# A SYSTEMATIC APPROACH FOR MONITORING AND EVALUATING THE CONSTRUCTION PROJECT PROGRESS

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## *ABSTRACT*

*A persistent problem in construction is to document changes which occur in the field and to prepare the as-built schedule. In current practice, deviations from planned performance can only be reported after significant time has elapsed and manual monitoring of the construction activities are costly and error prone. Availability of advanced portable computing, multimedia and wireless communication allows, even encourages fundamental changes in many jobsite processes. However a recent investigation indicated that there is a lack of systematic and automated evaluation and monitoring in construction projects. The aim of this study is to identify techniques that can be used in the construction industry for monitoring and evaluating the physical progress, and also to establish how current computer technology can be utilised for monitoring the actual physical progress at the construction site. This study discusses the results of questionnaire survey conducted within Malaysian Construction Industry and suggests a prototype system, namely Digitalising Construction Monitoring (DCM). DCM prototype system integrates the information from construction drawings, digital images of construction site progress and planned schedule of work. Using emerging technologies and information system the DCM re-engineer the traditional practice for monitoring the project progress. This system can automatically interpret CAD drawings of buildings and extract data on its structural components and store in database. It can also extract the engineering information from digital images and when these two databases are simulated the percentage of progress can be calculated and viewed in Microsoft Project automatically. The application of DCM system for monitoring the project progress enables project management teams to better track and controls the productivity and quality of construction projects. The use of the DCM can help resident engineer, construction manager and site engineer in monitoring and evaluating project performance. This model will improve decision-making process and provides better mechanism for advanced project management.*

***Keywords:*** *AutoCAD, Construction Management, Database, Digital Monitoring Photogrammetry*

## 1. INTRODUCTION

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 safely measured and followed. It is mainly the responsibility of the general contractor to update the Architect/Engineer, who, in turn, updates the owner. Figure 1 shows the traditional project progress monitoring process and the progress reports are updated on a periodic printed form; issued in most of the cases on a monthly basis. These reports discuss the current project progress with planned schedule of work in terms of time and budget to forecast the project finish date. These reports also mentioned the constructability problems, quality issues including test results, contract changes including modification in design and increase/decrease in quantities, pending issues from progress meetings. The photos are attached to these reports to show the achievement of milestones. This traditional construction management system provides a project manager with the various reports such as progress control, earned value management and resource management. Project manager spend most of his time for developing and updating of these reports instead of execution and to take in-time decision to finish the work within prescribed time scale.

The successful project completion requires the concerted effort of the project team to carry out the various project activities, and it is the project manager who at the centre of the project network is responsible for orchestrating the whole construction process. The project manager has to maintain the project network and monitor against slippages in cost, time and quality for the duration of project. In achieving this, the project manager relies heavily on a reliable monitoring system that can provide timely signalling of project problems, whether they are real or potential.

In practice little has been done to address the problem of project progress monitoring and control. The most of the research efforts in the field of project control still focus on the development of cost control models [1]. This paper describes the current status of an ongoing research project which aims to develop an easy to use tool or expert system to monitor and control the construction progress at the construction stage. A different class of computer application system are discussed in this paper, which will be used for monitoring and updating the project progress by incorporating engineering information from digital images and AutoCAD drawings. To achieve this object a prototype system was proposed namely called Digitalising Construction Monitoring (DCM) system. This is authors' believe that this system can assist project manager to develop the project progress reports with speed, within time

