

## **The DCM model: A Strategy for Implementing the Information Technology Techniques at the Construction Phase**

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### **Abstract**

In today's construction industry, information and automation technology must be viewed as potential resources. Computer Integrated Construction (CIC) is an emerging technology and this study attempts to investigate the issue of implementing CIC at construction stage by evaluating and monitoring the progress of construction sites. A persistent problem in construction is to develop the as-built actual physical progress schedule of construction scene. Managing project information during the construction phase is an important task yet difficult task, however, information exchange between the different phases of a project is not ideal and typically paper-based and parties during each phase of life-cycle spend time and effort to manage information manually. Manual monitoring of construction sites is costly and error prone. Consequently, this study addresses Digitalize Construction Monitoring (DCM) automated model for monitoring and evaluating the physical progress of the project. DCM is an ongoing component of the digital scheduling and evaluation of work progress system for construction industry at Construction Technology and Management Centre (CTMC), University Technology Malaysia (UTM) by the cooperation of Ministry of Science, Technology and Innovation (MOSTI), Malaysia. The research reported in this paper focuses on the issue related to digitalizing the project progress monitoring and proposing prototype software, which integrate the AutoCAD drawings and digital images. User can retrieve 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. By introducing the DCM at the construction phase it allows the resident engineer, project manager, construction manager, and site manager to develop the physical progress report of construction and helps in decision making. This system bridge the gap for monitoring and controlling the construction work by implementing the information technology techniques.

**Keywords** Construction Management, 3D CAD, Monitoring, Expert System, Photographs.

## **1. Introduction**

Memon et al, (2004) mentioned that construction is information intensive and complex industry and traditional computational techniques have failed industry because of the sheer 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). Project progress monitoring and control is one of the most important tasks of construction project management. Every team member needs to know, in a timely and accurate manner, how is the project progressing, where they are currently in comparison to 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 (Memon et al, 2005). It is mainly the responsibility of the general contractor to update the Architect / Engineer, who in turn updates the owner. Under construction management contract, this responsibility shifts to the project manager, who has to ensure that all project criteria are met, if not exceeded. The traditional construction management systems provide a project manager with the various reports such as progress control, earned value management and resource management; however these reports and functions in the traditional systems are still limited in 2D concept (Kang et al, 2004).

To monitor and evaluate the progress is one of the most important, yet difficult tasks of construction management. Accurate documentation of construction events not only minimises the possibility of disputes and claims, but also facilitates construction innovations and improvements. Currently however, the construction industry relies heavily on written reports to document the actual physical progress. Written reports require good writing skills and unbiased judgements. In general, not all construction site personnel write well. Due to the language ambiguity and the fact that details are usually omitted during writing so it is difficult to reconstruct a complete picture of what actually occurs during construction. A recent survey of a large-scale project management information and control systems (monitoring over 1,500 public works projects) showed that the need for data entry at the project level was the major obstacle to the success of the systems as whole (Futcher 2001). In fact, McCullough (1997) reported that an average 30-50% of the time of field supervisory personnel spent recording and analysing site data. This lack of accurate documentation usually causes confusion and difficulty in handling claims and disputes; furthermore many innovative ideas to improve constructibility and design are lost.

Abd.Majid et al, (2004) mentioned that with the development of new scientific management concepts, comprehensive management techniques have been applied from inception to completion of construction operations. Abd.Majid et al, (2004) also added that after the project has started, monitoring systems are established that measure actual cost and progress of the work at periodic intervals and the reporting system provides progress information that is measured against the planned schedule of work. The resulting time schedule, subject to periodic revision and correction during construction, is the essential basis for the day-to-day time control of the project. Such a schedule serves as an exceptionally effective early-warning device for detecting when and where the project is falling behind.

An integrated project progress monitoring and evaluation system namely called Digitalize Construction Monitoring (DCM) has been developed to assist project managers in developing the actual physical progress reports. DCM calculates the percentage of progress by integrating the Digital images and AutoCAD drawings and plots the actual progress bar chart. Project monitoring data are stored in a database with input provided from AutoCAD drawings and Digital images from construction site as construction

progress. The percentage of progress are calculated by integrating the information from 3D CAD drawings and 3D Model from digital images and compared with the as-planned schedule of work and as-built schedule bar chart were shown in Microsoft project.

In line with the National Information Technology Agenda, which was formulated in 1996, the Malaysian Government has been aggressively promoting IT and its application in every sector including the construction industry (Mui et al, 2002). The Construction Industry and Development Board (CIDB) Malaysia, and construction firms have realized that it is vital to have a structural approach to implement Information Technology in the construction industry, which is the second largest industry after manufacturing industry (Abd.Majid et al, 2004). The Digitalize Construction Monitoring (DCM) model is a part of substantial research project, to develop the Tele-construction for the Malaysian construction industry, which automates a wide range of construction process. This research is carried out at Construction Technology and Management Center (CTMC), Faculty of Civil Engineering, University Technology Malaysia. By introducing the DCM model monitoring and evaluating for the construction activities and developing the actual physical progress report can be carried out by using Expert System.

