpulan maklumat, terdapat keperluan dan cadangan untuk mempertimbangkan sistem kawalan serta penilaian kemajuan projek secara automatik. Tujuan kajian ini dijalankan adalah untuk mengautomasikan kemajuan projek dan membangunkan model yang boleh mengukur serta menentukan kemajuan projek secara automatik. Komputer dan teknologi visual yang wujud di pasaran boleh mencapai matlamat tersebut dengan menyediakan para profesional pembinaan dengan antara muka pengguna dari model jenis 3-Dimensi. Sistem pakar yang berasaskan pengetahuan dan teknik mengintegrasikan perisian telah digunakan di dalam kajian ini bagi mencapai objektif ke atas proses pengawasan dan automasi. Gambar-gambar digital yang diambil dari tapak pembinaan, lukisan AutoCAD projek dan pelan kerja terjadual di dalam Microsoft Project adalah merupakan asas-asas yang digunakan di dalam pembinaan model kajian ini. Sebaik saja sistem dilayari, model secara automatik akan menginterpretasikan perincian tentang elemen struktur daripada jadual yang terancang, nilai koordinat 3D daripada lukisan 3DCAD dan juga gambar digital model 3D. Untuk mencapai objektif pembangunan sistem automatik ini, satu segmen berasaskan segiempat mudah telah dipilih. Model 3DCAD telah dibangunkan untuk segmen tersebut dan model 3D juga telah dibina dengan merujuk dan menanda pada gambar digital ke dalam Photomodeler. Bahasa pengaturcaraan Microsoft Visual Basic 6 telah digunakan untuk membangunkan antara muka pengguna dan juga mengintegrasikan maklumat dengan Microsoft Project. Akhirnya, kemajuan projek dikira dalam bentuk peratus dan akan dipaparkan di dalam perisian Microsoft Project. Pembinaan model yang dikenali sebagai Automated Construction PROject Monitoring (ACPROM[®]) telah muncul sebagai satu sistem yang interaktif dan lengkap, serta keupayaannya telah didemonstrasi, diuji dan disahkan oleh industri pembinaan di Malaysia. Model ACPROM[®] ini telah disahkan dengan mengumpul data dari projek yang sedang dijalankan termasuklah jadual yang terancang di dalam Microsoft Project, lukisan AutoCAD dan gambar digital sebagai data kemajuan yang berterusan. Keputusan pengesahan ini menunjukkan bahawa model ACPROM[®] boleh dilaksanakan untuk menentukan kemajuan fizikal sebenar dengan mengintegrasikan antara lukisan-lukisan dan gambar-gambar digital. Dalam kajian ini, model ACPROM[®] telah dibangunkan dengan jayanya dan boleh digunakan sebagai satu platform untuk mengawal dan mengawasi kemajuan fizikal dengan menggunakan aplikasi yang berasaskan komputer.

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LIST OF ABBREVIATIONS

| | |
|-------------------|--|
| 3D | Three Dimensional |
| 4D | Four Dimensional |
| A/E/C | Architecting/Engineering/Constructing |
| ADC | Automated Data Collection |
| AI | Artificial Intelligence |
| AI | Average Index |
| ALS | Airborne Laser Scanning |
| AOA | Activity on Arrow |
| AON | Activity on Node |
| API | Application Programming Interface |
| APPC | Automated Performance Project Control |
| ASCE | American Society of Civil Engineering |
| ASPRS | American Society of Photogrammetry and Remote Sensing |
| BPM | Building Project Models |
| CAD | Computer Aided Design |
| CADCIMS | Computer Aided Design/Construction Information Management System |
| CBR | Case Based Reasoning |
| CCD | Charge-Coupled Device |
| CI | Construction Industry |
| CIC | Computer Integrated Construction |
| CIDB | Construction Industry and Development Board |
| CL | Case Library |
| CMM | Co-ordinate Measuring Machine |
| CPM | Critical Path Method |
| CPU | Central Process Unit |
| CST TM | Construction Simulation Toolkit |