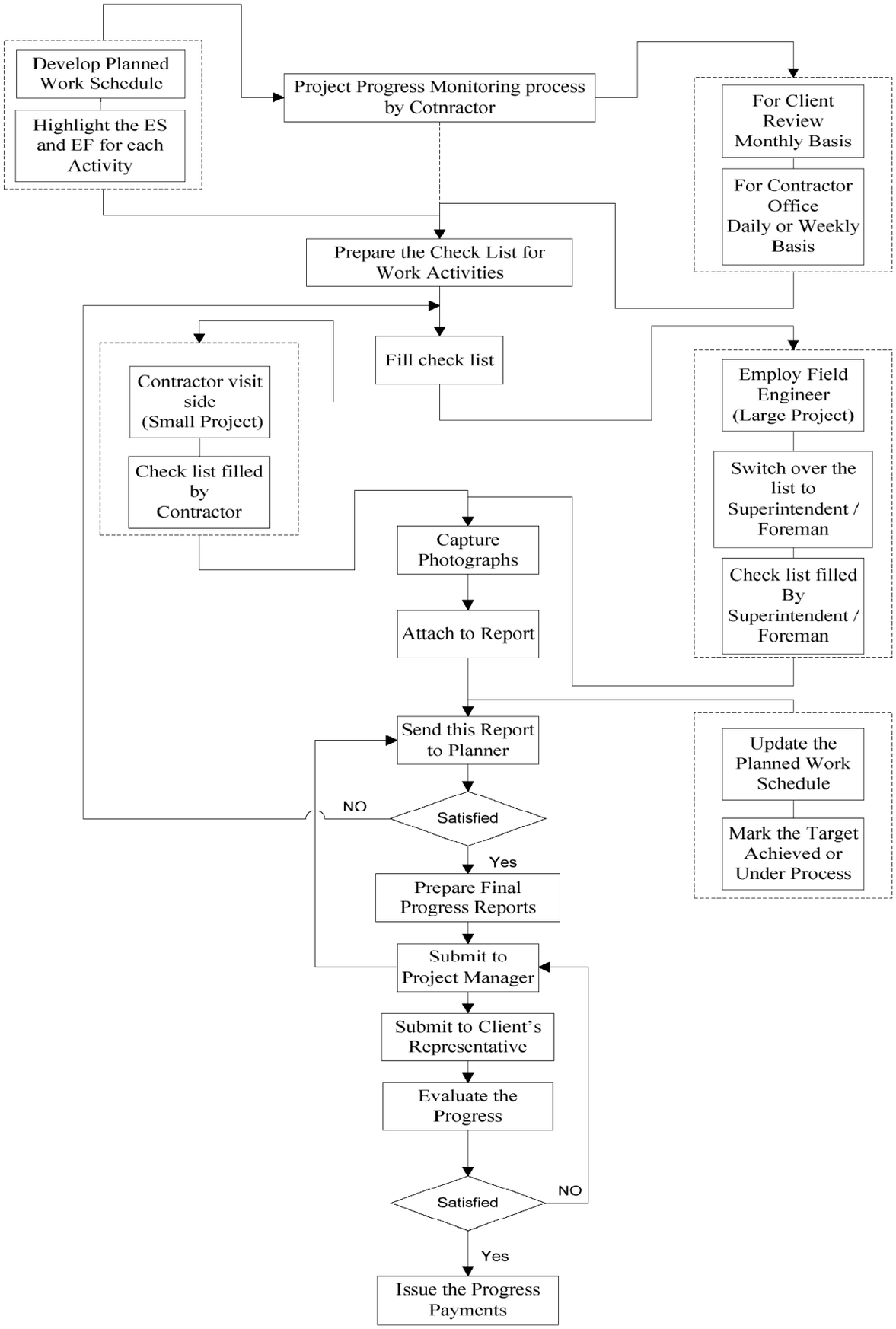


***Figure 1: Flowchart for traditional project progress monitoring practice***

and accurate to pursue for successful completion of construction work according to clients demands.

## 2. BACKGROUND OF STUDY

This section provides a brief overview of studies reported in the literature relating to digitalising the construction monitoring for construction project. A number of commercial software packages that relate to this topic are also listed. The sources outlined here provide the basis of the analysis of project monitoring and the system development presented in the following sections.

The existing computer-based construction tools seem to provide a wide of functions to manage design and construction information. The researchers attempted and developed the systems such as; ESSCAD by Wang [2], PPMS by Cheung [3], VIRCON by Dawood [4], PHOTO-NET II by Abeid [5], CADCIMS by Stumpf [6], OSCONCAD by Maria [7], DIPAD by Streilein [8] and ADC by Sacks [9]. From the intensive review, researchers developed the integration model for project progress and the ideas for developing automated real-time monitoring systems are rapidly growing with the advancement in the information technology. However, the information integration has not been ideal in current practice. 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 digital images. This study uses the close range photogrammetry to develop the 3D Model from digital images with the help of PhotoModeler pro version software, which is requirement for accurate photogrammetry. This system enables the project manager to simulate the traditional practices and Artificial Intelligence to evaluate the physical progress of construction activities and develop the progress bar chart in Microsoft project.

