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# GEOGRAPHICAL INFORMATION SYSTEM (GIS) IN MALAYSIAN CONSTRUCTION INDUSTRY AND ITS APPLICATION TO PROJECT MANAGEMENT IN MANAGING CONSTRUCTION PROJECT – A LITERATURE REVIEW

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**Abstract**

Geographic information system (GIS) is a computer based tool and being used extensively to solve various engineering problems that involve the integration and analysis of large volumes of spatial and descriptive data from a variety of sources to which most of the project management software is lacking. In spite of the growing popularity, its complete potential to the construction industry has not been explored. The primary objectives of this paper are to describe GIS technology and explore potential construction applications that can benefit from the implementation of this technology. This research carried out study on the Geographical Information System (GIS) and its application to Project Management in Malaysian Construction Project. Practical considerations regarding GIS application to the construction industry are also addressed. This research is expected to investigate the views expressed by public and private sector clients, consultants and contractors which registered with their respective umbrella organizations in Malaysia. The descriptive survey method will be used, which comprised qualitative data gathering via pilot interviews and quantitative data gathering via structured questionnaires. Content analysis, multi-attribute analysis and rank correlation test will be used in the analysis of the data. The full paper will widely report the GIS application in project management for construction project and to define the benefit of GIS to the party involve in construction industry.

**Keywords:** Project Management; Construction project; Geographic information system (GIS).

## 1. Introduction

The new 'construction environment' so created is increasingly more complex and sophisticated, needing more advanced technologies to meet the organisational and operational demands of the day. In the past twenty-five years, construction technology has advanced deeper into the gamut of Information and Communication Technology (ICT), with innovations and developments that have far reaching implications for the construction industry (Ozumba and Shakantu, 2008).

Construction project in Malaysia is constantly in a period of change with developments in technology, systems and processes propelled by improvements in Informationand Communication Technology (ICT). This makes higher levels of sophistication within buildings and infrastructure facilities are possible (Hassan, 2005). According to Ozumba and Shakantu (2008), a lot of effort that has been put into developing ICT systems for construction activities and adapting innovations from other areas. Some of the technologies that have benefited construction include, Mobile Computing, Mobile Communications, Artificial Intelligence (AI), Automation and Robotics, Global Satellite Positioning System (GPS), Geographic Information System (GIS), Embedded Technology, Barcode Technology, Automatic-Identification systems (Auto-ID), RadioFrequency Identification systems (RFID), Four Dimensional-Computer Aided Design (4D-CAD) and graphics, Virtual Reality (VR), Augmented Reality (AR), Extranets and Intranets and etc., (Mair, 1999; Retik et al, 1999;Retik and Shapira, 1999; National Institute of Standards U.S., 1998; Flanagan et al, 2000; Jang and Skibniewski, 2007; RFID Centre, 2005; Wang et al, 2007).Therefore, there is a need for the construction industry to shift to a new paradigm in integrating this technology to its full benefits.

In Malaysia, Geographic Information System (GIS) application was started inDigital Cadastral Database (DCDB) and the National Topographic Database by the Department of Survey and Mapping in the mid-1980s with put into place the foundation for the development of GIS in the country. Various national and state initiatives were

undertaken in a concerted effort to harness the power of GIS for the better management of the environment, natural resources and for macro-economic planning (MalaysiaGIS.com).

Nowadays, many disciplines embraced the power of GIS in maximizing the use of spatial data to solve discipline specific problems that are traditionally solved by using conventional computing and manual methods. GIS has also penetrated into engineering practice and research to the point that many traditional civil engineering applications are applicable on GIS platforms (Venigalla and Casey, 2006)

## 2. Problem Statement

In construction industry the information required for planning and design are stored in different form, such as drawing, specifications, CPM and bar charts. The traditional approach for scheduling and progress control technique such as bar charts and the critical path method are still being used by the project managers for planning which a serious disadvantage for the decision making purpose.In planning process the project manager has to repetitively reorganize and interpret the information collected from various resources. This process is tedious and prone to errors (Cheng and Yang, 2001). There is pressure on the project managers to shorten the delivery times and the current scheduling and progress reporting practices are in need of substantial improvements in management (Vijay,Bansal& Pal, 2006).

