EXECUTIVE INFORMATION SITE MANAGEMENT SYSTEM FOR MONITORING PROJECT PERFORMANCE: SYSTEM REQUIREMENT STUDY

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Abstract: Progress monitoring and control is one of the most important tasks of managing projects. Basically, construction works produce a lot of information that are required by top managements to track the work progress at site. A recent issue highlighted by top managements is the inefficiency in obtaining information from project sites on time. Hence, the focus of this research is to establish a computerized information system that can be utilized by top managements in order to evaluate the construction progress, known as Executive Information Site Monitoring System (EISMS). In order to develop EISMS, a Classic Waterfall Model has been considered as a basis for the system development whereby it began with identifying the system requirement followed by the system design (product design and detail design), coding, integration and finally the system testing and implementation. As relevancy to research field, this paper focuses on the development of system requirement. The research is presented in two study phases. In the first phase, initially it was conducted a descriptive survey study on “important futures”, followed by a descriptive study also on managerial priorities in Key Performance Indicators (KPI) of EISMS. The survey results “work progress” as the most “important features” for the system. Furthermore, the survey addresses managerial priorities on KPI to be emphasized in EISMS. As the study shows, development of the system requires three primary databases which include planned work schedule, 3D-CAD drawing, and actual work completion at site. In second phase, it is to elaborate propose EISMS framework model. Furthermore, it designed in a novel monitoring and control algorithm to track the “work progress”. Initially, it was to compute planned and actual work progress and thus the schedule variance at any selected specific date. Within this study, a trial based version of EISMS schedule variance analysis was implemented during the construction phase of one case study to investigate any shortcoming of a developed system in calculating schedule variance of project.

Keywords: Construction Project Management, Executive Information System, Project Progress Monitoring, Site Progress

INTRODUCTION

Since 1990’s with introduction of the “three ring circus” in construction industry; “complex, uncertain and quick” [22], it is widely recognized that “construction is information intensive industry”. Furthermore, the presents of “*rethinking in construction*” initiatives [14] convinced construction stakeholders to invest in Information Computer Technology (ICT) to manage the projects more efficiency. Researches stated that the purpose of computer based information system in the construction industry is to integrate the collection, processing and transmission of information so that the engineering professionals can obtain more insight into the operations and functions they are managing. Indeed, for effective monitoring of a project, an organization should have a system that is able to provide critical information whenever it is required and share the information from a single source within the organization to support its daily operations and decision making. The ICT provides the construction industry a potential tool to increase the efficiency and effectiveness of information exchanges within the organization.

Jaafari and Manivong's [22] review on PM systems, Korde et al. [26] review on construction performance models, Zhang and Yuan [46] review on IT application on construction management and also Zhong et al [47] review on theories in real time project control. They highlighted several decades of improving functionality of ICT in the construction industry. In one aspect, the ICT application expanded through effective and systematic "auditing information flow" as a critical method to improve project monitoring and control practices. As stated by Chassiakos and Sakellaropoulos [9] the classifications of ICT implementation in construction leads to; " Conceptual frameworks of web databases, Electronic Document Management (EDM) systems, Information analysis in construction, Web-based applications in construction management., Application service providers (ASP), Construction information standardization."

Construction management research typically will focus on the shortcomings of the Executive Management (EM). There are many evidences in the body of research as highlighted by Harrison [18]. Lots of information requested by the EM about its daily operations can influence the profit of an organization. However, in a preliminary descriptive quantitative research [semi-structured questionnaires of 56 Class A Contractor, under the contractor service association (PKK) Malaysian contractors] it is investigated that top management usually having an inefficiency in gaining access to information system from the site for their information requirements.

Various construction personnel in the field need feed backs from the EM to support and make decisions on their ongoing work. The relationship can be defined as "direct line" and "communication pattern" in the construction industry and formal "family tree" construction management structure [17]. For the EM level, the frequency of information needed to support relevant managerial decision making is high compared to the other organization levels. Therefore, as an "Information System (IS) strategy", the Executive Information System (EIS) takes into account the needs of top management executive. EIS classifies the information for the EM, and reduces the mismatch of different information received; simultaneously, avoids information over load receiving, avoids defects of general misunderstanding of information sites and the EM. It increases the co-ordination of information and decision making needs of the EM. Hence, there is a great need for system that can provide information from the site to the top management in a fast, reliable and effective way. Through automation, it will help the top management to control and manage the site progress efficiently.

RESEARCH OBJECTIVE AND METHODOLOGY

This research was carried out to develop a system called the Executive Information Site Monitoring System (EISMS). The system would be able to analyze data obtain direct from site and provide real time information to the top management.

Preliminary understanding of the research subject was obtained through intensive literature review and followed by discussions with expert panels of the construction industry. Wide ranged topics were covered during literature review including communication, control and monitoring, automation and construction organization. Topics on executive information system and Earned Value Method (EVM) on monitoring performance were also given priority at this stage.

