INVESTIGATING THE ISSUE OF PROJECT PROGRESS PERFORMANCE AND PROPOSING A PROTOTYPE SOFTWARE: A CASE STUDY OF MALAYSIAN CONSTRUCTION INDUSTRY

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ABSTRACT

Real-time monitoring and control on site construction is a growing field and still in its infancy. A persistent problem in construction is to develop the as-built actual physical progress schedule of construction scene. The primary aim of this study is to propose prototype software for monitoring project progress automatically. Consequently, this study addresses Digitalizing Construction Monitoring (DCM) model for monitoring the physical progress of the project.

A questionnaire survey form designed and conducted in the Malaysian Construction Industry to investigate the existing practice for evaluating and monitoring the construction site progress and utilization of computer based application system for monitoring project progress performances. The respondents were asked to indicate their view using a five-point scale. This paper discusses the initial results of a pilot survey and proposing and developing prototype software for improving the construction project progress monitoring.

User can retrieves the project information in form of images and by using photogrammetry techniques every detail of building should be precisely documented to obtain reliable measurement from photographs and simulated with CAD drawings to develop the physical progress report. The integration of photos and drawings will enable construction manager to develop progress reports in a more consistent and accurate way and more accurate as-built project schedule can be transferred to facility manager. This system bridges the gap for monitoring and controlling the construction work by implementing the information technology techniques.

KEYWORDS

CAD drawings, Digital Photograph, Project Monitoring and Control, Project Progress Reports, Photogrammetry.

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INTRODUCTION

It is widely recognized that construction is an information intensive and complex industry. Traditional computational techniques have failed our industry because of the shear number of information interfaces and complex relationships. 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 (Kumaraswamy 1993). Present trend and proliferation towards multi-participant mega projects have heightened the need for effective and efficient evaluation and monitoring by stakeholders. Effective and systematic monitoring and control of information flow is a critical ingredient through the life cycle of construction projects, such as control of information to describe the required work, support decision making and analyzing the physical progress (Syed 1998). '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' refers to reviews of ongoing projects as defined by (Kumaraswamy 1996). However, this research study extends the concept of evaluation to include monitoring, so that it broadly covers all project reviews against established performance targets. Progress reporting involves the recording of construction achievements for detection of deviations from actual plan and for forecasting project performance This paper focuses on the issue of evaluation and monitoring of construction project and developing a systematic model considering the Malaysian construction industry's viewpoint.

The need has long existed for tools to streamline the job of systematic evaluation and monitoring for management of construction activities. Although manual, paper-based information flow on construction projects still dominates, computers are increasingly becoming a central component of project information systems. Several areas in construction management, such as scheduling, estimating, cost control, and accounting, employ well-established computer applications. To carryout the laborious calculations and data tracking for these tasks, they represent a small portion of the day-to-day construction management activities. A questionnaire survey form designed and conducted in the Malaysian Construction Industry to investigate the existing practice for evaluating and monitoring the construction site progress and utilization of computer based application system for monitoring project progress performances. This paper addresses, a different class of computer application for construction management, namely for managing the monitoring and evaluating system for construction projects and improving progress reporting and control system by incorporating detail information from site photos and AutoCAD drawings.

A questionnaire survey form designed and conducted in the Malaysian Construction Industry to investigate the existing practice for evaluating and monitoring the construction site progress and utilization of computer based application system for monitoring project progress performances. To design the questionnaire survey form the intensive literature review and unstructured interview with experts and practitioners was carried out. In the questionnaire survey form, the Likert scale and ranking in order on a single issue were the three most common assessment approaches used. Most of the data obtained from the questionnaire survey was analysed using relative weight method, which was explained by Abd.Majid (1997).

EXISTING COMPUTER-BASED PROJECT MONITORING AND EVALUATION SYSTEMS

This section provides a brief overview of several studies reported in the literature related to the information system for construction projects. A number of commercial software packages that are related to this topic are also listed.