## **2. Related work on Computer-Based Construction Progress monitoring system**

Digital Hard Hat (Liu 1994 and Stumpf, et al., 1998) provided documentation and management of project information in formats such as text, video, sound, and images. It can make use of a variety of formats for storing as-built information: users can input the daily activity description, cautions and problems, or lesson-learned in multimedia format. Construction engineers can capture construction progress or problems were vividly with video, voice, and image type formats along with textural descriptions. This system allows construction engineers to access as-built information in a fast and easy way to detect potential delays and cost overruns quickly. Wang (2001) developed the expert system integrating construction schedule with CAD drawing (ESSCAD), mainly with knowledge-based system programming technique and software integrating techniques, which can automatically interpret the CAD drawings of a building and extract data of its building components, breakdown the project into activities, determine the logic dependencies among activities, estimate the work quantities and durations of activities, finally generate a primary construction schedule for the project. Abeid et al. (2003) described the development and implementation of PHOTO-NET II, an automated real-time monitoring system for construction projects programmed in a Delphi environment. The system links time-lapse digital movies of construction activities, critical path method (CPM) and progress control techniques. This system accepts the digital images taken from multiple cameras store them in chronological order and links them to a database that contains schedule information; the progress graph has been developed showing planned versus actual schedules.

These systems are good for solving a specific problem, but the scope of these systems is limited to conceptual construction planning. From the related research it has been cited that many studies have been conducted to develop the integration model for a project and the ideas for developing automated real-time monitoring systems are rapidly growing with the advancement in the information technology. From the literature it has been cited that very few have given concern to develop the actual physical progress bar chart by capturing the information from images.

## **3. A frame work 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.

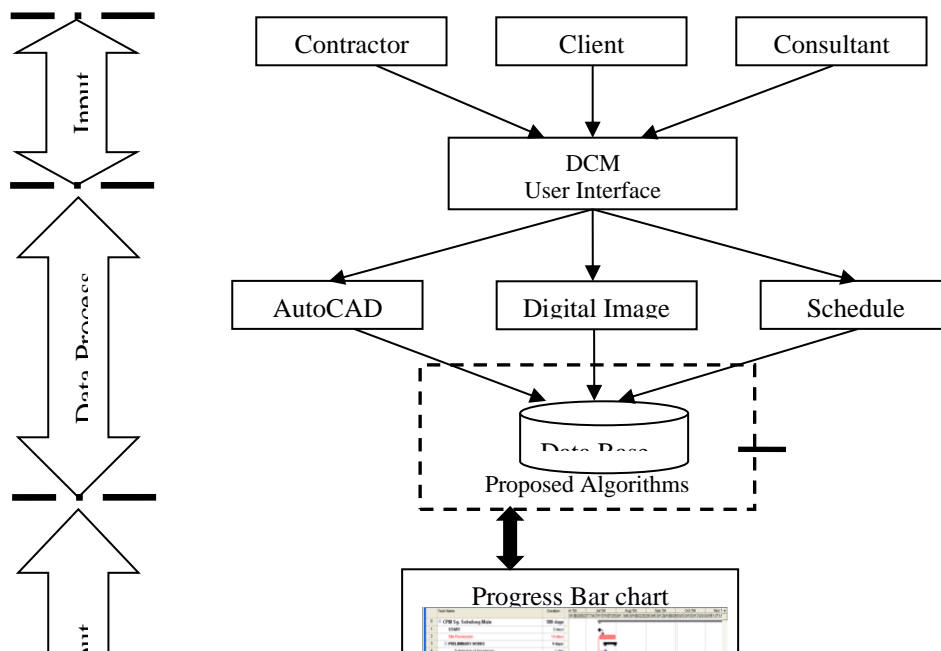
Further more we are interested in examining how issues of project monitoring fit within a larger context of integrated project management systems and standard data models for representing and exchanging all forms of project progress information among all project participants. The research reported in 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 work culminated in the design and testing of a prototype model, namely called Digitalize Construction Monitoring (DCM) model. While 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 analysing 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 (Kang et al. 2004, Cheung et al. 2004, Abeid et al. 2003, and Saad 1999). On the basis of these researchers' recommendations, a development framework was established 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. The following sections explain the frame work for the system development; describe the procedures adopted for each element of the framework, and comment on the results. The objective of developing a Digitalized Construction Monitoring (DCM) model is to systematize the construction monitoring and evaluation of a project. DCM is implemented using object oriented concepts and event driven programming. The object oriented concepts were utilized in the graphical user interface of constructing the DCM processes. Graphical interfaces were created in the Photogrammetry and photomodeler environment and then exported into Visual Basic™ (event driven programming). Relational Data base was implemented using Micro Soft Access™ engine to store project related information. The simulation concept of DCM model is currently being used to test and check the validity.

#### 4. 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.



### **Figure 1: Frame work of Digitalize Construction Model**

Digitalized 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.