From the intensive literature review, discussions with expert panels and a questionnaire survey, the system requirement for EISMS was established and from there EISMS was developed based on the Classic Waterfall Model. Classic Waterfall Model has been considered as a basis for system development whereby it started by identifying the system requirement followed by product design, detail design, coding, integration and finally the system testing and implementation [7]. As relevancy to research field, this paper focuses on the development of system requirement. The waterfall model was adopted because of its simplicity and straight forward model which suit the EISMS. The EISMS was designed to be a user-friendly stand alone software which does not required incremental development, parallel developments, program families, accommodation of evolutionary changes, formal software development and verification, and stage wise validation. The EISMS has been developed to provide schedule variance for the top management to digest quickly the situation of work progress at site. Within this study, a trial based version of EISMS schedule variance analysis was implemented during construction phase of one case study to investigating any shortcoming of developed system in calculating schedule variance of project. The prototype was tested on the construction of a 2½ storey bungalow in Taman Cemerlang Height Selangor Malaysia.

VARIOUS CONSTRUCTION MONITORING SYSTEMS

This section provides a brief overview of several studies reported in the literature relating to construction monitoring system for construction project. The sources outlined here provide the basis of the analysis of project monitoring and the system requirement study presented in the following sections. Effective control of information flow is a critical ingredient throughout the life cycle of construction projects. Lock [29] investigated that the purpose of computer based information system for engineers is to integrate the collection, processing and transmission of information so that the engineering professionals can gain more insight into the operations and functions they are managing. Syed and Froese [42] state that the primary function of the computerized information system is to improve the efficiency of the project manager in retrieving project information from existing records.

Mazerolle and Alkass [31] proposed a Data Base Management System (DBMS) in a project control process to store information on each delay when it occurs. Hiroshi and Nobuoh [19] described a filing system of construction pictures and its integration with a database. Hamilton [16] stated that, using a relational database improves record management process such as tracking the progress and location of shop drawings, within a firm, listing present and past projects, maintaining correspondence, calculations, telephone records, and memoranda.

MULTROL, a multimedia project control and documentation system, was developed by Liu et al. [28]. This system allows the storage and retrieval of project information in the format of text, image, video and sound. A prototype system, CAD Construction Information Management System (CADCIMS) developed by Stumpf et al. [41]. The interfaces had been developed among the Schedule Generator, the CADD system, and the database. The Virtual Construction (VIRCON) system was developed by is composed of a core database of building components, which are in turn, integrated with a CAD package (AutoCAD 2000), a Project Management Package (MS Project), and Graphical user Interfaces.

Wang [44] presented an expert system ESSCAD (Expert System Integrating Construction Schedule with CAD drawing) developed for integrating construction scheduling with CAD drawings. Abeid et al.[3] describe the development and implementation of an automated real-time monitoring system for construction project programmed in a Delphi Environment. This system links time lapse digital movies of construction activities, critical path method (CPM) and progress control techniques.

Streilein [40] formulated a DIPAD software, which combines digital Photogrammetric methods with the capabilities of a CAD system. The overruling principle of DIPAD is, that the human operator assigns responsibility for the image understanding part (high level grouping), and the computer for the actual measurement and data handling. Afterward, Abeid [3] developed the PHOTO-NET techniques, a system that links time lapse digital movies of construction activities, critical path method (CPM) and progress control techniques.

DeChant [13] mentioned that by using close-range Photogrammetry instead of taking traditional contact measurements, the photos were converted into AutoCAD models using Photomodeler pro-version software. Pappa et al. [37] implemented the photogrammetry techniques for Gossamer Spacecraft Structures and he described that the science of calculating 3D object coordinates form images is a flexible and robust approach for measuring the static and dynamic characteristics of future ultra-lightweight inflatable space structures. He selected Close-range Photogrammetry, a flexible and robust technology with a demonstrated potential for measuring Gossamer-type structure. Greco [15] described Photogrammetry as one of techniques for obtaining reliable measurements from photographs and other type of images.

Even in the mid 1990s, the use of computer-assisted virtual design modeling, also known as building information modeling or BIM (Kimberly & Patrick, 1995) was on the rise in the construction industry. The BIM design process allows for a far more interactive compilation of design data from multiple sources than the common 2D design development. BIM interacted with various stages of the building life cycle where it is capable of supporting and improving the building life cycle. With BIM, architects, engineers, contractors, and owners can streamline projects through coordinated digital design information and documentation; create more accurate visualizations and simulations with regard to performance, appearance, and cost; and deliver their projects faster, more economically, and with reduced environmental impact.

Zubair et al. [32] proposed a prototype model, namely called Digitalizing Construction Monitoring (DCM) developed by integrating AutoCAD drawings and digital images. The user can retrieves the project information in the form of images and using photogrammetric techniques to obtain reliable measurement from photographs and stimulated with

CAD drawings to develop the physical progress report.
Considering purview statements, researches on computerized project monitoring were focused on, integrating project management system with image processing of camera photos, camera records, AutoCAD capabilities. Hence, it has not given attention to develop monitoring tool for top management. Besides, EISMS is considering needed integration in model development, focus on the work progress at the site and report directly to top management in real time. Thus, with the development of EISMS, it hopes that the system can benefit top management to improve decision-making process and can provide better mechanism for project monitoring.