Most construction project employ scheduling methods to monitor and control the progress of work and develop progress reports, which involves the recording of construction achievements for detection of deviations from actual plan and for forecasting project performance. The primary control system used by project managers to obviate or mitigate time-based claims in construction industry is construction schedule [10]. The current practice of project control is entirely dependent on cost, schedule, and quality reports and personnel performance reviews [11]. Monitoring project time is one of the many challenges for the project manager. Time monitoring seeks to assess how well the project adheres to the planned schedule over a period of time. There are a variety of ways in which a construction schedule can be presented. The more common types of construction schedule include: Gantt chart, activity on the arrow, precedence network and line of balance. Bar charts or Gantt charts are a powerful communication tool and an extremely useful, visual and graphical medium in construction scheduling.

A persistent problem in construction industry is to develop the as-built physical progress schedule of construction scene. The as-built project information presents how construction is actually performed. The research reported in this paper focuses on the issue related to developing the digitalised actual physical progress report during the construction stage. As-built schedules are costly to prepare because of the amount of research necessary to determine the actual dates and considerable judgment is also required. Since detailed records are not always available and even if they are, work on the site does not necessary confirm the planned schedule. This state of affairs leads authors to propose the prototype system for developing as-built schedule automatically.

In addition the scenario discussed in above paragraph, a questionnaire survey was conducted within Malaysian Construction Industry. Zhang [12] stated that questionnaire survey is an effective, convenient, economical investigation tool for obtaining data and sampling the opinions of individuals in spatially diverse locations. Al-harthy [13] listed that the questionnaire survey usually provides large amount of data in a short time with relatively ease of preparation, distribution and tabulation of answers and responses can be given easily and quickly. Therefore, a close-end questionnaire was designed for this study; to identify the current practice. The result of survey supports the authors to propose the system, as MCI utilising the traditional practice for monitoring and progress reporting. The following sections discuss the result of questionnaire survey and propose a framework model to overcome the limitation of current practice in the MCI.

## 3. QUESTIONNAIRE SURVEY WITHIN MALAYSIAN CONSTRUCTION INDUSTRY

The questionnaire survey form was designed to verify the existing methods and processes which are related with the project progress monitoring. It is important at early stage to decide for analysing method before developing any system of data collection. So, Statistical Analysis method has been considered to analysis the collected survey form. The data was collected by using measurement or likert scale method. Five scale rating was used to determine the severity of influence on project progress monitoring techniques by client, consultant and contractor. Al-Hammad [14], Abd.Majid [15] and Al-harthy [13] used and explained the Average Index Method to analysis data in the ordinal or ranking scale. This study also uses Average Index Method to analysis data of survey and explained as follows:

$$\text{Average Index} = \left[ \frac{\sum_{i=1}^{5} a_i x_i}{5\sum_{i=1}^{5} X_i} \right] \text{for five scale rating.} \qquad (3)$$

Where,

$a_i$ = Constant expressing the weight given to i,
$X_i$ = variable expressing the frequency of the response for;
i = 1, 2, 3, 4, 5 and illustrated as follows:
$X_1$ = frequency of the 'very rare' response and corresponding to $a_1 = 1$;
$X_2$ = frequency of the 'rare' response and corresponding to $a_2 = 2$;
$X_3$ = frequency of the 'slightly frequently' response and corresponding to $a_3 = 3$;
$X_4$ = frequency of the 'frequently' response and corresponding to $a_3 = 4$; and
$X_5$ = frequency of the 'very frequently' response and corresponding to $a_5 = 5$.

Table 1 shows the result of questionnaire survey which were conducted within Malaysian Construction Industry (MCI). The table 1 highlighted a need to propose a digitalise system for construction monitoring and progress reporting. The

