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DECISION MAKING TOOLS FOR INFRASTRUCTURE PROJECT PLANNING

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ABSTRACT Nowadays, most of the infrastructure project developments undertaken are complex in nature, demanding greater skill and technologies, fast track work practices, good decision making and analytical skill, and capabilities to utilize Information Communication Technologies (ICT) specifically in planning phase. During this stage, a lot of vague alternatives were found from strategic to operational level. Therefore, it is desirable to find ways to enhance the efficiency of decision making to avoid such misunderstanding and conflict within organisation or group of people. Further, this paper discusses an overview and applicability of Decision Support System (DSS) tools particularly for project management planning. The main objective of DSS tools is to assist project stakeholders towards better and efficient decision making. Various DSS tools have been developed in the area of construction management in every project life cycle. However, most of the tools were found complicated or it is lack of usability and simplicity. These drawbacks will defeat the purpose of DSS which is to support decision making process. Thus, a framework of DSS environment is proposed to overcome previous shortcomings particularly for project management DSS applications.

Keywords: Infrastructure Project Planning, Decision Making, Decision Support System.

1. INTRODUCTION

Physical infrastructure has become a factor of growth for economies in many of developing countries. It plays an important role in the improvement of living standards and promoting regional cooperation and trade. Infrastructure projects such as of roads, highways, railways and bridges indirectly facilitate greater communication and enhance agricultural and industrial production. Non-residential, commercial structures and facilities play a role in boosting the region's tourism, entertainment, business, and cultural sectors.

As these projects are growing complex in nature and consume huge amount of construction capital and efficient coordination, therefore, the management and planning aspect of infrastructure project must be handled with a great care. Otherwise, those project will tend to be cost overruns and benefit shortfalls (Flyvbjerg, 2007). Research found that those problems were rooted as early as planning stage where there are too many alternatives and uncertainties were not entertained (Niekerk & Voogd, 1999).

Therefore, many researchers have attempted to solve these problems by using decision support system. However, most of the tools were complicated and lack of benefit and usability. Due to this situation, those tools were found only concentrated on model development and left the fundamental concept of computing. Hence, the objectives of this study are to discuss decision making concept and proposed tools that possibly be associated to infrastructure planning.

This paper starts with discussing the concept and problems of infrastructure planning followed by decision making concept and phases. Then, the paper elicits the tools to support decision making, recent trend in DSS and challenges of current DSS models. As a result, a proposed framework is presented to overcome current DSS defects within construction project management context.

2. INFRASTRUCTURE PROJECT PLANNING

Typically, infrastructure project planning is based on top-down approach where it is ranging from strategic to operational planning (Niekerk & Voogd, 1999). The term *strategic* is devoted to incorporate issues relating to long term planning while *operational* focuses on how to get tasks done. Initially, an earlier framework has been proposed by Grigg (1988) which modelled infrastructure planning to few stages and classification (see Figure 1).

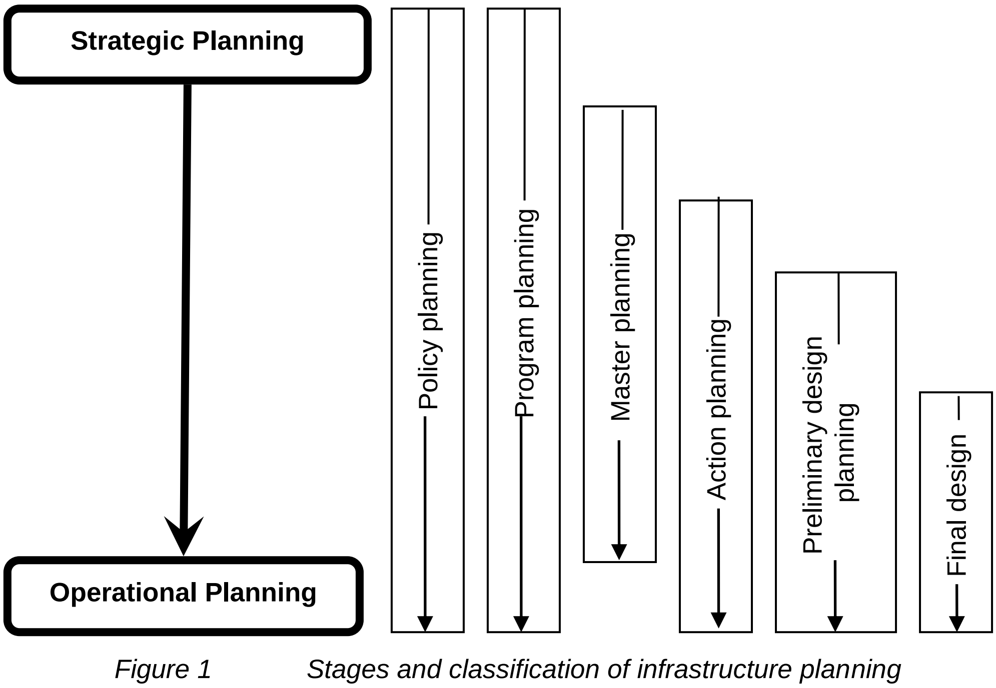

Figure 1 Stages and classification of infrastructure planning (adapted from Grigg (1988))

Heijden (1996) reported that most of the European countries experiences a rising complexities in infrastructures planning and it is difficult to manage. This is indicated by the trend of increasingly longer period of planning and decision making with respect to each projects. Some project may exceed up to ten years of planning stage due to several factors such as technical, financial, management bureaucracy, organisational affairs, culture, societal and political influences. Traditionally, projects were dominated by classical engineer results in a mono-disciplinary approach with a focus on the technical engineering issues such as physical aspect and its use (Perez & Ardaman, 1988). Thus, this approach had left the aspect of management and social evaluation.

