DIGITALIZING CONSTRUCTION MONITORING (DCM):AN OVERVIEW OF MALAYSIAN CONSTRUCTION INDUSTRY AND PROPOSING PROTOTYPE SOFTWARE

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Abstract: Real-time monitoring and control on construction site is a growing field and still in its infancy. Managing project information during the construction phase is an important task yet difficult task, currently; however, the construction industry relies heavily on written reports to document site conditions, which requires good writing skills and unbiased judgments. Manual monitoring of construction sites is costly and error prone. A persistent problem in construction is to develop the as-built actual physical progress schedule of construction scene. Consequently, this study addresses Digitalizing Construction Monitoring (DCM) model for monitoring and evaluating the physical progress of the project. A pilot survey was carried within Malaysian Construction Industry to investigate the common methods and processes of project progress evaluating and monitoring and utilization of existing computer based application system for monitoring project progress performances. 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 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. 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: CAD drawings, Digital Photograph, Project Monitoring and Control, Project Progress Reports, Photogrammetry.

1. INTRODUCTION AND BACKGROUND

This paper discuss about the current project progress monitoring methods within the Malaysian Construction Industry (MCI) and propose a prototype model to automate the process of project progress reporting. Abd.Majid (2004) highlighted that the Malaysian Construction Industry which is the second largest industry after manufacturing industry. Chehayeb and AbouRizk (1995) mentioned that most construction project employ some form of cost and schedule to control and update the project progress. Chau et al. (2004) stated that for the most construction projects still clients' requirements are presented in terms of paper-based working drawings and important task for the contractor is to formulate a project schedule that links different construction activities on the basis of these working drawings. In this process, planners have to take into consideration practical construction sequence, proper workspace logistics, and feasible resource allocation, which includes labor, material, equipment and the use of site space. Memon et al. (2005) mentioned that project progress monitoring and control is one of the most important tasks of construction project management and every team member needs to know in a timely and accurate manner, how is project progressing, where they are currently in comparison to the initially set plans.

O'Connoer and Yang (2004) stated that the construction industry has been criticized for its slow adoption of emerging technologies. However it is believed that in recent years this trend has been changing. During the past decades, previous research efforts have been made towards advanced four-dimensional (4D) planning models by integrating three-dimensional (3D) visualization with the time attribute. McKinney and Fischer (1998) studied the effectiveness of a hybrid 4D application using the contemporary software primavera, AutoCAD, Jacobus simulation tool kit, and walkthru. Zhang et al. (2000) developed a 3D visualization model with schedule data at the level of construction components. Kamat and Martinez (2001) presented a 3D visualization model depicting the entire process of a typical construction activity. Chau et al (2004) presented a 4D visualization model for construction planning and site utilization by integrating a 3D geometrical model with a project activity schedule. 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.

Brilakis and Soibelman (2005) mentioned that the capability to automatically identify shapes, objects and material form the digital image content through direct and indirect methodologies has enabled the development of several civil engineering related applications that assist in the design, construction and maintenances of construction projects. Brilakis and Soibelman (2005) highlighted that digital cameras and image databases are gradually replacing traditional photography while owners demand complete photograph logs and engineers store thousands of image for each project to use in a number of construction management tasks. However construction companies tend to store the images and attach with the progress reports when submitted to client for claims. The process of developing the monthly progress reports are manually or depend on the experience of engineer/planner. Memon et al. (2006) highlighted that manual or paper-based information flow on construction projects still dominates even computers are increasingly becoming a central component of project information systems within MCI.

A questionnaire survey form designed and conducted within MCI to investigate the issues related to current practice for monitoring the construction project progress and utilization of computer based application system for monitoring project progress performances. The questionnaire survey also identify the need for digitalizing construction monitoring, in line with National Information Technology Agenda, which was formulated in 1996 and Mui (2002) mentioned that Malaysian Government has been aggressively promoting Information Technology (IT) and its application in every sector including the construction. Questionnaire survey form was designed after the intensive literature review and unstructured interview with experts and practitioners. Most of the data obtained from the questionnaire survey was analysed using relative weight method, which was explained

by Abd.Majid (1997). The analysis of questionnaire survey highlighted the need of digitalize system for monitoring project progress. Considering the results and needs this paper proposes a model for monitoring construction project progress by integrating the AutoCAD drawings and digital images with a project activity schedule in Microsoft Project. One of the major objectives of this work is to provide a flexible 4D graphical visualization capability that is also convenient to use for short term re-scheduling and communication, usually for a specific part only of the whole project, because this is often required during the construction process. Hu et al. (2005) described that 4D visualization can represent construction scheduling and process graphically as well as 3D models, and 4D model can assist planning process and reducing the waste costs and control the time.