Using a relational data model, a first attempt was made to integrate the existing systems. CAD/Construction Information Management System (CADCIMS) represents a new way of information integration which allows design information in CADD to be integrated with a construction information framework (Stumpf et al.1995). CADCIMS was developed using Microsoft Access V2.0, a relational database management system in the Microsoft Windows environment and integrated with existing commercial or research prototype systems. To develop the as-built schedule of the progress MCACES database was linked via open database connectivity (ODBC) to provide historical cost and productivity information. The purpose of CADCIMS was to build an information framework to capture, store, retrieve, and manage the as-built information, including multimedia data types, and to provide facility operation and maintenance personnel with accurate construction information. Chehayeb and AbouRizk (1995) discussed about the Simulation-based project control (SimCon) that provides the basis for implementing the progress reporting and control in a simulation model and develop the progress report by exception capability from a hierarchical breakdown structure that will minimize progress reporting at the very detailed level. SimCon is implemented using object-oriented concepts, event driven programming, relational database and a simulation engine. The basic current progress reporting mechanisms focus on reporting progress at the lowest level of detail in Work Break down Structure (WBS). SimCon presents a methodology of improving hierarchical representation of project information that allows simulation-based project control.

Stumpf et al. (1998) proposed Digital Hardhat (DHH) system at U.S. Army Corps of Engineers. The DHH technology enables dispersed users to capture and communicate multimedia field data to collaboratively solve problems, and collect and share information. The DHH is a pen-based personal computer with special Multimedia Facility Reporting System software that allows the field representative to save multimedia information into a project-specific database, which is then accessible to others through the World Wide Web. Results of the DHH system shows that the system improves the documentation of site conditions by integrating multimedia and database technologies.

Abeid et al. (2003) developed an automated real-time monitoring system PHOTO-NET II (so-called web-based system) for construction projects programmed in a Delphi Environment (object-oriented Pascal-based visual programming language). This system links time-lapse digital movies of construction activities, critical path method (CPM) and progress control techniques to show the planned versus actual schedules. PHOTO-NET II connects archived film clips to schedule and progress information to minimize the occurrence of construction disputes. This system uses the Internet as a communication medium between the cameras and the remote computer(s) and the ability to control the playback frame rate when playing back the time-lapse movies. In the end product this system displayed two dynamic diagrams: (1) the planned versus actual schedules in a bar chart format; and (2) the planned versus actual percentage of completion in a histogram format.

Cheung et al. (2004) described a Web-based construction project performance monitoring system (PPMS) to exercise the construction project control and as a project monitoring tool. He used eight different categories for project performance measurement and establishes performance indicators and their measurement. The data are stored in a centralized database and project performance data are provided by contractors via Internet. The PHP Hypertext Processor was adopted as the programming language for the PPMS to facilitate interactive interfaces and supports powerful databases. The smooth functioning of the PPMS relies heavily on the internet and the databases system.

The existing computer-based construction management tools seem to provide a wide variety of functions to manage design and construction information. However, manual and paper-based information flow on construction projects still dominates. In view of the above, an automated construction monitoring system DCM is proposed, discussed and tested in following sections. In essence, the DCM makes use of the Digital images, AutoCAD drawings and planned bar chart to streamline the monitoring process and therefore enables speedy and convenient data and dissemination.

CONDUCTING SURVEY

For this work, the common methods and process of project evaluation and monitoring were identified through an intensive literature review and unstructured interviews with professionals and project managers. In order to identify the most significant category, a preliminary survey was conducted in the Malaysian Construction Industry. A total of 150 contractors selected randomly from the list of Construction Industry Development Board (CIDB) of Grade VII and questionnaire was delivered via post and forty six responses were received. The questionnaires were completed by directors, project managers, and site managers.

The questionnaire was designed into two sections: the first section consists of general information about the respondent's organization and second section obtained information about the current practice for monitoring the project progress in the Malaysian Construction Industry. The main intention of this survey was to highlight and produce the common methods and processes of project progress evaluation and monitoring and also to know the existing computerized project progress monitoring system. The result of questionnaire survey will help to propose the system for digitalizing construction monitoring.

ANALYSIS AND RESULTS

The next logical step, after collecting the information was to analyze available data. The relative weight method was used to identify the most critical factor for evaluating and monitoring the construction project progress for Malaysian Construction Industry.

Abd.Majid (1997) described in detail about the average index method based on the following formula.

$$\text{Average Index} = \left[\frac{\sum_{i=1}^{5} a_i x_i}{5\sum_{i=1}^{5} X_i} \right] \text{where:}$$

a_i = Constant expressing the weight given to i;
x_i = Variable expressing the frequency of the response;
i = 1,2,3,4,5.