| | |
|-------|---|
| DCS | DeChant Consulting Services |
| DHH | Digital Hard Hat |
| DSM | Digital Surface Models |
| EOP | Event-Oriented Programming |
| FIAPP | Fully Integrated and Automated Project Processes |
| FIRS | Field Inspection Reporting System |
| FM | Facilities Management |
| GDP | Gross Domestic Product |
| GSI | Geodetic Services Inc |
| IBIS | The Information Base for Integrated System |
| ICIM | Integrated Construction Information Model |
| INCA | INtelligence CAmera |
| ISPRS | International Society for Photogrammetry and Remote Sensing |
| IT | Information Technology |
| ITC | Information Technology in Construction |
| ITCON | Information Technology in Construction |
| JKR | Jabatan Kerja Raya |
| KBES | Knowledge-based Expert System |
| KBESs | Knowledge-Based Expert Systems |
| MCI | Malaysian Construction Industry |
| MFL | Microsoft Foundation Libraries |
| MFR | Multimedia Facility Reporting |
| MIC | Malaysian Industrial Classification |
| MOCA | Model Based Constructibility Analysis |
| MS | Mean Score |
| NASA | National Aeronautics and Space Administration |
| NBA | Network Builder Assistant |
| NRA | Network Review Assistant |
| O&M | Operators & Maintainers |
| PBIS | Paper Based Inspection System |
| PC | Personnel Computer |
| PERT | Program Evaluation and Review Technique |
| PMICS | Project Management Information Control System |
| PPMS | Project Performance Monitoring System |

| | |
|-----------------------|--|
| PSZ | Perpustakaan Sultanah Zanariah |
| PWD | Public Works Department |
| R | Ranks |
| RDBMS | Relational Data-Base Management System |
| RO | Relative Orientations |
| RRL | Review Rule Library |
| SARAFDS TM | SARA Facility Development System |
| SQL | Structural Quarry Language |
| SRS | Schedule Review System |
| TM | Telecom Malaysia |
| UNISCO | United Nations Educational, Scientific, and Cultural Organization |
| USA | United States of America |
| USACE | United States Army Corps of Engineers |
| USGS | US Geological Survey |
| VB | Visual Basic TM |
| VBA | Visual Basic Application |
| VF | Very frequently |
| VIRCON | Virtual Construction |
| VR | Virtual Reality |
| WWW | World Wide Web |

LIST OF APPENDICES

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CHAPTER 1

INTRODUCTION

1.1 Introduction

The subject of evaluation is usually taken to be the post-project assessment of a completed project, as opposed to project appraisal, which is its pre-project feasibility assessment and monitoring which refers to reviews of ongoing projects. Every team member needs to know in a timely and accurate manner how is the project progressing where they are currently in comparison of the initially set plans. Whether deadlines are met, budgets are respected, required quality is achieved, modifications are kept to the minimum and safety measures are followed. This research extends the concept of evaluation to include monitoring, so that it broadly covers all project reviews against established performance targets. A direct comparison of performance against target using measurable indicators would convey the success level of the project itself. However, the success of its management can only be fairly evaluated by adjusting either the original targets or the performance levels in accordance with any critically changed conditions. Kumaraswamy (1993) mentioned that the proliferation of mega projects that transcend traditional boundaries, cross cultures, and span disciplines has increased the need for more rigorous evaluations of the projects and their management. Oglesby *et al.* (1989) criticized the construction industry for being slow to accept and apply modern management methods for planning and execution of projects; this is said poor construction performance. Stall worthy *et al.* (1985) described that lessons learned from both successes and failures need to be distilled and transmitted to improve the management of future projects.

In today's construction industry, information and automation technology must be viewed as potential resources. Soetanto *et al.* (2005) described that appropriate use of advanced Information Technology (IT) will help to achieve performance efficiency and effectiveness in the construction process. Marsh and Flanagan (2000) listed that evidence suggests that the industry is yet to realize full benefits from IT utilization. The Construction Industry Development Board (CIDB) Malaysia, the national body set up to standardize and modernize the construction industry and put efforts to promote IT in line with the government policy. CIDB has focused the Malaysian Construction Industry (MCI) master plan framework 2005-2015 that outlined IT as a key critical success factor with the objectives; (a) promoting continuous education to enhance and encourage competency skills, which relate to information and communication technology, (b) developing a construction industry knowledge community by exploiting information technology. Memon *et al.* (2004b) mentioned that Computer Integrated Construction (CIC) is an emerging technology and it is an approach to assist construction firms for responding to the difficult environment in which they are working. This study attempts to investigate the issue of implementing IT techniques during the construction stage specifically monitoring the project progress.

The as-built project information represents how construction is actually carried-out. Information is organized in various formats throughout the life-cycle of a construction project, from design, through construction, to facility operation and maintenance. Liu *et al.* (1994) described that information is extracted and used during the project life-cycle by many participants at different times, such as:

- (a) Designers/Engineers, who want this information to improve their design;
- (b) Construction engineers, who want to know areas where productivity can be improved;
- (c) Contractors, who would like to keep this information for their future job bidding; and
- (d) Owners, who want the information documented for payments and claims.