2. TRADITIONAL PROJECT PROGRSS MONITORING PRACTICE

Harris and McCaffer (2001) described monitoring is the act of checking actual progress and actual resource usage against planned and the act of taking decisions to alter the likely future outcome and bring the project back on the planed schedule is control. Thus the planner must collect the information on the rate of progress to date and current resources usage in order to update the computer model and monitor progress. Traditionally this information is collected from daily site progress reports and minutes of meetings and updated to computer by analyzing these reports. Hinze (1998) described monitoring to record the actual start and finish dates for activities while the project is underway, and control relates to the analysis of the impacts of any schedule deviations and evaluation of what remedial actions should be taken.

The basic mechanism of monitoring the project progress traditionally is shown in Figure 1. The diagram is a good analogy for professional people; we start the cycle by developing the check list for work activities for monitoring the project progress traditionally. Monitoring project progress involves making measurements as the project proceeds and comparing those measurements with the desired or expected dates. The process of monitoring progress will start when contractor developed the check list for work activities; before the start of construction work. These check list are filled by contractor in the case of small project. In the case of large scale project, a field engineer or site engineer employed and he will fill these reports. The photographs of progress of work are captured and attached to the reports. Project planner updates the progress by using planning and scheduling software such as Microsoft Project and Primavera. These reports are send to project manager; and if he satisfied these reports will be submitted to client's representative for the claim of money.

The project manager has to maintain the project network and monitor against slippages in cost, time and quality for the duration of the project (Blackburn 2002). Regular and accurate reporting on project progress offers a continuous vital diagnosis for the project status, enabling different project team-members to make proper decisions on any necessary corrective actions to safeguard the project and ensure its completion (Saad 1999). In achieving this, the project relies heavily on a reliable monitoring system that can provide timely signaling of project problems, whether they are real or potential.

3. CONDUCTING SURVEY WITHIN MALAYSIAN CONSTRUCTION INDUSTRY

The main purpose of conducting the questionnaire survey was to highlight the current practice and support the existing practice for monitoring the project progress, which were identified through the unstructured interviews with the professional, industry requirements, and by attending the seminar and workshop related to construction project management. . In order to identify the most significant category, a preliminary survey was conducted in the Malaysian Construction Industry. A total of 200 contractors selected randomly from the list of Construction Industry Development Board (CIDB) Malaysia of Grade VII and questionnaire

was delivered via post. The total filled questionnaire received was forty seven within three months duration. The questionnaire form was completed by directors, project managers, and quantity surveyors and Figure 2 shows the composition of respondent. The measurement used to collect most of the variable relevant for this study was ordinal or ranking scale. Specifically, Likert scale was used to measure most of the variables. For example in this study, the measurement used to measure level was five Likert Scale. For detail explanation on different types of scaling please consult Siegel et al., (1988).

4. 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 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 $a_4 = 4$; and

X_5 = frequency of the 'very frequently' response and corresponding to $a_5 = 5$

These average index could be further interpreted back to reflect the respondents rating. Abd.Majid and McCaffer (1997) and Abd.Majid (1997) used a discrete scale converted to a continuos index (average index) which then can be split into discrete categories, so in this case discrete categories were classified as follows:

(a)　　　Very frequently (VF)　　3.5 ≤ Mean Score < 4.50 (b)　　　Frequently (FR)3.5 ≤ Mean Score < 4.50

(c)　　　Slightly frequently (SF) 3.5 ≤ Mean Score < 4.50 (d)　　　Rare (RA)　　　3.5 ≤ Mean Score < 4.50

(e)　　　Very rare (VR)　　　　3.5 ≤ Mean Score < 4.50

The calculated mean score can also be converted to a percentage index as suggested by Abd.Majid and McCaffer (1997).