Based on the results of the preliminary questionnaire as shown in Appendix A, the projects performance monitored by using schedule/time plan in the range of very frequently and having mean score of 4.109 percentage. The process for monitoring the project progress by utilizing the easily available scheduling software such as Microsoft project and Primavera P3 in the range of very frequently and having mean score of 3.935 percentage. However, for computerized Applications system for project progress monitoring, no suggested method falls under the very frequently or frequently category, only SKALA having mean score of 2.022 percentage under the slightly frequently category.

The result of the questionnaire survey initially conclude the need of proposing and developing a software package, which evaluate and monitor the project progress automatically and update the progress bar chart automatically. The following sections of this paper discuss the proposed monitoring system.

FRAMEWORK FOR THE PROPOSED MODEL

As illustrated by the preceding discussion, numerous studies have focused on information flow throughout construction projects monitoring, and a number of computer programs have been developed to support this area. However we have not found a thoroughly comprehensive treatment of the construction site photographs and drawings of construction projects, particularly as they relate to computer support tools. Further more we are interested in examining how issues of project monitoring fit within a larger context of integrated project management systems and standard data models for representing and exchanging all forms of project progress information among all project participants. The research reported in this paper took a step towards this objective by attempting to simulate the 3D Model from digital photographs and 3D AutoCAD drawings of super structure concrete elements specially beams and columns.

This system did address some areas not covered by other existing systems mentioned above; a major objective of the system was to serve as a focal point for collecting and analyzing data about project physical progress and flows for integrated computer systems rather than create a new class of software application. Several researchers have addressed different aspects of development methodologies for monitoring system (Dzeng et al. (2005), Chau et al. (2004), Kang et al. (2004), Cheung et al. (2004), Abeid et al. (2003), and Saad (1999)). On the basis of these researchers' recommendations, a framework model is proposed as shown in Figure 1. The model includes four phases: Input data requirements, Data process procedure, out put and action. Each phase of the proposed model includes different steps and procedures and identifies its final product.

Phase-I (Input the data):

In the phase-I, user will have to input the general project information such as title of the project, users' information and etc. By pressing the submit icon, user is required to add the data as an input of the planned bar-chart, 3D CAD drawing and 3D Model developed from digital images. The uploaded information will be processed in the phase II of the proposed framework.

Phase II (Process the uploaded Data):

In this phase the database is developed from 3D CAD drawings and from digital images and showing 3D coordinates values. The algorithm is developed for detecting 3D coordinate information automatically from 3D CAD drawings and other algorithm is developed to capture the information from planned schedule of work activities such as planned start and finish date and duration of activities. The Relational Database Management System (RDBMS) is developed which contains the 3D coordinate values from 3D CAD drawings of all the structural members, in our case beams and columns only. 3D coordinate values from the 3D Model of digital images captured from construction site are calculated. The information from the 3D Model of digital images is uploaded in the database as construction work progresses, weekly or fortnightly or considering the nature of construction work. The database developed from CAD drawings are called Primary database and from digital images are called secondary database. Once the database is uploaded, the simulation process will start which will calculate the actual progress of work by simulating the 3D coordinate values and will calculate the progress of work in percentage. The result of simulation process will be viewed in the Microsoft project bar chart as an Output of the process.

Phase III (Out Put result):

During the phase III, the out put result of simulation process will be viewed. Microsoft project will show the comparison of planned schedule and actual progress of work.

Phase IV (Action):

Based on the information gathered at previous phase, phase-IV suggests the action or any remedial measure to over come the problems related to progress of construction. The scope of this research is limited up to phase III and to suggest an appropriate action, which is to be carried out in further studies.