Modern planning approach involved several multi-disciplinary stakeholders that may have different views and interests. Key participants at this stage may consist of land owner, clients, statutory bodies, developers, consultants, financiers, etc (Howes & Robinson, 2005). The variety of different stakeholders may impact to the group conflict due to different personal judgement. Hence, these trends increased the available alternatives and contribute to complexities of current decision making process in infrastructure project planning. For an instance, the past mistake was illustrated by the Dutch freight rail line project (Heijden, 1996). This is the result of a chaotic project planning which is not based on a broad societal consensus and many aspects of uncertainties had been ignored.

Later, a more refined problems related to infrastructure project planning and decision making had been studied by Niekerk & Voogd (1999). To inline with Grigg's model, these problems can be illustrated by referring the functional tasks ranging from strategic to operational level. Table 1 lists possible problems in decision making throughout planning stages. It can be seen that most of the problems concern on variety of alternatives and uncertainties.

Table 1 Problems related to infrastructure planning and decision making in strategic and operational level (Niekerk & Voogd, 1999)

Strategic Level	Operational Level
• Alternatives are often too broad an abstract. • Insufficient information about the effects of alternatives. • Insufficient information about the possibilities and effects of mitigating the flanking policies • It is difficult to generate direct feedback from public and politics	• Insufficient information and, hence, fundamental discussions about strategic issues. • Insufficient information about the possibilities and effects of mitigating and "flanking" policies. • Increase of uncertainty due to societal dynamics of plan-making process because of involvement of local politics and interest groups

Research shown that most of infrastructure projects around the world share the same characteristics in term of management aspects, shortcoming, cause of drawback and solutions (Flyvbjerg, 2005). Planning and decision making is often occur as a multi-actor processes with conflicting interest throughout project team. As a consequence, the communication and misinformation problems may arise among team member as the planning of infrastructure project will consume long time and efforts.

2.1 Decision Making for Infrastructure Planning

Decision making is a transparent process, where the contents of the problem determines the planning and design decision consequently (Heijden, 1996). These decisions should be fed up by content related information and knowledge. This is the task where team member should involve in brainstorming, collaboration and knowledge transfer process. Therefore, it is vital to understand the fundamental concept of decision making.

According to Simon (1977), there are three phase of decision making which consist of *intelligence*, *design*, and *choice*. Later he added *implementation* as a fourth phase. Turban, Aronson, & Liang (2005) recently adapted the four phase Simon's model by inserted the aspect of *monitoring*. The decision making process starts with the intelligence phase where the reality (real world situation) is examined and the problem is identified and defined. There is a continuous flow of activity from intelligence to design to choice, but at any phase there may be a return to a previous phase (feedback). Formulation and modelling is essential for this process.

The problems of too many alternatives and uncertainties in infrastructure planning can be precisely modelled by using traditional technique such as *decision-event* approach or a more advanced technique i.e. *system* or *decision support* (Schmidt & Freeland, 1992).

3. DECISION SUPPORT TOOLS

Based on the classical Grigg's model, a more recent framework has been introduced specifically focusing on policy-making process (Howes & Robinson, 2005). One of the most fundamental issues in the delivery of infrastructure concerns on what types of infrastructure are required and how they should be provided. The policy framework influenced the level of infrastructure provision and production and depends on policy objectives, the implementing institutions, levels and type of resources, knowledge, information and communication systems, and the environment (Howes & Robinson, 2005). This framework has shown that there is a need to adopt ICT as a driving force to enhance decision making within infrastructure planning. Therefore, it is desirable that most managerial decision can be assist by using Decision Support System (DSS).

DSS are computer programs that aid users in problem solving or decision-making environment. The system have detailed knowledge, data, models, algorithms, user interfaces, and control mechanisms to support a specific decision problem (Bhargava & Tettelbach, 1997). They are especially valuable in situations in which the amount of available information is prohibitive for the intuition of an unaided human decision maker. As a result, DSS are gaining an increased popularity in various domains, including business, military, medicine, engineering and built environment (S. Eom & Kim, 2006).

Furthermore, DSS can aid human cognitive deficiencies by integrating various sources of information, providing intelligent access to relevant knowledge, and aiding the process of structuring decisions. They can also support choice among well-defined alternatives and build on formal approaches, such as the methods of engineering economics, operations research, statistics, decision theory and computer science (Turban et al., 2005). They can also employ artificial intelligence methods to address heuristically problems that are intractable by formal techniques (S. B. Eom, 2000). Thus, proper application of decision-making tools increases productivity, efficiency, and effectiveness and gives many businesses a comparative advantage over their competitors.