EXECUTIVE INFORMATION SYSTEM

One of the roles of top manager is making decisions. The decisions made by top management are therefore important since they primarily affect the long term future of the whole organization. In order to carry out their jobs effectively, top management bases their decisions on accurate, timely and reliable information. Approaches to satisfy the information needs of top management have led to the development of a computerized system in the form of the Management Information System (MIS) and later Decision Support Systems (DSS). However, despite their relative superiority over non-computerized systems, and the relative success with middle management, this system failed to satisfy the need of senior executives. One of the main causes of this failure is best summarized by the term "information overload". An alternative to the traditional reliance on subordinates for the supply of information was the development of information systems used directly by executives. The result was the emergence of the executive information system. Since the term was first introduced in 1982, the trend of senior managers having direct access to computers has grown. In general, executive information system are enterprise-wide decision support system (DSS) that help top-level executives analyze, compare, and highlight trends on important variables so that they can monitor performance and identify opportunities and problems. Executive information system and data warehousing technologies are converging in the marketplace. Turban and Aronson [43] described an executive information system as a computer-based system that serves the info needs of top executive. It provides rapid access to timely info and direct access to management reports. The developed EIS is considered user friendly with the support of user graphics and provides reporting. In addition, it is connected to the Internet, intranet and extranets.

Several studies conducted on executive information system highlighted several keys issues. Kaniclides and Kimble [25] conducted a research on "A Framework for the Development and Use of Executive Information Systems". They concluded that clear knowledge in executive information system is essential before developing the system. While research done by Young and Watson [45] on "Determinates of executive information system acceptance" proved that executive information system is difficult to use and may fail and that ease of use alone does not ensure acceptance. Ong et al. [36] in their study of "Revitalizing Executive Information System Design and Development" proved that EISs have uncertainty characteristics that are impractical for individual executives. While, Jirachief pattana [23] in "The impacts of Thai Culture on Executive Information Systems Development" found that executive information system should be created only if the users want to be involved in its development process.

Many issues and problems highlighted by previous studies with regard to executive information system need to be addressed. Hence further development of EIS will enhance the features and reduce the problem faced by the previous system. Within consideration of these needs the development of EISMS is discussed. This paper emphasizes on the system requirement study, from construction perspective. It is concentrates to excavate industry needs to fulfill through system requirement considerations.

DESCRIPTIVE USER REQUIREMENT FOR EISMS

The Executive Information System as computerized information systems is designed to be used by top management without the need of intermediaries. The aim is to provide fast and easy access to information from various sources, both internal and external to the organization.

As stated before, a descriptive user requirement survey was conducted within 56 Malaysian construction contractors. Within which the selection of contractors was random based. The respondent sample has chosen from "certified Class A" Malaysian contractors.

For the purpose of analysis of data collected through the questionnaire, the Statistical Package for Social Science (SPSS) software was selected which are frequency analysis and average index analysis. Data obtain through selective-based format question were analyzed by using frequency analysis and the result has been tabulated in the form of frequency number and percentage according to total respondents. While data obtain through rating-based format question were analyzed by using average index analysis. The average index is calculated as follow [1]:

$$\textbf{Average Index} = \frac{\sum a_i x_i}{\sum x_i}$$

Where;
ai = constant expressing the weight given to i,
xi = variable expressing the frequency of response for
i = 1,2,3,4,5 and illustrated as follows:
x1= frequency of the "Strongly Disagree / Strongly Not Contributed / Not Important" and corresponding to a1 = 1,
x2= frequency of the Disagree / Not Contributed / Less Important" and corresponding to a2 = 2,
x3= frequency of the "Neutral / Fair / Moderate" and corresponding to a3 = 3
x4= frequency of the "Agree / Contributed / Important" and corresponding to a4 = 4
x5= frequency of the "Strongly Agree / Strongly Contributed / Very Important and corresponding to a5=5

In order to determine the degree of importance of the constructability principles considered in this study the classification of the rating scales proposed by Abd. Majid and McCaffer [1] have been used. The classifications of the rating scales are as follows:

Strongly Disagree/ Strongly Not Contributed/Not Important/Never (1.00 ≤ Average Index < 1.50)
Disagree/Not Contributed/Less Important/Less Frequent (1.50 ≤ Average Index < 2.50)
Neutral/Fair/Moderate/ (2.50 ≤ Average Index < 3.50)
Agree/Contributed/Important/Frequent (3.50 ≤ Average Index < 4.50)
Strongly Agree/Strongly Contributed/Very Important/Very Frequent (4.50 ≤ Average Index < 5.00)

Table 1: Results of Descriptive the Survey on EISMS requirements (first part)

			Average Index	Classification
First Part	**a)**	**Important features for EISMS development**	**Average Index**	**Classification**
	a.	Claims status	4.51	Very important
	b.	List of delay and completed activity	4.40	Important
	c.	Key performance indicator	4.27	Important
	d.	Executive summary report	4.24	Important
	e.	Store information of work progress	3.87	Important
	f.	Summary of contract information	3.82	Important
	g.	3D visual of work progress	3.58	Important
	h.	Calendar of contract period	3.42	Moderate
	b)	**Softwares used for construction drawing**	**Average Index**	**Classification**
	a.	AutoCAD	4.49	Frequent
	b.	Sketchup	2.24	Less frequent
	c.	IntelliCAD	1.85	Less frequent

Survey was containing within two parts, first part conducted to investigate EISMS "important features". Second part was comprised of one question to identify the Key Performance Indicators (KPIs) priorities by top management for monitoring construction work completion. In first part, the "important features" of EISMS development were investigated. The study concluded with eight "important features". It is included as; reporting claim statues, reporting list of delay and completed activities, reporting KPI's, reporting executive summary reports, storing information of work progress, providing summery of contract information, providing 3D visional of work progress, and finally providing a calendar of contract period. This part comprised of two questions; Question "a" and Question "b". Question "a" asked respondents to give their opinion in the Likert Scale format on the important features for the development of EISMS while. The result is summarized in Table 5 indicated "important features" of EISMS development. Question "b" asks respondent to rate their opinion on software that is frequently used to produce construction drawing. The result confirmed to propose AutoCAD based system in the EISMS development.