A persistent problem in construction has been to develop the as-built actual progress schedule of construction scene. The research reported in this study focuses on the issue related to automating the project progress monitoring. To address the issues of automating the project progress monitoring this study discloses various methods, processes and computer applications system for project progress monitoring. In order to identify the current practice within Malaysian Construction Industry (MCI), a questionnaire survey was conducted. The results of questionnaire survey identify the need to automate the existing construction monitoring practice within MCI. Considering the results of survey an automated system is proposed, tested and validated. The proposed system integrates the existing practice with modern technologies to automate the process of project progress monitoring. This system integrates the information from Microsoft Project, AutoCAD drawings and digital images. The system is tested within MCI to check the validity of the system. The significance of establishing the issues related to automating the site performance to provide benefits to planners, contractors, and owners. This system can assist in collecting and retrieving as-built project information effectively.

1.2 Background and Justification of study

Almost all facilities go through the life-cycle of planning/design, construction, facility operation/maintenance, and rehabilitation/demolition. Information drawn at each phase evolves throughout the life-cycle of a construction project. Collected information at each phase of the project is vital to the other phases. For example, contractor rely on design information (plans and specification) to plan/perform construction activities, and facility Operators & Maintainers (O&M) rely on accurate as built project information to operate/maintain facilities as shown in Figure 1.1.

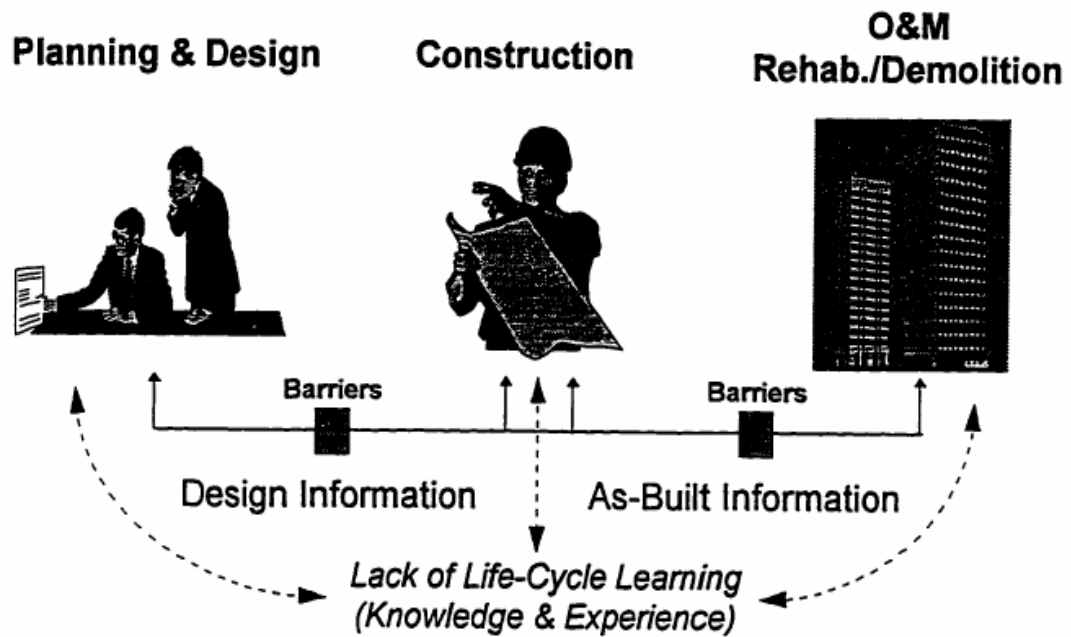


Figure 1.1: Facility Life-Cycle Information Management (Adopted from Chin, 1997)

Managing project information during the construction phase is an important yet difficult task because of the necessity of bridging the design phase and the facility use. Construction information management must support many tasks performed by different participants, as well as integrate these tasks by supporting information flow from one to another. Also, good information management ensures that knowledge or lesson-learned is fed back to the designers for future management, and that up-to-date as-built information schedule is available for facility operation / maintenance.

Currently, information exchange between the different phases of a life-cycle and participants of a project is not ideal. Information exchanges are typically paper-based, and the parties during each phase of life-cycle spend time and effort to manage information manually. Even though almost all organizations involved in facility design, construction and operation and maintenance rely on computers to perform their tasks. Opportunities and challenges exist in establishing an information framework which supports life-cycle information integration among participants/organizations throughout design and construction to operation and maintenance. The construction industry is one of the largest sectors of the economy

of any industrialized nation. As Malaysia is a fast growing industrial nation and construction industry remains one of main contributor in Gross Domestic Product (GDP). The information exchange in MCI is not ideal and carried out on traditional practice.