The success or failure of a building contract largely depends on the quality and timing of the information available to the contractors from the database. Thus, construction industry require a system which should be capable of integrating various types of data and provide the required information and data timely that will finally support various decision making and construction operations. GIS is a new tool in information technology and can improve the construction planning and design efficiency by integrating locational and thematic information in a single environment. The capabilities of GIS to store large database can be utilized to keep construction data in digital form.With the advances in the field of information technologies, construction industry has started taking advantages of some of these developments (Bansal and Pal, 2005). In general, the full potential of GIS applications in managing construction project or civil engineering structure has not yet been realized(Venigalla and Casey, 2006).

## 3. Research Aim and Objectives

The aim of this research is to explore the potential construction applications that can benefit from the implementation of GIS technology. Specifically, the primary objectives of the research are as follows:

- to explore potential GIS applications to the construction industry
- to investigate practical considerations that must be taken into account to ensure a successful adaptation of GIS to construction in planning and scheduling of construction project.

## 4. Significant of Study

This research would be beneficial to all various construction professional involved in managing the construction activities to ensure the project objectives are met.

## 5. Literature Review

### *5.1.* ***The Nature of Construction Project***

In order to understand the scope of management within construction, it is important to review the nature of construction projects to provide the understanding of the setting within which management is performed. Lavender (1996) reckons,*" construction is a complex production of a one-of-a-kind product undertaken mainly at the delivery point by cooperation within a multi-skilled ad-hoc team."*Each construction project is unique irrespective of its nature, size and volume (Fryer and Fryer, 2004; Newcombe*et al*, 1993; Calvert *et al*, 1995). This is particularly in respect of different combinations of construction techniques, the knowledge and skills required to design and construct, and the varying patterns of relationships between organizations engaged to implement the project. Lee (2006) further stated that construction projects are inherently complex and dynamic, involving multiple feedback processes and nonlinear relationships. While problems encountered during construction are fundamentally dynamic, they have been treated statically within a partial view of a project. As a result, schedule delays and cost overruns are common in construction projects in spite of advances in construction equipment and management techniques. To

overcome these chronic symptoms, enormous efforts have been devoted to the planning and control aspects of construction management (Tan, 2005).

*5.1. Project Management*

The project management is applied to control and monitor the entire project lifecycle from inception until completion to ensure that the project is implemented according to plans and schedules and any deviations are corrected for timely completion, according to budget and to the right quality control in multifarious design and construction at site. The project manager controls all the resources at his disposal with its innumerable task and activities throughout the various phases and stages of the project to ensure overall project success (Tan, 2005).

Based on Oberlender (2000), the project management may be defined as, *"The art and science of coordinating people, equipment, materials, money, and schedules to complete a specified project on time and within approved cost."* Meanwhile, according to Project Management Institute (PMI), Project Management can be definesas, *"The art of directing and coordinating human and material resources throughout the life of a project by using modern management techniques to achieve predetermined objectives of scope, cost, time, quality and participant (stakeholder) satisfaction."*Fuller (1997) quotes that, *"Project management is a set of principles, methods, tools and techniques for the effective management of achieving objective oriented work."*

Project management has a strong tradition in the construction industry and widely used on projects of all sizes and complexity. Tan (2005) declares that Project management may be defined as the overall planning, co-ordination and control of a project from inception to completion aimed at meeting client's requirements in order to produce a functionally and financially viable project that will be completed on time within authorized cost to the required quality standard.

*5.3. GIS Technology*

GIS can be defined as "a system of hardware, software, people, organizations, and institutional arrangements for collecting, storing, analyzing, and disseminating information about areas of the earth" (Dueker and Kjerne 1989). According to Cheng and Yang (2001), GIS is a computer system for capturing, storing, make inquiries, analyzing and displaying data related to geography. It can be able to control and process geographic data and presents many different applications extensively.Cowen (1988) identified four important approaches: (1) Data base approach; (2) application approach; (3) toolbox approach; and (4) process oriented (or technological) approach (Jeljeli et al. 1993).