*Table 1: Result of questionnaire survey within MCI*

| Techniques / Options | Clients | | Consultants | | Contractors | |
|---|---|---|---|---|---|---|
| | MS | R | MS | R | MS | R |
| **Factor (1) Methods of Project Progress Monitoring** | | | | | | |
| (a) The money Plan (Cost weightage) | 4.429 | 1 | 3.923 | 2 | 3.909 | 2 |
| (b) The time Plan(Time weightage) | 4.143 | 2 | 4.077 | 1 | 4.182 | 1 |
| (c) The Resource Plan (Manpower weightage) | 2.571 | 3 | 3.000 | 3 | 3.068 | 3 |
| **Factor (2) Process of Project Progress Monitoring and Evaluating** | | | | | | |
| (a) Traditional Approach | 4.000 | 1 | 3.769 | 2 | 3.477 | 2 |
| (b) Software for scheduling | 3.286 | 2 | 4.077 | 1 | 4.023 | 1 |
| (c) Real-time Monitoring System | 1.429 | 3 | 2.154 | 3 | 2.136 | 3 |
| (d) Field Inspection Reporting System (FIRS) | 1.000 | 4 | 1.692 | 4 | 1.952 | 4 |
| **Factor (3) Computerized Application Systems for Project Progress Monitoring** | | | | | | |
| (a) Digital Hardhat (DHH) system | 1.143 | 3 | 1.692 | 3 | 1.977 | 2 |
| (b) SKALA System | 1.429 | 1 | 1.769 | 2 | 2.000 | 1 |
| (c) PHOTO-NET II | 1.286 | 2 | 1.385 | 4 | 1.955 | 3 |
| (d) A web-based construction Project Performance Monitoring System (PPMS) | 1.000 | 4 | 1.923 | 1 | 1.614 | 4 |

result of survey shows that traditional or paper-based information flow on construction projects still dominate; as computers are increasingly becoming a central component of project information systems and used for developing the planned schedule. The several areas in construction management, such as scheduling, estimating, cost control, and accounting, employ well-established computer applications. To carry-out the laborious calculations and data tracking for these tasks, they represent a small portion of the day-to-day construction management activities. The result of survey also highlighted that the updating the project progress still carried out manually, no computerised system is used for developing the project progress automatically.

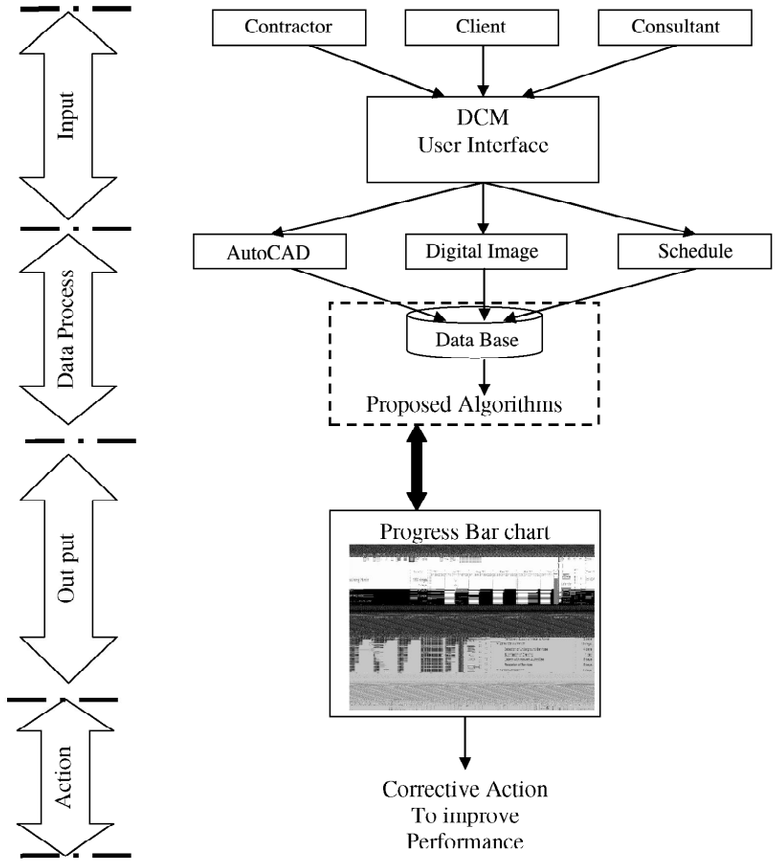


*Figure 2: Developed frame work of digitalising construction monitoring*

## 4. THE PROPOSED PROTOTYPE SYSTEM

The basic theory behind 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. The objective of developing a Digitalised Construction Monitoring (DCM) model is to systematise the construction monitoring and evaluation of a project. DCM is implemented using object oriented concepts and event driven programming. The object-oriented concepts were utilised 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 TM (event driven programming). Relational Data base was implemented using Micro Soft Access TM engine to store project related information. The simulation concept of DCM model is currently being used to test and check the validity. The main goal of DCM model is to propose an interface process model between the 2D digital photo and detail design drawings and update the physical progress chart by integrating the information.