Table 2: Results of Descriptive the Survey on EISMS requirements (Second Part)

	Key performance indicators	Average Index	Classification
Second part	a. Work progress	4.27	Important
	b. Material quantity	4.18	Important
	c. Number on labor on site	4.13	Important
	d. Number of plants and machines	4.11	Important
	e. Time variance	4.09	Important
	f. Schedule variance	3.96	Important
	g. Time Performance Index	3.76	Important
	h. Non Conformance Report	3.73	Important
	i. Schedule Performance Index	3.65	Important
	j. No. of Accident	3.44	Moderate

Second part of survey comprised of one question. It was to identify the Key Performance Indicators (KPIs) priorities by top management for monitoring construction work completion KPIs can be defined by either the quantitative results of a construction process, i.e., percent completion and resources management or by qualitative measures such as worker behavior on the job [12].Accurate analysis of construction work performance can be attained only after the key performance indicators are determined and monitored. It was investigated there are ten essential KPIs that have been highly suggested for developing EISMS as the "important requirement". The system must provide data of work progress obtain directly from site, system must provides timely delivery of summary of Material information, as well as labor and plant, showing time variance and schedule variance, showing time performance index and Non conformance report, showing schedule performance index and finally number of accidents.

The question asks respondent to rate (in Likert Scale format) their opinion on how important is the KPIs for the top management of the organization. Within which these KPIs are to monitor work completion at site. The results shows that almost the entire listed KPIs given are important for top management of the organization in order to monitor work completion at site except for the indicator that was "number of accident" that lies on moderate category. However, "work progress" With average index 4.27 was recognized the most important KPI for top management to monitor construction work completion. Within that reason, this research is focused to develop a novel way of tracking "work progress" to be implemented in EISMS.

FRAMEWORK MODEL FOR EISMS

Several researchers have addressed different aspects of the development methodologies for a monitoring system [2], [28]. EISMS is designed for two distinct Executive management levels, one for "head office" and the other is for "site office" environment. Although, the aim of this paper is to high light the requirement study of developed EISMS, this section is briefing the of architectural system design of EISMS. (Figure1-a) It is design as the head office is connected to the site office via Internet while head office staffs are connected to each other by local area networks (LAN) and is based on client server architectural. In term of Web-enabled system design for project management tools, the "Technology, Process, People and Knowledge Management" are considered in EISMS simultaneously as expressed by Alshawi and Ingirige [4]. While in web-enabled EISMS the start date and finish date of each element of construction works is keyed in the system from the site office and stored in the head office environment. Thus, 3D-CAD for finished element and its schedule are keyed in at the head office. Hence, the results can be viewed by the top management at the head office. As the flow chart of the EISMS framework model is as shown in Figure 1-b.

In this regard, EISMS framework is designed in based on four phases which comprise of; data input for phase I, data process for phase II, output result for phase III and action for phase IV. The phases of the EISMS's framework model are described as below: (a) Phase I (Input the data): In the phase I, user will have to input three primary data which are the EISMS's master schedule, 3D-CAD, and completion work for each activity at selected period intervals during the construction stage. The uploaded information shall (reword) be processed in the phase II.

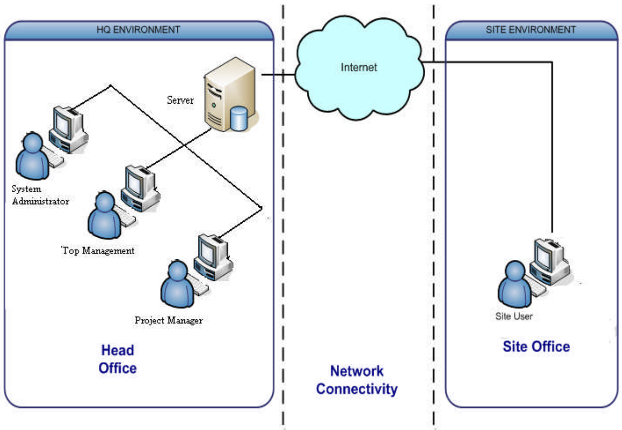

Fig. 1-a: EISMS system architecture

(b) Phase II (Process the uploaded Data): In the phase II, data acquired in phase I will be stored in the database at the head office environment. By using various computations, the data will produce various outputs. (c) Phase III (Output Result): During the phase III, the output produced can be displayed and viewed. The outputs are 3D schematic

visuals of work progress, planned work progress, actual work progress, list of delayed activities, executive summary report, Gantt chart and S-curve. (d) Phase IV (Action): Referring to the information gathered during previous phase, phase IV suggests the action that should be taken by top management to solve the current problems (decision making and problem correction) for purpose of controlling.