Geographic Information System (GIS) can be described as system-oriented information to geographic data with ground reference or a specific coordinate system. The actual definition varies GIS functionality such as databases, technology and decision makers. Burrough (1986) views that GIS is a set of tools that are able to collect, store, retrieve, modify and display data from real-world space. GIS is a system that is able to manipulate geographic data and be able to produce a map that can be connected to multiple elements.

Fig. 1 depicts the various modules of a GIS.According to Jeljeli et al. (1993), data input is the procedure that encompasses all aspects of transforming data captured in the form of existing maps, field observations, and sensors (including aerial photography, satellite imagery, Global Positioning System (GPS) receivers, and recording instruments into computer-readable form and writing the data to a GIS database (Burrough 1986).

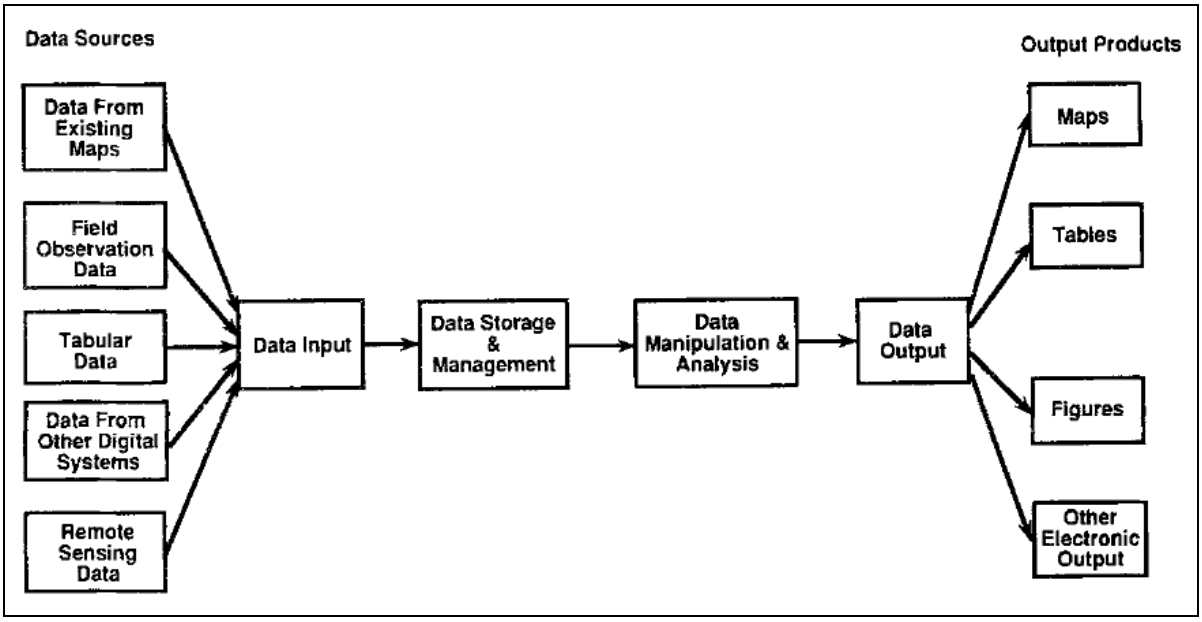


Figure 1: Principal Modules of Geographic Information System (GIS), Jeljeli et al. (1993)

Spatial data have four basic components that significantly differentiate them from any type of data: (1) Geographical positions; (2) descriptive attributes; (3) spatial relationships, i.e, topography; and (4) temporal relationships. The data storage and management module focuses on the manner in which data regarding these components are structured and organized. Among the types of data base structures that art recognized today, relational structures are commonly used to organize attribute information in GIS.