Sulaiman *et al.* (2006) highlighted that construction, together with services, manufacturing agriculture and mining sectors, are the main contributors to Malaysia's GDP and economic growth. Mui *et al.* (2002) listed that MCI is one of the largest industries in Malaysia and contribute 10.3% to the national Gross Domestic Product (GDP) in 1997, second after the services sector which contribute 11.06% and manufacturing sector remains third which contribute 10.1%. In the annual report of Bank Negara Malaysia for the year 2005 the contribution from construction sector having the smallest share of 2.7% in GDP, but in any major economic crisis, construction would be the first sector to be affected and recovered. Thus it can be considered to be a barometer to a country's economic performance. Saad (1999) mentioned that despite its size, the construction industry has suffered from a lack of sophistication in information management practices, which can cause poor productivity, delays, and other unexpected conditions jeopardizing the smooth and timely completion of the project. Consequently, the efficiency and competitiveness of the construction industry is a major concern for society as a whole.

As the issues of globalization and trades deregulation, stringer requirement of time, cost and quality and advancement of technologies have become more critical, the sector has to find ways to enhance its operational efficiency and effectiveness. One of the possible solutions is to use Information Technology (IT) techniques to control, document and communicate construction information. Sulaiman *et al.* (2006) discussed the current status of IT applications in MCI and mentioned that IT as a key enabler was recognized to be an inseparable tool to sustain business and become more competitive. Alshawi and Putra, (1994) quoted that advances in technology has been hindered by the fragmentation of the construction industry, which has forced a large number of researchers to look for some alternative means to tackle the problem. There is a need to develop system to tackle the problems and to improve the construction processes for high quality construction projects.

The researchers are well known with the current problems of construction industry and practitioners participating in national R&D programs aiming to improve the performance of the industry. Although there have been many IT applications developed for the Architecture/Engineering/Constructing (A/E/C) industry, the industry has not improved significantly. Most contractors have not employed a systematic way to collect, store, analyze, and reuse construction information. Due to the lack of systematic management, construction information is often inconsistent, and occurrences of mistakes are common. As a result, designers and construction managers receive little feedback from constructions phase unless a serious problem occurs, and the quality of a construction facility suffers. Fragmented organization, traditional and local practices, poorly developed supply networks effect the performance of construction industry. The methods of monitoring and controlling the construction project progress, to develop the as-built schedule and legal and social barriers still exist which prevent effective life-cycle project information management.

The motivation for this study is to explore the technical aspect of project information management. The emergence of advanced computer technologies such as fast personal computers, database, network and multimedia enables the current project information management paradigm to move forward to all digital information management, i.e. integration and sharing of information in a paper-less office environment. Taking advantages of IT techniques, this research study pursues solution to eliminate these barriers, develop strategy, methodology, and propose an automated model which improves project progress monitoring practice.

1.3 Problem Statement

The importance of monitoring a project is well recognized in the A/E/C industry. However, Navon and Shpatnitsky (2005) noted that project performance data are still mostly collected manually which is slow and inaccurate. Due to manual nature of current monitoring and control methods, project mangers spend a disproportionate amount of time collecting and processing construction data,

typically causing the construction manager to be distracted from the more important tasks of supervising and controlling the project (McCullough, 1997). Navon (2005) described that due to current data collection methods which are time consuming and expensive, many construction companies do not collect extensive data and even less so in real-time. Chin (1997) mentioned that there have been many IT applications developed for the Architecting/Engineering/Constructing (A/E/C) industry, the industry has not benefited significantly because of the lack of a consistent information management strategy through the life-cycle of a facility.

Information is generated and updated over the life-cycle of a project in various form. In a typical construction project, construction phase usually starts after advertising and awarding contracts. Before construction starts or at the pre-construction stage, contractors should submit the detailed planned schedule of work and get approval from Architect/Engineer. It is also essential to maintain accurate as-built information for facility operators/maintainers. Information schedule is maintained continuously to monitor construction progress and daily reports are generated along with pictures and video images to keep track of the progress of activities.

It is crucial to keep construction monitoring information updated consistency in its entirety, since well-captured actual construction information (called as-built information) reduce the chances of costly claims and disputes. It is difficult but important to maintain information consistency to provide accurate project information and to develop the as-built schedule of the actual progress of the work. There is a need to provide a better paradigm to manage the as-built construction schedule, which not only allows the designers to understand construction problems, but also save time and efforts during the construction phase, which represents about 85-90% of total life-cycle costs (Bell and Gibson, 1990).