As shown in Fig.1, EISMS requires three primary data which are the master schedule as Data 1, AutoCAD drawing as Data 2 and completion date for each component of construction works at site as Data 3. According to architectural design of EISMS, Data 1 is prepared by the project engineer from the head office and Data 2 is prepared by AutoCAD operator. Data 3 is input into the system from the site office. The first two data (Data 1 & Data 2) will be prepared before the commencement of the construction while Data 3 is acquired during the construction stage.

Master schedule is based on items system of bill of quantities which its sequence of tasks follow 'Malaysian Standard Method of Measurement' (SMM2). The information from the construction master schedule together with the summary of contract price is used by project engineer to produce EISMS's master schedule. The conventional contract arrangement would require the contractors to tender their price during procurement stage. The breakdown of the tendered price of the contractor shall be summarized in the summary of contract price table. Before actual physical construction commence, the contractor has to prepare construction master schedule. Thus, In the EISMS's master schedule, schedule weightage for each element, start date, finish date and duration are be given for every construction tasks. For a double story building project, construction items normally comprised of preliminaries, work below lowest floor finish, frame, upper floor, roof and rainwater goods, staircase, external wall, external door and window, internal wall and partition, internal door and ironmongery, internal floor finishes, internal wall finishes, internal ceiling finishes, external finishes, sanitary fittings, builders work in connection, mechanical and electrical, external works, testing and commissioning and lastly handing over. Sample of EISMS's master schedule from the research case study is shown in Table 3 within which it covers "preliminaries" and "work below lowest floor finish". The 3D-CAD (Data 2) drawing will be prepared by contractor AutoCAD operator before construction commencement. The AutoCAD operator uses the 2D format drawing to upgrade to 3D format drawing. Each element of activities will be uniquely named by verifying the layer name to it.

Based on Data 1 and Data 2, the system will produce a digital form to be filled by site personnel as Data 3. The digital form contains list of component of construction tasks element. Site personnel input, the date of completed works of construction tasks component in the digital form and the system stores the information in a database at head office.