According to Adjei-Kumi, Retik and Shapira (1996), the GIS database can be divided into two types of data; graphics data (space) and non-graphical data (attributes). Spatial data should be managed in order to have a good technique for storing and accessing data. Spatial data is now stored and managed via a database management system (Database Management System - DBMS). DBMS is designed to store and manipulate data in large quantities. DBMS iscritical element before a variety of GIS application forspatial data analysis is to be done. The DBMS must be completed and arranged so that the result of accurate analysis and control can be achieved.

*5.5.Integrated GIS Application with Project Management*

According to Jeljeli et al. (1993), the need to share and integrate data among project participants in the various phases of the facility delivery process has been recognized by several researchers in the field (Fenves et al. 1988; Choi and Ibbs 1990; Reinschmidtet al. 1989; and Meyer 1991). The purpose of sharing data is attributed to two main factors which are to develop and reinforce a common description of the proposed facility, and to coordinate the efforts of various participants in the facility delivery process (Meyer 1991).

The traditional approach for scheduling and progress control techniques such as bar charts and the critical path method are still being used by the project managers for managing construction project. This approach evidently provide serious disadvantage for the decisionmaking purpose as the spatial aspects fail to provide the required information. There is pressure on the project managers to shorten the delivery times and thus the current scheduling and progress reporting practices are in need of substantial improvements in quality and efficiency (Cheng and Yang, 2001 and Bansal, 2005).

It should be seen that integration of GIS and Project management might assist a planner in a better perception of a project as well as in the integration of other parties' activities in the planning process. Furthermore, in large scale projects, a visual representation of the schedule can be extended to monitoring not only the construction process itself, but also all the auxiliary activities, including onsite plant and equipment. In addition, the practical and educational benefits of being able to visualize construction at a fine level of detail are significant. The application of geographic information system in project management is still new in Malaysian Construction industry. Therefore, this research will able to give benefits to people that directly responsible towards the management of construction

project. GIS will allow construction managers and different people involved in project with different backgrounds to get the information about the progress of the project and support decision making. GIS will provide a common basis of understanding and communication among all these people (Jeljeli et al., 1993).

Cheng and Chen (2000) developed an automated schedule monitoring system by using GIS to assist the construction managers to control the erection process for precast building construction. A case study is taken where structural elements were prefabricated in the manufacturing plant and transported to job site for installation. The schedules for prefabrication and transport of the structural elements to the job site are developed based on installation schedule. The study suggested that the use of GIS environment improves the real time schedule monitoring system and construction process as well improves the construction efficiency. The barcode system combined with wireless radio technology for identification of precast member is applied to collect and transmit the job site data to the control center automatically. Through a real time monitoring of the construction process the scheduled components for erection are repetitively tracked and well controlled to assure the lifting schedule is implemented as planned.

GIS does in fact create high quality maps that communicate considerable amounts of information in an efficient and attention getting manner. GIS is both a database system with specific capabilities for spatially referenced data, as well as a set of operations for working with the data. Visualizing construction progress in three dimensions provides the construction project manager with a more intuitive view of the construction sequence. 3-D visualization allows the construction manager to view the construction activities during any stage of the construction process (Oloufa and Espino, 1992 andJeljeli et al., 1993).Jeljeli et al. (1993) reckons that GIS can assist in theselection of proper equipment suitable for the working conditions at a constructionsiteduring the construction phase. Factors affecting the selection of a particular plants and equipment used are the soil characteristics, proximity to construction site, or weatherand temperature which possess spatial components. Different GIS techniques,such as classification, measurement, retrieval, proximity and overlay operations,can be used to assess the suitability of particular equipment to aconstruction site. Similar techniques can be employed to examine the suitabilityof a construction method for a particular project.