Develop Planned
Work Schedule

Highlight the ES
and EF for each
Activity

Project Progress M
by Cotn

Prepare the Ch
Work Ac

Fill chec

Contractor visit
side
(Small Project)

Check list filled
by
Contractor

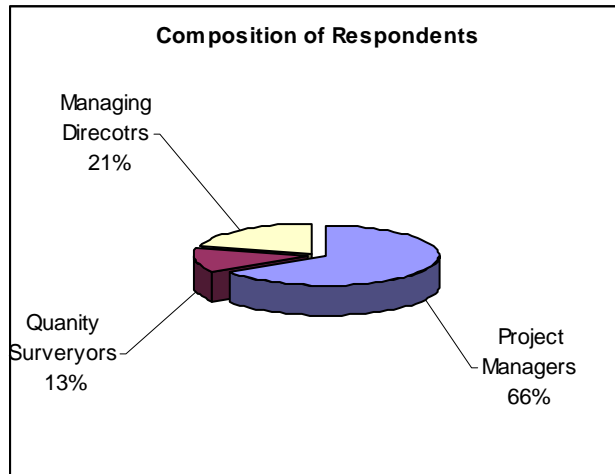*Figure 1 Traditional Project Progress Monitoring Process*

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Figure 2. Composition of Respondent within Malaysian Construction Industry

Table 1 shows the result of preliminary questionnaire survey. The project performance monitored by using schedule/time plan having mean score of 4.128 and lies into very frequently discrete category. Similarly the process for monitoring the project progress by utilizing the easily available scheduling software such as Microsoft project and Primavera P3 in the category of very frequently and having mean score of 3.936. However, for computerized Applications system for project progress monitoring, no suggested method falls under the category of very frequently or frequently, only SKALA having mean score of 2.0210 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.

Table1Results of Pilot Question Survey within MCI

Methods of Project Progress Evaluation and Monitoring	
Suggested methods	**Total Mean Value**
The money Plan	3.979
The time plan	4.128
The resource plan	3.021

Process of Project Progress Monitoring and Evaluating	
Suggested methods	**Total Mean Value**
Traditional Approach	3.468
Software for Scheduling	3.936
Real-time Monitoring System	2.191
Field Inspection Reporting System (FIRS)	1.98

Methods of Project Progress Evaluation and Monitoring	

Suggested methods	Total Mean Value
Digital Hard Hat (DHH) System	2.00
SKALA System	2.0210
Photo-Net II	1.957
A web-based Construction Project Performance Monitoring System	1.702

5. PROPOSING THE FRAME WORK MODEL FOR DIGITALIZNING MONITORING PROCESS

As discussed in previous section and also the result of survey highlights the need of digitalize monitoring system within MCI and where monitoring the project progress is carried-out by traditional method of capturing the photographs and placing these into monthly progress reports. 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. Numerous studies have focused on information flows at construction project progress monitoring stage, 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 digital images and AutoCAD 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.

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). The research reported in this paper took a step toward this object by attempting to simulate the 3D Model from digital images and 3D AutoCAD drawings of super structure concrete elements. . On the basis of these researchers' recommendations, a framework model is proposed as shown in Figure 3. 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.

This work culminated in the design of a prototype model, namely called Digitalizing Construction Monitoring (DCM). 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 analyzing data about project physical progress and flows for integrated computer systems rather than create a new class of software application.