As built information must be collected accurately and efficiently and it must be accessed quickly and conveniently so that construction personnel can take decision for any type of delays. Currently, most as-built information is stored on paper, which is difficult to access and requires large storage space. A computerized information system can store data more efficiently, and information can be located

and viewed quickly through computerized searching. Photos and videos are taken to document details that are difficult to describe. These requirements for storing and retrieving construction as-built information demand a new breed of management system.

To get a full job updated and control periodically, project manager or project engineer at the site does a full entry update for the preceding week. Thus the planner must collect the latest information on the rate of progress and current resource usage in order to update the computer model and develop the physical progress reports. Although on-site conference is ideal, the project team will update a hard copy of scheduling for the project. Updating includes activities to start, activities in progress, and activities to be completed.

The traditional methods of recording construction physical progress is done by the site engineer by filling daily reports and when is required to stipulate what percentage of contract is completed or its degree of progress, these daily progress reports will materially aid in computing such percentage. In the work progress measurement, the parties will still evaluate the progress of work manually by determining the work measurement on site. For updating the progress of the construction site on manual based, digital photographs are also used as an information source. There exist barriers in the practice of paper-based exchange of project information, which often wastes time and inconsistent in getting the estimation of their work progress, which lead them to the major problem in construction.

As a project progresses, the site management team makes and keeps long reports related to the occurrences on a daily basis (Abeid and Arditi, 2002a). As the words are open to interpretation, pictures are taken and added to these reports. The information or monitoring system compares the actual site physical progress against the planned schedule of work to develop the progress of construction scene. During the construction period, advancement of the work is monitored by measuring and reporting the field progress at regular intervals. These reports are analysed and time-control measures are taken to keep the work progressing on schedule. After the project starts, monitoring systems are established that measure actual progress of the

work at periodic intervals. The reporting system provides progress information which is measured against the programmed targets.

Development in information technology are changing the way that construction teams generate, store, transmit, and co-ordinate information. Hence, the inference process should be adapted with the real world environment. Human is able to learn and capable of processing complex problems with uncertainty, imprecision, and incomplete information. Which concludes that the process of human inference is effective for solving the construction management problems (Ko and Cheng, 2003).

1.4 Aim and Objectives of the Research

The aim of this research is to develop an automated system for project progress monitoring using Information Technology (IT) techniques. Normally monitoring project progress is done by paper-based and photographs of the work are attached to show the progress. The focus of this research is to develop a model which can automatically evaluate project progress. Haykin (1999) described that Artificial Intelligence (AI) techniques can be used for developing computer programs to carry out a variety of tasks, at which human are used to produce results. In this study Knowledge-Base Expert System (KBES) is developed to update the actual work schedule and the source of information is from photographs and AutoCAD drawings.

In achieving the above mentioned aim, objectives have been identified, which includes:

- (a) To identify the various methods of measuring project progress performance;
- (b) To identify the current processes for project progress monitoring;
- (c) To investigate and identify various computer application systems for project progress monitoring;

- (d) To identify the 3D Image based modelling techniques by using digital images;
- (e) To develop automatic process that can extract information from planned schedule and AutoCAD drawing; and
- (f) To develop automated project progress monitoring system that integrates the information from planned schedule, AutoCAD drawings, and digital images.

1.5 Scope and Limitation of the Study

The main focus of this research is to develop an integrated system for project progress monitoring and reporting. Based on construction managers' and main contractor's point of view, the proposed system should integrates the information from planned schedule of work, AutoCAD[®] drawings, and digital images captured from construction site. Performance of proposed system is tested on a case study for construction of building projects within Malaysian Construction Industry. The case study, however takes a small portion of building inspection by concentrating on super structure concrete elements especially beams and columns. Figure 1.2 is a graphical representation of the research scope. The scope of this study is limited to evaluate and monitor the physical progress of super structure concrete elements of a project especially beam and columns.

1.6 Research Methodology

This section discusses the research methodology in an attempt to materialize the aim of this study in the light of existing knowledge and investigation evidence. In achieving the aim and objectives, a research methodology is required and Figure 1.3 highlights the essential stages of conducting this research. The figure 1.3 shows the four essential phases for conducting the research and each phase include different

activities. In an attempt to achieve the aim and objectives of this study, activities involved in each phase are briefly discussed.