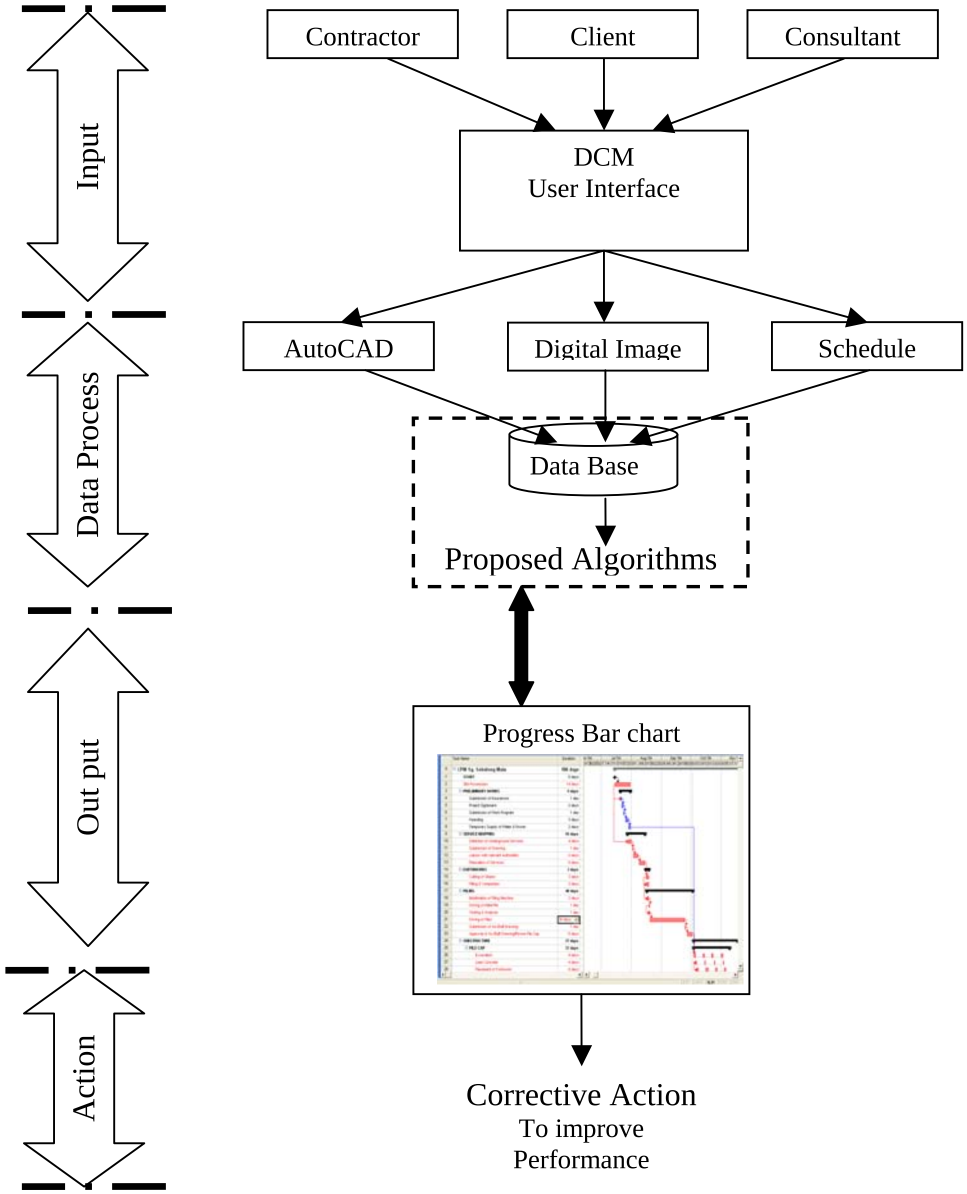

Figure 1: DCM Framework model

DIGITALIZING CONSTRUCTION MONITORING (DCM) MODEL OVERVIEW

Digitalizing the construction phase is the recent demand of the Malaysian Construction Industry and for the third world countries, where monitoring the project progress is carried-out by traditional method of capturing the photographs and placing these into monthly progress reports. Malaysian construction industry, which is the second largest industry to implement the Tele-Construction strategies and this study, is one part of that approach. The major object of developing this model is to the link between existing method of evaluating and monitoring the physical progress of construction scene with modern technology by developing an Artificial Intelligence to emulate the human brain.

Digitalizing Construction Monitoring (DCM) Model is a software package in the window environment, which is under development at Construction Technology and Management Center (CTMC), University Technology Malaysia (UTM) that integrate the digital images capture from small-details concrete structure elements at construction sites, AutoCAD drawings for the these structural elements and standard scheduling tools such as a Micro Soft Project. A prototype simulator is being developed using visual basic programming language in Windows programming environment that provides user with the ability to create self-contained windows applications. The visual programming features provide strong links to the Visual components Library classes of the Window System.

The proposed Model is intended to be a user-friendly application that is easy to access by different project team members. The main objectives and the scope of the system are as follows:

a) To enable computer system to solve the problem intelligently by emulating the human brain.

b) To reduce the amount of time spent recording, preparing and posting reports.

c) To improve the tracking and control of the project and activities status.