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.
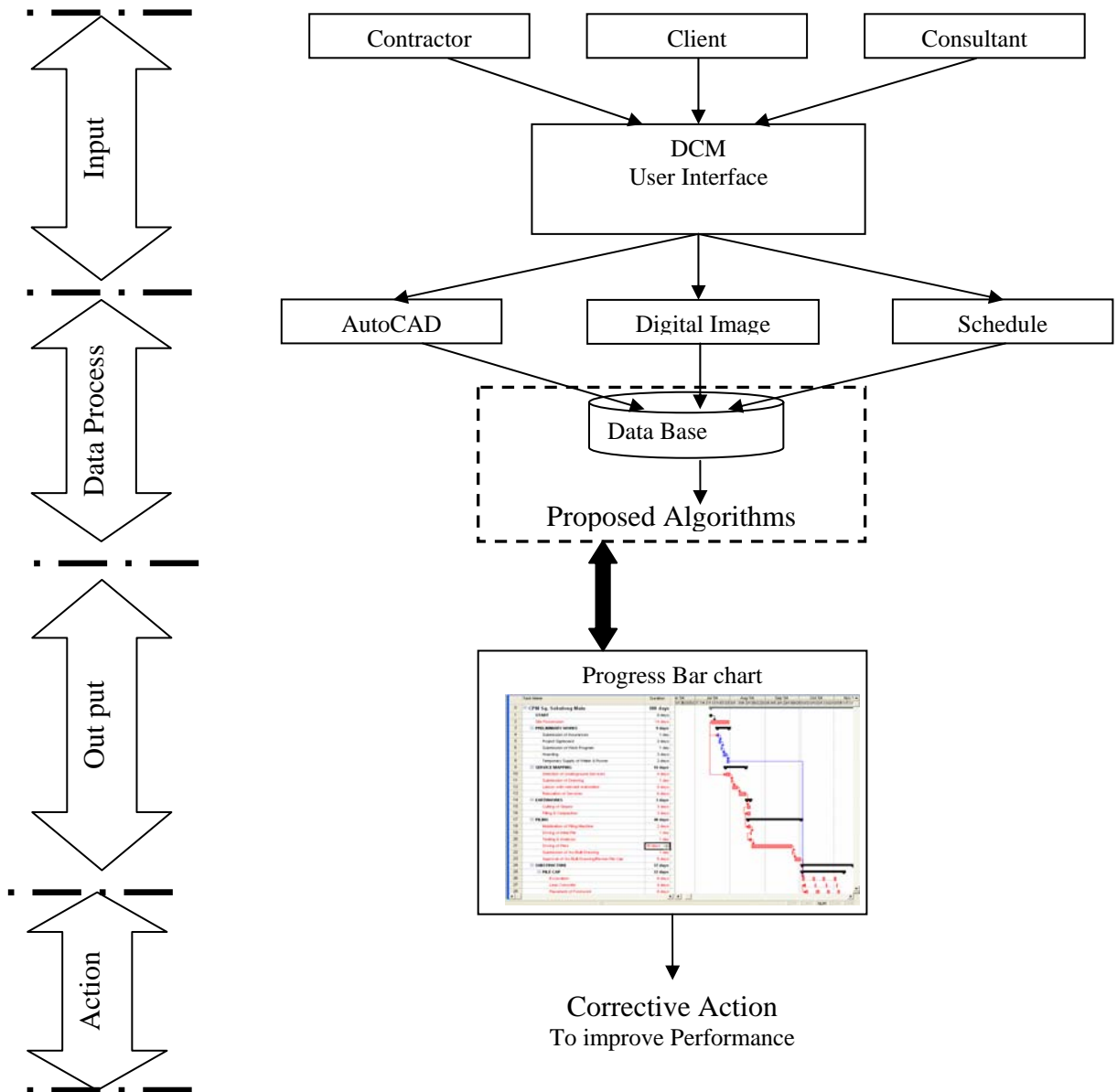
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Figure 3. Frame work Model of Proposed System

6. CHARACTERISTICS OF DIGITALIZING CONSTRUCTION MONITORING (DCM)

The basic theory for developing the model is to extend the traditional approach to represent the dynamic and simultaneous construction operation by incorporating inter-relationships between hierarchical process of monitoring 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 mechanism 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 computer were used. The rapid growth in the availability and power of microcomputers, coupled with their continuously decreasing cost, has made it possible for

construction manages to effectively and efficiently analyze the massive amounts of data necessary to monitor and control the project progress. Taking into account these characteristics, DCM was designed into knowledge-based programming method. The DCM consists of AutoCAD, digital photogrammetry techniques, database management system, knowledge-base expert system, DCM user interface to browse the information.

7. STRUCTURE OF DCM MODEL

Figure 4 shows the process flow diagram for the DCM, in which graphical information achieved in the format of digital images and 3DAutoCAD drawings. This system uses the consumer-grade digital camera and easy available software to develop the integration. Digital images will be captured from the construction site as work progress. The PhotoModeler software was used for post processing the acquired images to develop the 3D model. Photomodeler software has the efficiency to do camera calibration and orientation automatically. Photomodeler correlate the points form one references image with corresponding points on the other image, through this procedure 3D model will be developed and 3D co-ordinate values for the marked points will be achieved in the table format. The shop-drawings for the project normally developed in the 2DAutoCAD format. These drawings will be reproduced into 3D AutoCAD format. Normally AutoCAD highlight the 3D coordinate values by selecting any point on the drawing.

The algorithms will be developed to extract the co-ordinate information automatically from 3DAutoCAD drawings and 3D model developed in PhotoModeler, once they are browsed into the user interface of DCM. The database developed from AutoCAD drawings were called as primary and other from digital images are called secondary. The algorithm will be developed to extract the information related to duration, planned start date and planned finish date of the selected work activities from planned schedule of work. The algorithm for the integration of information from database and planned work schedule developed to calculate the progress of work automatically. The progress of work will be highlighted into percentage. The algorithms will be developed to show the actual progress of work with comparison to planned schedule work automatically. Through this way the object of digitalizing the construction monitoring process will be achieved and operational and strategic benefits will be achieved.