Figure 2 shows the framework model for the proposed system. The proposed system is divided into four different phases. In phase-I, the input information will be browsed by the user in the

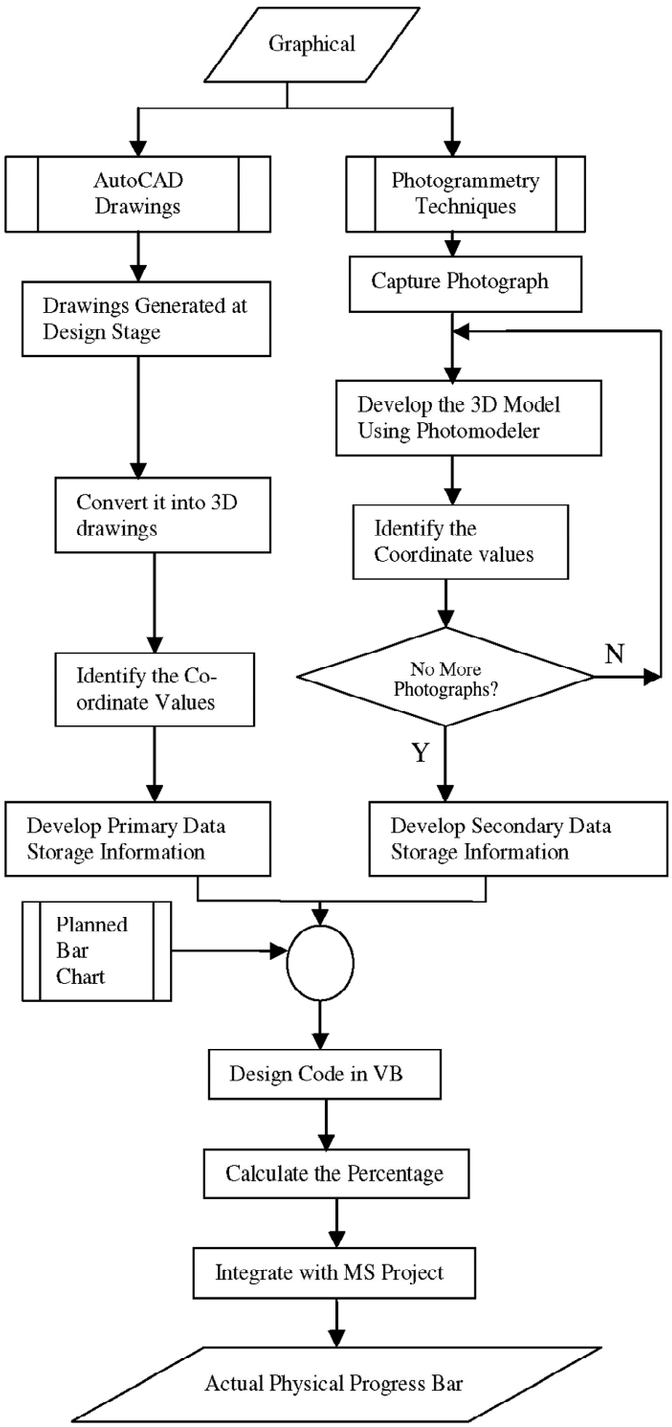


***Figure 3: Process flow diagram***

format of planned schedule of work, txt file and 3DAutoCAD file. Once user browsed all the information, phase-II start, which is to process the information. The process is done by automatically, as DCM user interface was designed, developed and computer programme are written in Visual Basic. During this phase, the percentage of progress will be calculated by integrating the database. These databases were developed during the Phase-II as user browsed the required information and content the 3D co-ordinate values from digital images and 3DAutoCAD drawings.

The phase-III will show the result interface of the system. This phase also shows the result in graphical format. As seen in Figure 2, the graphical information is shown in Microsoft Project Gantt chart. The next and last logical step of prototype system is to take Action as a remedial measure. This step activated when project manager realises the delays are happening and required to boot the progress and to take decisions for successful completion within prescribed time.