COMPONENTS AND STRUCTURE OF DCM

The basic theory for developing the model is to extend the traditional approach to represent the dynamic and simultaneous construction operations by incorporating inter-relationships between hierarchical processes of evaluating and development in the field of Information technology. With the continued development of easy-to-use computer software and improved graphical presentation media, many of the practical problems associated with formal scheduling mechanics have been overcome. Some of the function involved in project management, especially those concerned with project monitoring and evaluation (developing the actual physical progress bar chart) were virtually impossible to execute with any great speed before computers were used (Levine 1989). The rapid growth in the availability and power of microcomputers, coupled with their continuously decreasing cost, has made it possible for construction managers to effectively and efficiently analyze the massive amounts of data necessary to monitor and control the progress of the many interrelated tasks together to make a construction project. Taking into account characteristics and functions of DCM, it was programmed with knowledge-based system programming method.

This system demonstrates the computer vision integrate 3D CAD drawings of the project to produce construction as-built schedule. Computer vision defined by (Raynar and Smith 1994) was that; take 2D images or photos as input and produces descriptive information as out put. The actual construction is represented by the digital images of the construction scene and AutoCAD represents the original structural drawings of the elements. The scope of the research is to develop a vision or integrating system for processing images of the construction scene and for making the comparison with AutoCAD drawings. Figure 2 shows the structure of the DCM, the link between the digital images, CAD drawings and Planned Bar-chart is established and event-oriented programming (Visual Basic 6.0) is used to integrate the information from images and drawings to calculate the actual physical progress of the work and to show the actual progress of the work.

TESTING OF DCM MODEL

Based on the conceptual model in Figure 2, entities and relationships were mapped into separate database in DCM. DCM currently supports the management and collection of as-built information on components, construction drawings, and related multimedia information such as a construction photographs and video clips. Taking advantage of relationships between entities, DCM provides multiple ways to access desired construction information from 3D Model of digital images and 3D component model in AutoCAD. The DCM will be operated through a user interface, to which access is via the set-up domain of the prototype. By installing the system, the user can access the various built-in functions; first he has to add the general information such as title of project, name of owner, consultant and contractor, then by clicking on submit icon it links to main page of the DCM and user have to browse the required information in the interface. Once user added all the required information then by clicking on start process icon it will start calculating the percentage of progress by comparing the primary and secondary databases. A pilot study was carried out to check the validity of DCM and results of pilot study would be incorporated to improve the efficiency of DCM. Figure 3 shows the result interface for pilot study and then by clicking on view icon it will interlink with the bar chart, which shows the planned schedule of work and actual physical progress. Initially this research is limited to develop the prototype for the superstructure concrete elements such as beams and columns only.

By integrating the structural member drawings and digital photos of the construction site and planned schedule of work supports for multiple ways to access/manage desired information was accomplished, while improving information consistency and redundancy. DCM allows the construction engineers to capture up-to-date as built information, analyze progress and helps during decision making. Structured and efficient information storage would help to improve information transfer to facility operators/maintainers. The concepts and prototype software (DCM) presented in this paper is in use for updating the actual physical progress automatically of the Larkin Mosque construction project at Johor Bahru, Malaysia. The project is at its initial set-up, so the analysis of the system will be discussed in other publication.