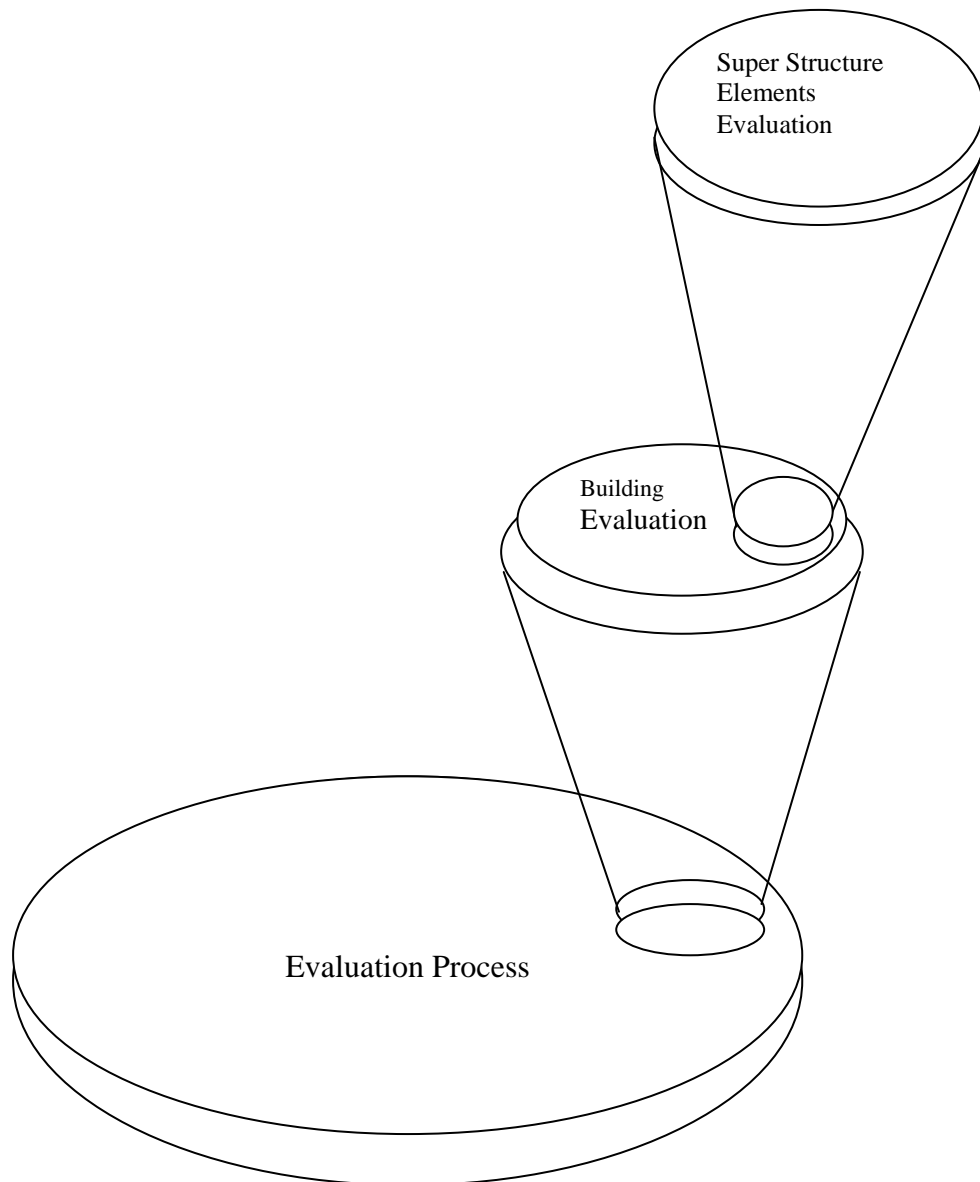


Figure 1.2: Graphical Presentation of Limitation for Research's Scope

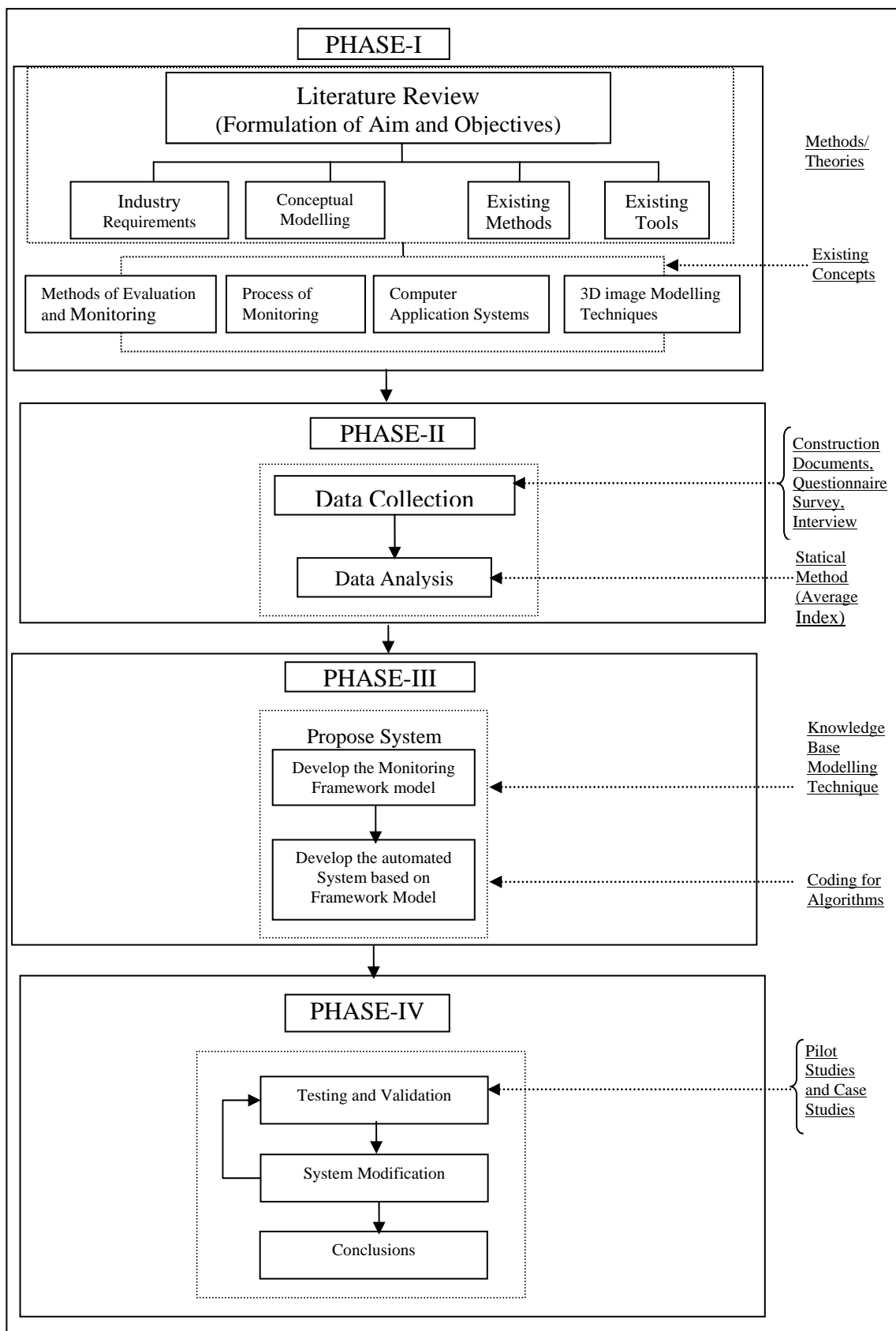


Figure 1.3: Research Methodology

In Phase-I, a comprehensive literature was carried-out to formulate the aim and objectives of this study. During the literature review focus has been given to the industry requirements, methods of evaluation and monitoring, conceptual modelling methods, existing project progress monitoring methods and tools for developing systems. Literature review helps to design the questionnaire survey form to collect data for the methods and process of monitoring and evaluation and also for the computerized application systems in the construction industry for monitoring and controlling the project progress. Phase-II discusses the data collection process through questionnaire survey and unstructured interviews with professional during the site visits and seminars. Unstructured interviews were conducted to know the existing practice within construction industry. Data also collected by reading the construction documents, which help to formulate the current project progress monitoring techniques in the industry. This phase also discusses the different scientific methods for analysing the collected data. The result of data analysis identifies the need for developing the system which was discussed in Phase-III. Phase III discuss in detail the process of designing and developing the framework model. Phase-IV describes the testing strategy for the system. So this research also follows the traditional approach for validation and testing. The proposed model will be implemented on any selected building construction project to check the technical aspects; modification can be interpreted if there is a need of any improvements. The more detail discussion on the research methodology is discussed in Chapter 5, Section 5.2.2.

1.7 Significance of the Study

This study is unique in the sense that no previous attempts have been made on the subject in-spite of the wide spread importance of the construction monitoring and updating the project progress. Surely the contribution of this study will improve the industry's performance and also help the subject of implementing the Information Technology in Construction (ITC). By implementing the proposed system on the real construction project it will improve the efficiency of the construction monitoring process. The result will help to improve the decision making process and stored data

will be useful at the time of arbitration. The results of this study expedite the procedure of monthly progress payment. In the case of termination of the contract during the construction process, this system is a useful tool to calculate the progress up-to-date and identify the remaining work. Finally the results will improve the efficiency, effectiveness and satisfaction in between the main participant of construction project.