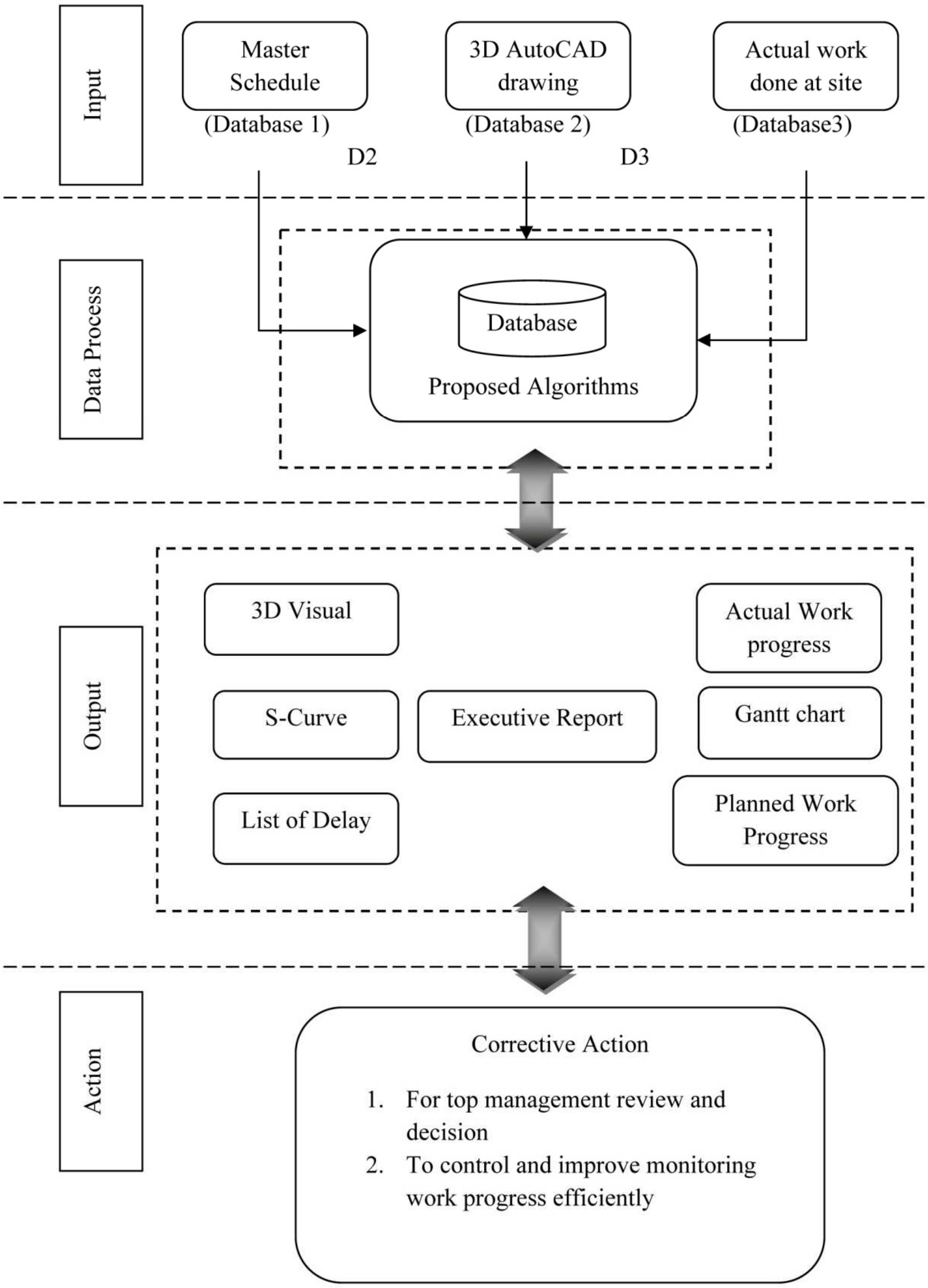

Fig. 1-b: Framework Model of EISMS

To feed the EISMS with the Data 3, it can be typed or keyed in weekly or any other selected period interval depending on how frequent the reports need to be updated for top management.

Furthermore, paper is going to enhance issue of monitoring and control of *"work progress"* as the most *"important"* KPI of EISMS. It designed to propose a novel monitoring and control algorithm to track the "work progress". It was to compute planned and actual work progress and thus schedule variance at any selected specific date. Two computation models namely computation of planned work progress and actual work progress have been introduced in EISMS.

EISMS Monitoring and Control Model of Work Progress

The EISMS computation models developed are based on combining Earned Value Method (EVM) with the focus on the schedule control. Schedule variance will indicate activity at site are ahead or delay. EVM will indicate monetary value of work performed. Instead EISMS measures the “schedule-value variance” between the planned and actual work progress is measured. Besides, as one of the main principles of executive information system in construction is to produce transferable report for future project [17]. The EISMS reflects more consideration of schedule-value variance in the ratio scale. It is reporting in percentage rather than in monetary term.

In contrast, there are other models emphasized on ratio kind of reports; Cost Performance Index (CPI), Schedule Performance Index (SPI) and combined Cost- Schedule Index (CPI × SPI). In comparison, EISMS is a method of reporting Schedule Performance Index (SPI × EVI) multiplied by Earned Value Index (SPI × EVI). In this regard, to eliminate introducing of complicated approach, the study directly implements its own calculation algorithm to show analysis (SPI × EVI).

Calculation Algorithm of Planned Work of EISMS

Planned work progress can be defined as a cumulative percentage of planned completion activities. EISMS computes the planned work progress in percentage W_n^p, at evaluation date D_n^e, based on the formula given below;

$$W_n^p = \sum_{i=1}^{I} \sum_{j=1}^{J(i)} E_{n(i,j)}^p \qquad (1)$$

Where;
- i = index for the construction task, i = 1, 2, 3…………………., I
- j = index for the element of construction task i, j = 1, 2.….., J(i)
- n = index number of evaluation date

$E_{n(i,j)}^p$ is planned weightage in term of percentage of elements j of construction task i at selected period t which can be computed from multiplying duration ratio Rn(i, j) to planned weightage of its construction element E(i,j).

$$E_{n(i,j)}^p = \mathbf{R}_{n(i,j)} \times \mathbf{E}_{(i,j)}$$

$E_{(i,j)}$ value can be obtained from the master schedule (Data 1), while $R_{n(i,j)}$ can be obtained by dividing theduration of completed element j of construction task i against its total duration as shown below;

$$R_{n(i,j)} = \frac{D_{(i,j)}^0 - D_{(i,j)}^s}{d_{(i,j)}}$$

Where;
- $D^0_{(i,j)}$ = $D^f_{(i,j)}$ if $D_n^e > D^f_{(i,j)}$, task completed or
- $D^0_{(i,j)}$ = D^e if $D^s_{(i,j)} < D_n^e < D^f_{(i,j)}$, task on progress or
- $D^0_{(i,j)}$ = $D^s_{(i,j)}$ if $D_n^e < D^s_{(i,j)}$, task not start yet
- D_n^e = evaluation date of number n
- $D^s_{(i,j)}$ = date of element j of construction task i
- $D^f_{(i,j)}$ = finish date of element j of construction task i
- $d_{(i,j)}$ = total duration of element j of construction task i
- i = index for the construction task, i = 1, 2, 3…………………., I
- j = index for the element of construction task i, j = 1, 2.….., J(i)
- n = index number of evaluation date

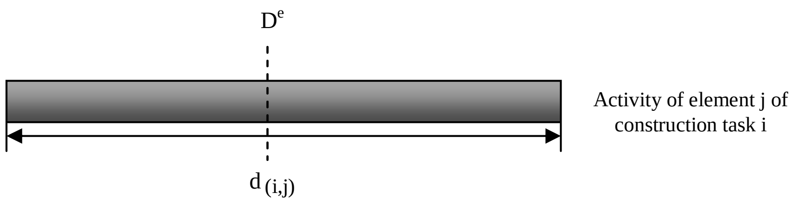

Fig. 2: $D^s_{(i,j)}$, D_n^e, $D^f_{(i,j)}$ and $d_{(i,j)}$

Total duration and the weightage of the element of construction task can be obtained from EISMS’s master schedule. Summary of Information Flow for Calculation algorithm of monitoring Planned Work Progress in EISMS is shown Figure 3.