### **5. 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 analyse 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. The DCM consists of AutoCAD, Photogrammetry techniques, Database management system, Knowledge base system, DCM simulation to formulate the user interface.

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 output. 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.

## **6. Testing of (DCM) model**

Based on the conceptual frame work model in Figure 1, 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 as shown in Figure 2 and 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 as an example shown in Figure 4, by clicking on start process icon it will start calculating the percentage of progress by comparing the primary and secondary databases. Figure 3 shows the result interface 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, analyse 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 Car Park 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.

## **7. Conclusions**

This paper presents the development of Digitalizing the Construction Monitoring (DCM) Model that provides a vehicle for monitoring and controlling the physical progress by developing the computer-based applications. This research has demonstrated the integration of graphical and non-graphical interfaces such as photomodeler software, CAD and computer based construction systems using RDBMS. The (DCM) model is developed by using the Relational Database Management System (RDBMS) and demonstrates the possibility of integrating the information from digital images and 3DCAD drawings and allowing the superintendents to systemize the construction monitoring, evaluation and reporting the actual physical progress more precisely. The prototype software described in this paper is capable of communicating the digital images, AutoCAD drawings and Microsoft Project scheduling and proposed system suitable for remote or off-shore projects.

The research described in this paper attempts to overcome the limitations of the previous research development in the area of evaluating the construction phase. This is by using a model-based approach whose emphasis is on capturing graphical and textural information about building elements and directly

storing them into database. A system like digitalizing the construction monitoring (DCM) evolving in an integrated frame work 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, cost and quality of construction projects. 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.

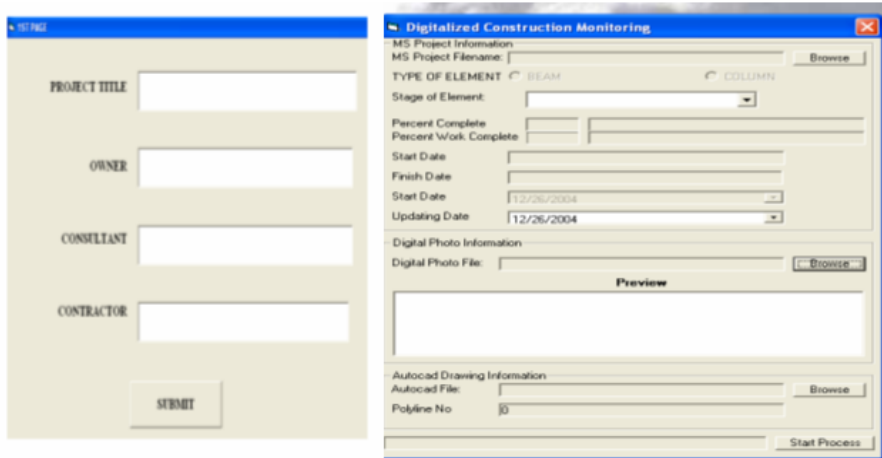


Figure 2: User Interface of DCM Model

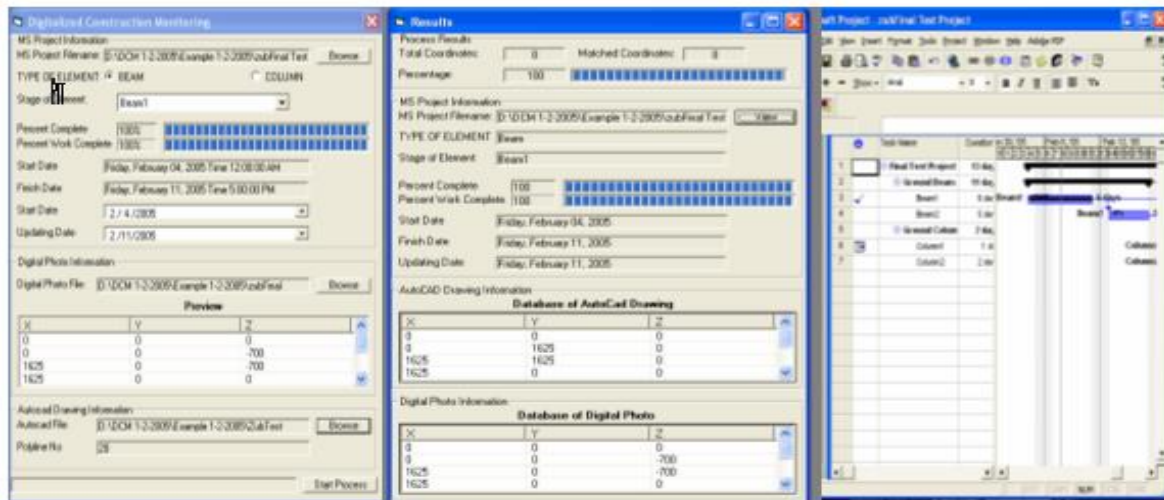


Figure 3: Result of Pilot Study by implementing DCM Model

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