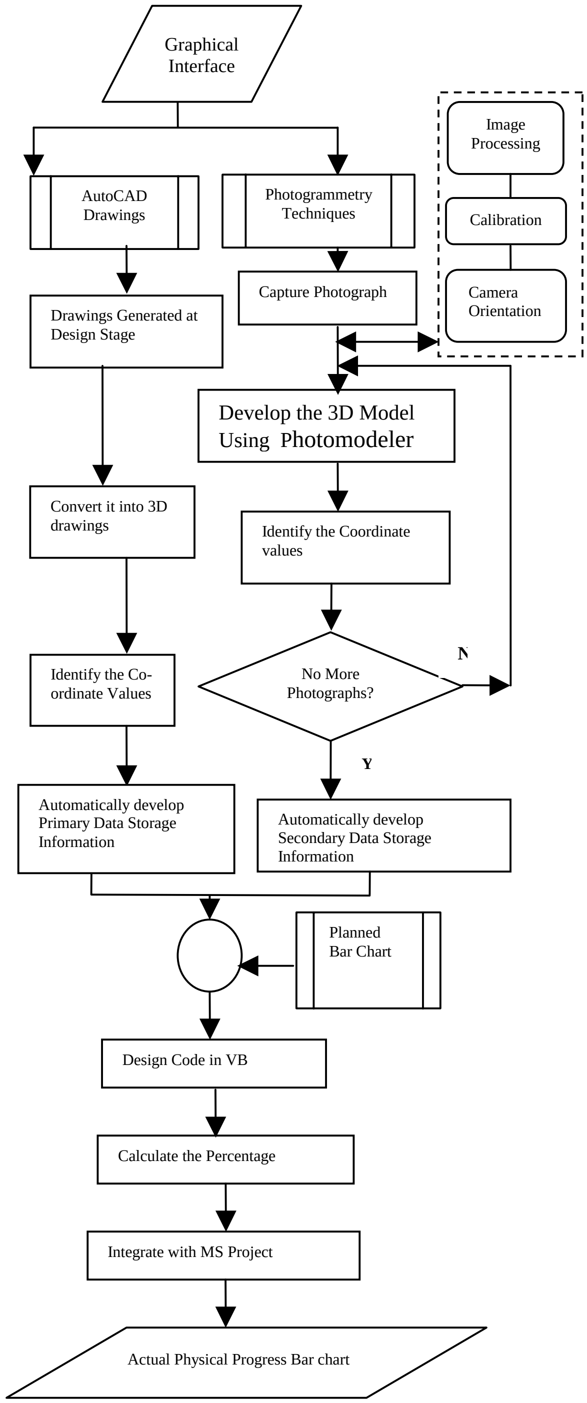

Figure2: Process Flow Diagram of DCM

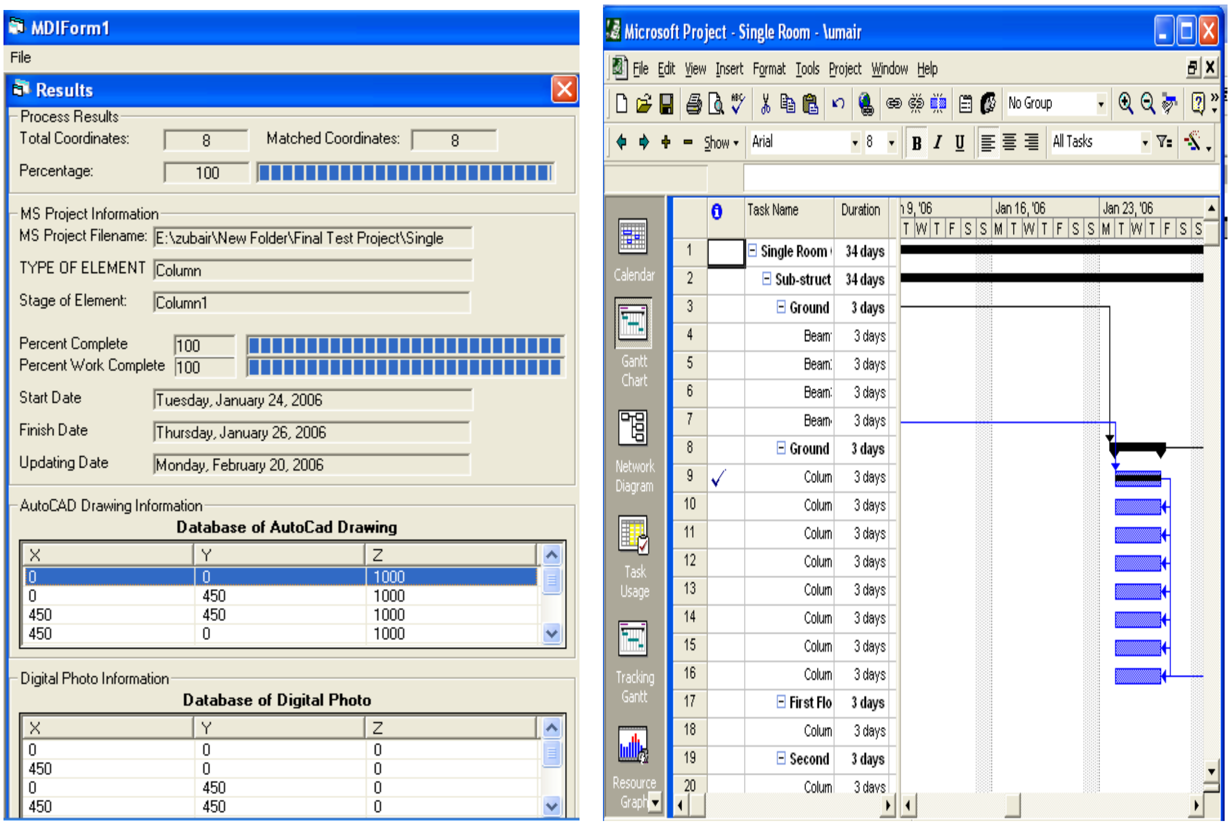

Figure 3: Result of Pilot Study by implementing DCM Model

CONCLUSIONS

This paper discuss the results of the questionnaire survey carried out in the Malaysian Construction Industry, which identify the need of automating system for project progress monitoring. Based on the results, Digitalizing Construction Monitoring (DCM) Model proposed and initially tested on a pilot project. DCM provides a vehicle for monitoring and controlling the physical progress by developing the computer-based applications. DCM evolves in an integrated framework and will have an impact on the ability of a construction project team to meet client needs. The application of DCM model for monitoring the actual physical progress enables project management teams to better track and controls the schedule of construction projects. The lesson learned through this will be incorporated with the current research to develop construction monitoring, and evaluation automatically for the physical progress report. It is the authors' believe that by implementing the latest technologies in the field of construction, especially during the execution phase could minimize the potential problems and encourages lesson-learned and innovation.

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APPENDICES

Appendix A: The Result sheet of Preliminary Questionnaire Survey

Methods of Project Progress Evaluation and Monitoring							
Suggested Methods	Ranking Options					Total Respondent	Total Mean Value
	(1)VR-Very Rare	(2) RA-Rare	(3) SF-Slightly Frequently	(4) FR-Frequently	(5) VF-Very Frequently		
The money Plan (Cost weightage):	Respondant's waitage to Suggested Method (1)						
	1	6	4	18	17	46	
	Average Index Method						
	0.022	0.261	0.261	1.565	1.848		3.957
The time Plan (Time weightage)	Respondant's waitage to Suggested Method (2)						
	2	3	5	14	22	46	
	Average Index Method						