## 5. ARCHITECT OF THE DIGITALISING CONSTRUCTION MONITORING

The major task of developing this model is to develop the link between existing methods of evaluating and monitoring the physical progress of construction scene with modern technology. The main aim of DCM is to develop the project progress monitoring system that improves construction management methods in project progress reporting and control.

Figure 3 shows the process flow diagram for the DCM, in which digital images will be captured from site and 3D model will be developed by using Photomodeler software and AutoCAD used to display 3D information of the intended design. All the design parameters are stored in the primary and secondary data base and code are designed to calculate the percentage of actual progress. This percentage will be integrated with the Micro Architecture of the DCM Model, which shows a dynamic connection between the database and graphical information. The DCM model will be integrated with existing commercial or research prototype systems. The graphical information is created from 3D Model by using professional prototype system namely Photomodeler and AutoCAD 3D drawing. The primary data base from AutoCAD drawing has been developed at the start of the project by developing an Expert system and will be reluctant as any change order will be corrected in the data base. Secondary data base will be developed as construction work constructed and the source of information will be using photos. Visual basic will be used to build interfaces between the database developed from AutoCAD and Photos by using Photomodeler. By simulating both data base, it will calculate the percentage of progress considering the updating date and will transfer this information to Microsoft Project to show the actual physical progress in bar chart.

## 6. ALGORITHM FOR USER INTERFACE OF DCM SYSTEM

As discussed under the heading of Architectural of DCM, this system integrate the information from Microsoft Project, AutoCAD drawings and digital images and produce the end result in the format of Gantt chart in Microsoft Project. The figure 4 shows the detailed Algorithm for the proposed system. As figure shows, to start working on DCM, user needs to install the setup initially on his system and for successful running, user must be equip with AutoCAD to develop 3DAutoCAD model, planned work schedule in Microsoft Project and PhotoModeler software to develop the 3D Model. These three were considered the basic tools for DCM system.