1.8 Research Contributions

The main contribution of this study to the body of knowledge falls on the following aspects:

- (a) The study gives emphasis on identifying the methods and process of project progress monitoring and computer application system within Malaysian Construction Industry as well as it identifies the need to develop an automated system for current practice;
- (b) This study proposes a new method of evaluating the work progress by integrating the AutoCAD drawings, Digital Images and Microsoft Project.
- (c) This study has designed a reliable model to automate the construction monitoring process;
- (d) By testing the system on pilot project, improve the efficiency of the system. For further validation of the system, it was tested on the real construction project; and
- (e) The successful implementation of the system shows that system has been successfully designed and programmed and provides a vehicle for monitoring and controlling the physical progress by using computer-based applications.

1.9 Organization of the Thesis

This thesis comprises three major components which can be summarized as follows:

- (a) General investigation on the background of the problems related to construction management especially during the construction stage;
- (b) Reviewing the issues related to project progress monitoring which include the following; and
 - (i) Methods and processes of project progress monitoring.
 - (ii) Computer application systems, to monitor the project progress.
 - (iii) Existing practice for monitoring and updating the project progress.
- (c) Investigate and validate the above issues and proposing an automated system for existing practice and test the system by implementing on a case study.

The three main components of the research are presented in nine chapters and are briefly described as follows:

Chapter 1: Presents a general introduction to the subject and the specific problem under investigation. It also specifies the aim and objectives, research justification, the methodology of conducting the research work, the contributions of this study and a brief summary on the structure of the thesis.

Chapter 2: Presents the finding from the literature review. It focuses on the issues in construction especially considering project progress monitoring which include the following;

- (a) Overview of Construction Industry;
- (b) Information Technology Techniques in Construction Industry;
- (c) Methods of project progress monitoring; and
- (d) Processes of project progress monitoring.

The review on the above issues defined the problems that need to be investigated and helped to identify the scope of study that warrant further investigation.

Chapter 3: This chapter reviews the available management literature and establishes the existing computer application system for monitoring and updating the project progress.

Chapter 4: Investigates the available literature on developing the 3D Model from digital images, which includes the existing applications and system used in the industry. This chapter highlighted an approach to be used which extract the information from digital images and develop the 3D Model from digital images.

Chapter 5: Discusses the methodology adopted to achieve the objectives mentioned in Chapter 1. It starts by describing the methodology for literature review and different phases involved in conducting this research. It discusses the design of the questionnaire survey form and describing different statistical methods for analysing the collected data. The result will help to propose the Architecture for the system. Then it discusses in detail the basic tools involved in system and methodology for extracting the information from these basic tools. The last section of this chapter mentions the procedure for collecting the data at the time of implementing on any case study.

Chapter 6: Presents the data collection for the initial investigation to know the current practice for project progress monitoring before proposing an automated system. It also discusses the research population, questionnaire administrative and response to the questionnaire survey. Finally presents the analysis and statistical tests to establish the finding from the literature review and unstructured interviews with professionals. From the results of the questionnaire survey, the existing method of project progress monitoring, current practice for the project progress monitoring and computer application system for the project progress monitoring were identified.

Chapter 7: This chapter discusses in detail on the design of proposed system. Before discussing in detail about the developed user interface, it explains the objectives, development platform for the computer programming and proposed algorithm for the system. Then this chapter describes in detail about the steps involved in user-interface to achieve the end results. It starts by installing the set-up on the system to end result, which is preview of Gantt chart. In the middle of user-interface it requires the information by browsing the path for the different files such as; planned schedule in Microsoft project, extracted information from digital drawings in notepad, 3D AutoCAD file and for storing the values in data base requires the path in Microsoft Access. Finally this chapter takes into account the limitation for the proposed system.

Chapter 8: Presents the testing and validation of the system on pilot project and case study project. This chapter highlighted the results and provide the finding of the study. The results are compared with traditional method and automated system of project progress monitoring. It describes in detail about the comparison between proposed system and paper based information management system to derive the finding of the study.

Chapter 9: This chapter presents the findings of the research and recommendation for future work. Conclusions drawn from the finding and the recommendations are highlighted for further research on the subject matter. This chapter highlights the contribution of this study to the body-of-knowledge.

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