7. CONCLUSIONS

A survey was conducted within MCI and most of the respondents were the project managers and managing directors and they have work experience more that ten years. From the analysis of survey the need of developing an integrated model to automate the current practice of monitoring project progress was highlighted. To over-come this need a prototype system called Digitalizing Construction Monitoring (DCM) was proposed. With the development of DCM, the major task of developing link between traditional or existing methods of monitoring progress and modern technology techniques of Artificial Intelligence were achieved. This system integrates the information from digital images, AutoCAD drawings and Microsoft Project. By proposing the prototype model of DCM, the object of this paper is achieved successfully. DCM will help the project managers and site engineers to monitor the project progress more effectively and accurately. It is authors' believe that by writing the code for the prototype model, this system will improves the decision-making process, productivity and reduce delays claims.
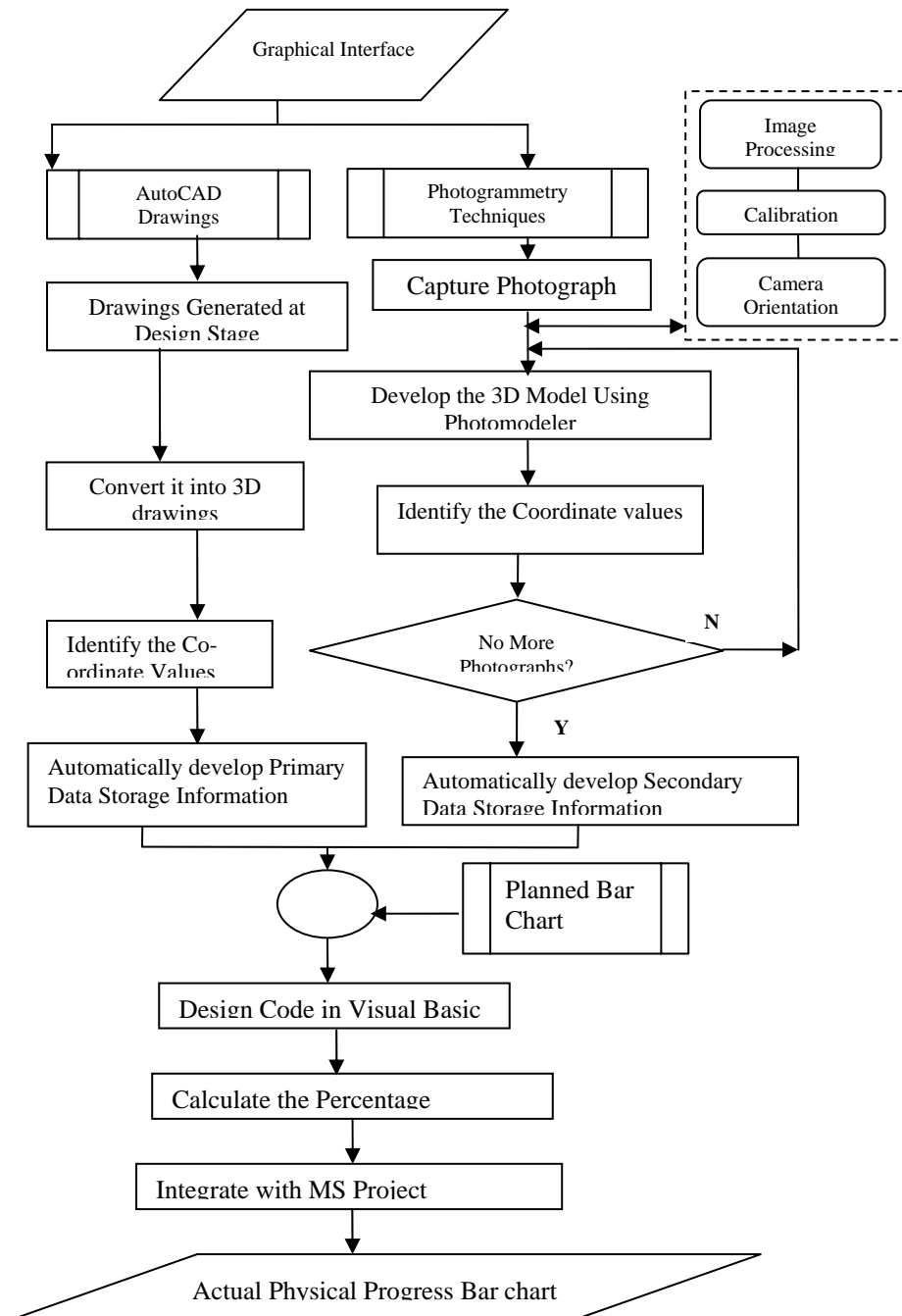
8. ACKNOWLEDGEMENT

Figure 4.Structure of process flow diagram for DCM model

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