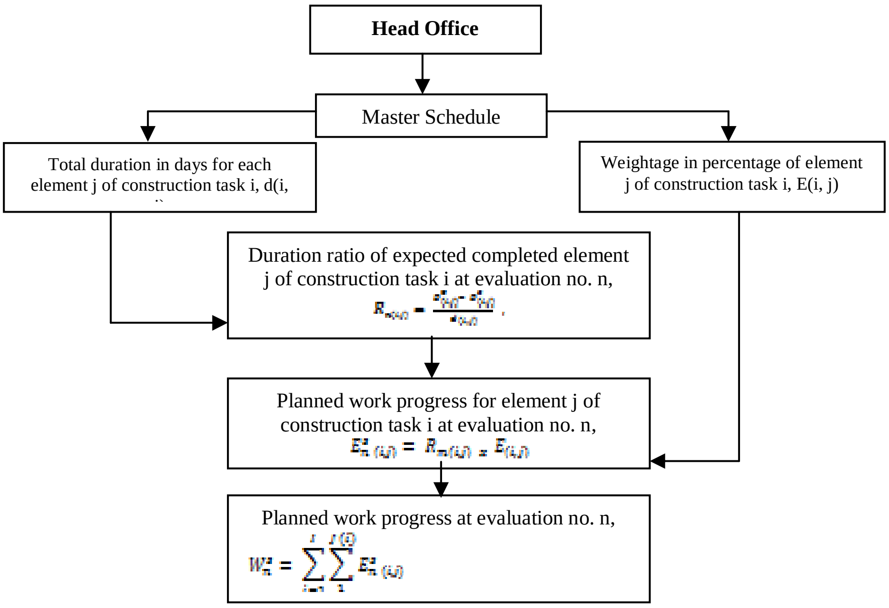

Fig. 3: Information Flow of Calculation algorithm of Planned Work Progress monitoring in EISMS

Calculation algorithm of Actual Work Progress of EISMS

The actual work progress can be defined as the cumulative percentage of actual work performed at site. EISMS computes the actual work progress in percentage, W_n^a, at evaluation date D_n^e, based on the formula given below;

$$W_n^a = \sum_{i=1}^{I} \sum_{j=1}^{J(i)} E^a_{n\,(i,j)} \qquad (2)$$

Where;

i	=	index for the construction task, i = 1, 2, 3………..…, I
j	=	index for the element of construction task i, j = 1, 2….., J (i)
n	=	evaluation date number n

$E^a_{n\,(i,j)}$ is actual weightage of elements j of construction task i in percentage at evaluation date, D_n^e which can be computed from the formula as given below.

$$E^a_{n\,(i,j)} = \frac{K^c_{n\,(i,j)}}{K^f_{\,(i,j)}} \times E_{(i,j)}$$

Where;

$K^c_{n\,(i,j)}$	=	number of completed work of component element j of construction task i
$K^f_{\,(i,j)}$	=	total number of component for element j of construction task

$K^c_{n\,(i,j)}$ is site input obtained from site office environment while $K^f_{\,(i,j)}$ is produced by the schedule matching database. The database is produced by matching element of construction task listed in the master schedule to 3D AutoCAD layers. For E(i,j) value, it can be obtained from the master schedule, D1. Summary of information Flow for Calculation algorithm of Actual Work Progress control in EISMS is shown in Figure 4.

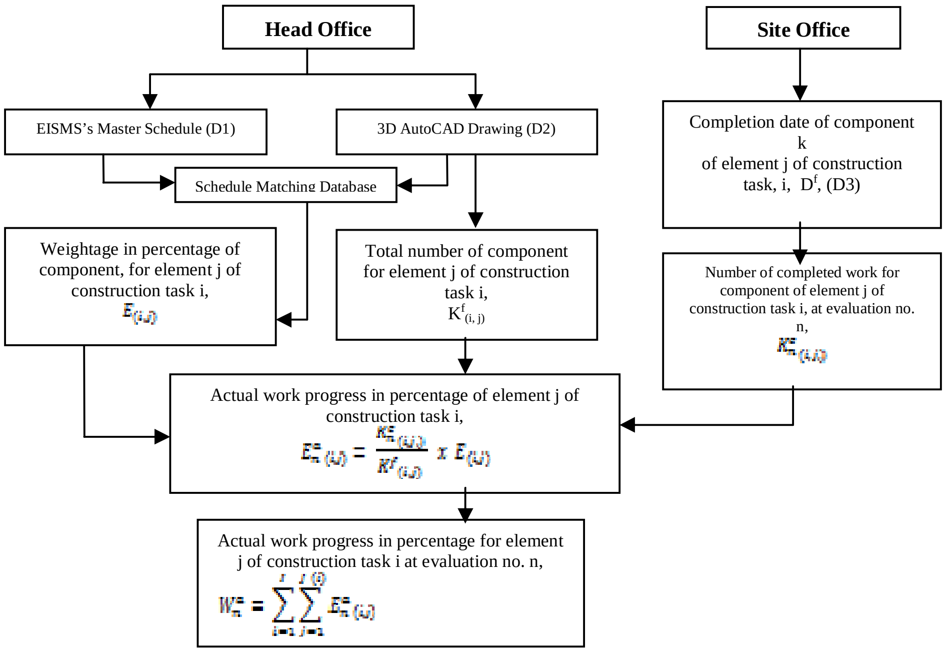

Fig.4: Information Flow of Calculation algorithm of Actual Work Progress control in EISMS