	0.043	0.130	0.326	1.217	2.391		4.109
The Resource Plan (Manpower weightage)	Respondant's waitage to Suggested Method (3)						
	3	11	17	10	5	46	
	Average Index Method						
	0.065	0.478	1.109	0.870	0.543		3.065

Processes of Project Progress Monitoring and Evaluating							
Suggested Methods	Ranking Options					Total Respondent	Total Mean Value
	(1)VR-Very Rare	(2) RA-Rare	(3) SF-Slightly Frequently	(4) FR-Frequently	(5) VF-Very Frequently		
Traditional Approach	Respondant's waitage to Suggested Method (1)						
	4	6	12	14	10	46	
	Average Index Method						
	0.087	0.261	0.783	1.217	1.087		3.435
Software for scheduling	Respondant's waitage to Suggested Method (2)						
	1	4	8	17	16	46	
	Average Index Method						
	0.022	0.174	0.522	1.478	1.739		3.935
Real-time Monitoring System	Respondant's waitage to Suggested Method (3)						
	16	13	10	5	2	46	
	Average Index Method						
	0.348	0.565	0.652	0.435	0.217		2.217
Field Inspection Reporting System (FIRS)	Respondant's waitage to Suggested Method (4)						
	17	18	5	6	0	46	
	Average Index Method						
	0.370	0.783	0.326	0.522	0.000		2

Computerized Applications Systems for Project Progress Monitoring							
Suggested Methods	Ranking Options					Total Respondent	Total Mean Value
	(1)VR-Very Rare	(2) RA-Rare	(3) SF-Slightly Frequently	(4) FR-Frequently	(5) VF-Very Frequently		
Digital Hardhat (DHH) system	Respondant's waitage to Suggested Method (1)						
	20	10	10	6	0	46	
	Average Index Method						
	0.435	0.435	0.652	0.522	0.000		2.043
SKALA System	Respondant's waitage to Suggested Method (2)						
	20	13	6	6	1	46	
	Average Index Method						
	0.435	0.565	0.391	0.522	0.109		2.022
PHOTO-NET II	Respondant's waitage to Suggested Method (3)						
	23	8	9	5	1	46	
	Average Index Method						
	0.500	0.348	0.587	0.435	0.109		1.978
A web-based construction Project Performance Monitoring System	Respondant's waitage to Suggested Method (4)						
	25	12	6	3	0	46	
	Average Index Method						
	0.543	0.522	0.391	0.261	0.000		1.717