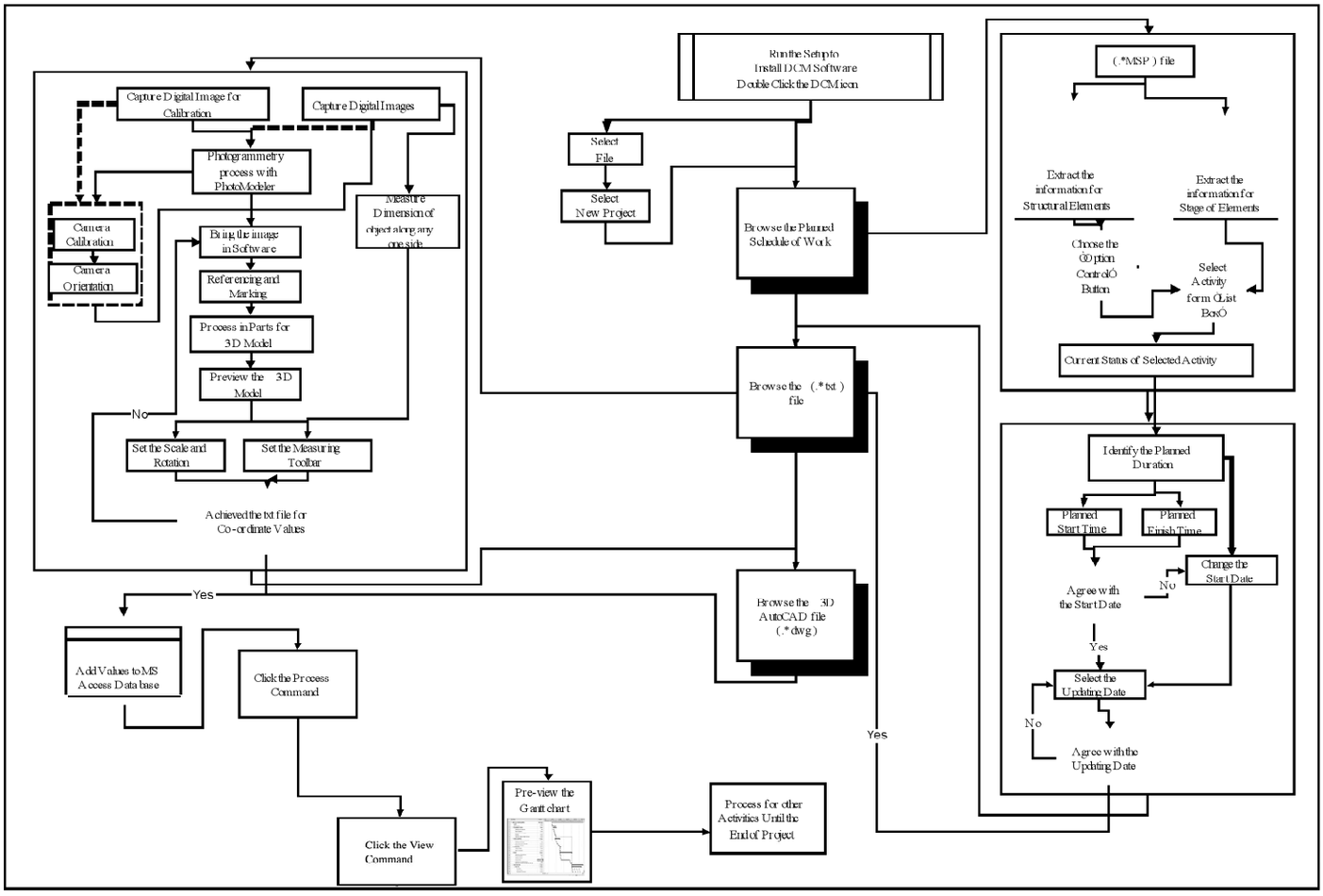


***Figure 4: Algorithm of DCM user interface***

The first logical step after installing and running the DCM system is to browse the planned schedule of work in Microsoft project. The figure shows the detail algorithm for browsing the work schedule. Once successfully complete this step, next step is to browse the {*.txt} file. This file is created from digital images by running with PhotoModeler Pro version. The detail of developing the 3D model from digital images is shown in figure. This algorithm is carried out before running the DCM for measuring the progress. Once {*.txt} file exported from PhotoModeler, then it is suggested to run the DCM system. As soon as {*.txt} file browsed the information will be grouped in Microsoft Access database to store the information.

The next logical step is to browse the 3DAutoCAD drawings as can be observed from the figure. As 3DAutoCAD file is browsed, the information is stored into database and user can start the process. By clicking on process command, it starts integrating the information in the database and calculates the percentage of progress. This percentage of progress can be viewed into the Microsoft Project. The algorithm is designed for this to show the view of comparison of progress between planned and actual progress.

Algorithm of user interface of DCM model is successfully designed. By implementing this algorithm model, it is authors' believe the efficiency of construction industry will be improved. The successful implementations of DCM will speedup the process of developing the progress reports and will help the project manager in decision making process. From the view of professionals in Malaysian Construction Industry, they suggested additional remarks for the usability of DCM especially when the contract dismantled during the contract period, DCM will be more effective and efficient as this stage also. They also suggested for the improvement of the model, which will be incorporated at the time of developing prototype system.

## 7. CONCLUSIONS

The research described in this paper attempts to overcome the limitations of the previous research development in the area of evaluating the construction phase. The main focus of this paper is to design a methodology for the monitoring and evaluation of construction project and developing a systematic model considering Malaysian construction industry's view point. A questionnaire survey was carried out within MCI and analysed and the result identify the need of digitalise system for MCI. In this regard this study proposes a system and discusses the methodology for designing the prototype model to systematising monitoring and evaluation of a project. The model allows users to document and retrieve project information in the form of digital images and close-range photogrammetry techniques are used to create 3D Model.

An integrated simulation model, named DCM (Digitalising the Construction Monitoring) is developed to integrate digital images of construction scene with AutoCAD drawings and it resolves the existing project progress reporting problems. Based on traditional approach, actual physical progress reports is developed manually by comparing the planned with actual

performance measured on site. The Digitalising the Construction Monitoring (DCM) model is developed by using the Relational Database Management System (RDBMS). The integration of digital images and drawings will enable construction mangers to develop progress reports in a more consistent and accurate manner and more accurate as-built project schedules can be transferred to facility managers for operation, maintenance, renovation and demolition. The DCM model will improve the decision-making and productivity of the construction activity.

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