Table 3: Example of Master Schedule (case study)

i (item)	DESCRIPTION	SCHEDULE WEIGHTAGE FOR EACH ELEMENT (%)	START DATE	FINISH DATE	DURATION (DAYS)
1	PRELIMINARIES	5.00	07/09/09	26/05/10	262
2	WORK BELOW LOWEST FLOOR FINISH	3.21	07/09/09	24/09/09	18
	Pad footing	1.28	25/09/09	02/10/09	8
	Stump	1.93	05/10/09	13/10/09	9
	Ground Beam	6.42	14/10/09	22/10/09	9
	Floor Slab				
3	FRAME				
	Ground Floor Column	1.56	07/10/09	21/10/09	15
	Suspended Floor Beam	2.34	22/10/09	04/11/09	14
	First Floor Column	1.56	05/11/09	19/11/09	15
	Roof Beam	2.34	20/11/09	04/12/09	15

To show an example of the calculation algorithm of monitoring work progress in EISMS, it has been tested in a case study. It was the construction of 2½ storey bungalows in Taman Cemerlang Height, Selangor, Malaysia. It was to calculate variance in the end of October 2009. The master schedule presented in Figure 4. It addresses work breakdown structure elements of each item. Indeed, it indicated also schedule weightage for each element, expected start & finishes date, and expected duration of elements. In table 4 calculation of schedule-value variance was figured out. The actual work progress was 14.87% and the planned works progress is 17.11%. Hence the schedule variance was -2.34 % which indicate the work progress at site was delayed by 2.34%. The delay is thanks to progress of "Ground Floor Column" and "Suspended Floor Beam". The figures of actual and planned work progress given above were evaluated using the formulae 1 and 2, which are presented in a calculation matrix in Table 3 and Table 4.

Table 4: Example of EISMS calculation of Actual Work Progress (case study)

Report of Planed Work Progress, for Date, D^e = 31/10/09

i	Construction Task, i	Element of Construction Task, j	Evaluation Date, D^e (date)	Start Date, D^s (date) From master schedule	Finish date, D^f (date) From master schedule	Condition of D^0	Status of Task Work Progress	D^0 (Date)	Total Duration, $d_{(i,j)}$ (day) From master schedule	$D^0 - D^s$ (day)	R_n (ratio) $\frac{D^0 - D^s}{d_{(i,j)}}$	E (%) From master schedule	E^a_n (%) = R_n x E
1	PRELIMINARIES	Preliminaries	31/10/09	07/09/10	26/05/10	$D^0 = D^e$ if $D^s < D^e < D^f$	in progress	31/10/09	262	55	0.21	5.00	1.05
2	WORK BELOW LOWEST FLOOR FINISH	Pad footing	31/10/09	07/09/09	24/09/09	$D^0 = D^f$ if $D^e > D^f$	completed	24/09/09	18	18	1.00	3.21	3.21
		Stump	31/10/09	25/09/09	02/10/09	$D^0 = D^f$ if $D^e > D^f$	completed	02/10/09	8	8	1.00	1.28	1.28
		Ground Beam	31/10/09	05/10/09	13/10/09	$D^0 = D^f$ if $D^e > D^f$	completed	13/10/09	9	9	1.00	1.93	1.93
		Floor Slab	31/10/09	14/10/09	22/10/09	$D^0 = D^f$ if $D^e > D^f$	completed	22/10/09	9	9	1.00	6.42	6.42
3	FRAME	Ground Floor Column	31/10/09	07/10/09	21/10/09	$D^0 = D^f$ if $D^e > D^f$	completed	21/10/09	15	15	1.00	1.56	1.56
		Suspended Floor Beam	31/10/09	22/10/09	04/11/09	$D^0 = D^e$ If $D^s < D^e < D^f$	in progress	31/10/09	14	10	0.71	2.34	1.66
						W^a_n planed work progress in Cost- schedule percentage							17.11

Variance report of Actual Work Progress, Date, D^e = 31/10/09

i	Construction Task, i	Element Of Construction Task, j	K^f (number) From Schedule Matching Database	K^s_n (number) From site input	Ratio of Actual Completion (ratio) = $\frac{K^s_n}{K^f}$	E (%) From master schedule	E^s_n (%) = $\frac{K^s_n}{K^f}$ x E
1	PRELIMINARIES	Preliminaries	8	2	0.25	5.00	1.25
2	WORK BELOW LOWEST FLOOR FINISH	Pad footing	6	6	1	3.21	3.21
		Stump	6	6	1	1.28	1.28
		Ground Beam	7	7	1	1.93	1.93
		Floor Slab	2	2	1	6.42	6.42
3	FRAME	Ground Floor Column	6	3	0.5	1.56	0.78
		Suspended Floor Beam	7	0	0.00	2.34	0.00
			W^p_n actual work progress in				14.87
		Variance of Cost- schedule percentage (%)					-2.24

List of delay

- Ground Floor Column
- Suspended Floor Beam

Conclusion

EISMS is an executive information system able to provide managerial information for the Executive Management (EM) to digest quickly the situation of work progress at site. It is to improved the efficiency of on time monitoring and control of construction work progress at site and to enhance the. This paper presented EISMS requirement study process. In EISMS framework design details the KPI and important future in perspective of executive managers is implemented.

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