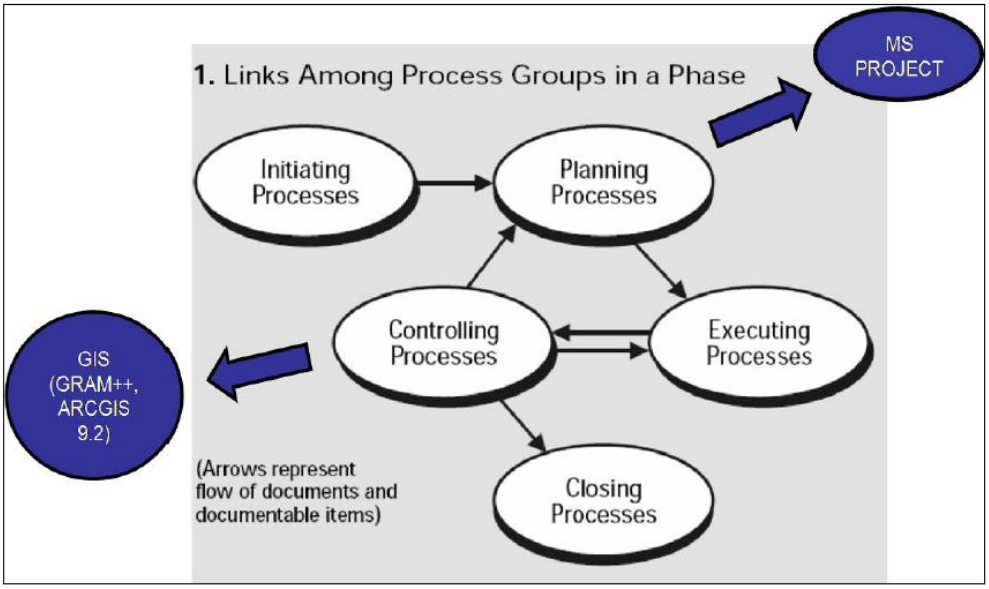


Fig.2: Links among Process Groups in a Phase and the various applications in the processes (Vijay, 2005)

Based on fig. 2 above show the Project management processes can be organized into five groups which are, (i) *Initiating processes*: recognizing that a project or phase should begin and committing to do so, (ii) *Planning processes*: devising and maintaining a workable scheme to accomplish the business need that the project was undertaken to address. (iii) *Executing processes*: coordinating people and other resources to carry out the plan. (iv) *Controlling processes:* ensuring that project objectives are met by monitoring and measuring progress and taking corrective action when necessary and (v) *Closing processes*: formalizing acceptance of the project or phase and bringing it to an end (Vijay, 2005).Jeljeli et al. (1993) define that several tools such as Primavera and Microsoft Project are used by the construction industry for scheduling purposes. The integration of these scheduling tools with

GIS may be difficult due to the requirement of coding within different programming environments. However, as the construction progresses, the network need to be updated frequently and the scheduling computations are carried out many times on the modified data, which is a time consuming process.Therefore, the proposed methodology uses GIS to carry out various scheduling computations in tabular form (Moder et al. 1983)

## 6. Research Methodology

The descriptive survey method would be used for the study, which the data needed are opinions of respondents that would be gathered using the technique of observation via pilot interviews and questionnaire surveys. Prior to the sending of questionnaire, pilot interviews would be conducted with a convenient sample of construction clients, professionals and contractors in Malaysia.

### *6.1 Data Gathering*

The method of data gathering would involve 3 stages:

- First stage

*Qualitative data gathering* where the constructs or recurring themes for questionnaire design would be obtained through pilot interviews with convenience samples of respondents drawn from the sampling frames.

- Second stage

*Quantitative data gathering* where the opinions of representative samples of the sampling frames would be obtained via questionnaire surveys which involving their ratings of the attributes of the identified constructs.

- Third stage

*Qualitative data gathering* where opinions of a convenience set of samples from the sampling frames would be obtained via semi-structured interviews.

## Conclusion

GIS is one of the fast emerging fields being utilized in various engineering projects whereas its complete potential to the construction industry has not been realized yet. GIS provides several benefits to the construction industry, in which most of the construction management software are lacking. GIS may improve the construction planning and design efficiency by the integration of spatial and attribute information in single environment. In Malaysia, this technology become more popular and its potentials is now being consider as potential advantage to improve the management of construction project.

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