3.1 Integrating Decision Technology with Infrastructure Planning

Much research has been conducted in the area of DSS, however only a few research considering DSS as planning tools specifically for infrastructure planning. Thus, this section will bridge the gap between the available decision technology concepts to management aspect of infrastructure planning. Based on the previous section on Grigg’s model, infrastructure planning comprises from strategic to operational level and DSS should support and maintain the existing management decision structure. As mentioned before, differences in project team will result to project conflict and communication problems. Hence, the following framework seems promising to adopt any infrastructure planning as tools by integrating DSS within current Information Systems (see Figure 2). In addition, this framework provides a proportional balance between conflict and communication as the decision type move from strategic to operational level.

Decision Type	Focus		Strategy
Strategic decision	Conflicts	Coordination	GDSS
Tactical decision			GDSS / DDM
Operational decision	Communications		DSS / DDM

GDSS : Group Decision Support System
DDM : Distributed Decision Making
DSS : Single User Decision Support System

Figure 2 Decision types, focus and strategy (H. B. Eom et al., 1990)

As mentioned before, infrastructure project planning teams involved various stakeholders that have different interest and objectives. GDSS is a type of DSS which can support group decision making and it is useful in strategic level. GDSS can be defined as an interactive computer based systems that facilitate the solution of semi-structured to unstructured problems by a set of decision makers working together as a group (Bohanec, 2001). They aid groups, especially group of managers, in analyzing problem situations and in performing group decision making task. In our context, GDSS is suitable to support group decision specifically in infrastructure project planning. Clearly, the above framework shows that GDSS has the capability to solve a lot of problems identified in Table 1. Furthermore, GDSS encompass all stand alone DSS's characteristic and this has been the major strength of GDSS as a tool to resolve conflicts within group of people.

3.2 Decision Support System for Construction Project Management

Recent advances in decision making technology have been spread into a wide and diverse area particularly in project management. A growing interest of DSS in construction project management has been identified as a promising and interesting research area. Much research has been conducted within project management life cycle phase including the initiation, planning, design and development, detailed design, contract and procurement, manufacture and construction, commissioning, and operation and maintenance (Harris & McCaffer, 2001).

From the late 1990s onwards, it is obvious that contribution of DSS applications in construction project management grows significantly. With faster hardware and advanced software, ICT has been used as a tool to support decision making in each project life cycle phase. Most of these researches have been applied in planning phase with different kind of application and DSS techniques. For an instance, Shen & Grivas (1996) attempted to deploy DSS for the preservation of civil infrastructure. The research was conducted to illustrate the database and knowledge base specification to assess the damage of pavement structure. Later, DSS application was spread to project planning area where building procurement (Kumaraswamy & Dissanayaka, 2001) and web-based for design build project selection (Molenaar & Songer, 2001) has been developed. Both of these researches employ knowledge base technology with some integration of AI techniques and statistics.

In recent years, DSS researchers in this area are moving forward to solve Multi-Criteria Decision Making (MCDM) problems. MCDM techniques such as Analytical Hierarchical Process (AHP) and Fuzzy Logic are the mostly used for qualitative based DSS particularly in contractor selection (Ibrahim et al., 2002), supplier selection (Kahraman et al., 2003) and equipment selection (Shapira & Goldenberg, 2005). Apart from that, there is also a DSS that has been implemented to evaluate concession project investment by using mathematical modelling and finance analysis (McCowan & Mohamed, 2002). Significantly, most DSS applications in these years have been develop in planning phase and moving towards qualitative modelling.

In addition to the currently prevailing quantitative modelling, simulation and optimization methods, qualitative methods will become increasingly important for exploring symbolic, qualitative aspects of the decision process: experience, intuition, judgment, and specialist expertise (Bohanec, 2001). This is important to minimize uncertainties and select the best alternatives as been investigated in previous section. Ideally, the new approaches would provide a seamless integration of qualitative and quantitative modelling. Hence, MCDM DSS is possible to be explored in construction project management area particularly in planning phase. The following table illustrates a list of DSS research in construction project management. Note that the table is not an exhaustive list of research in this area.

Table 2 Description of few DSS research in construction project management

Project Management Phase	DSS Technique	Research descriptions	Authors
Planning	Multiple Regression	A web-based DSS for Design/build project selection	(Molenaar & Songer, 2001)
Planning	Finance Analysis, Mathematical Modeling	Evaluation of concession project investment DSS	(McCowan & Mohamed, 2002)
Planning	AHP	DSS for contractor selection	(Ibrahim et al., 2002)
Planning	Fuzzy Logic, AHP	Group DSS for supplier selection	(Kahraman et al., 2003)
Planning	AHP	Selection of equipment for construction projects	(Shapira & Goldenberg, 2005)
Procurement	Knowledge-Base	Development of DSS for building project procurement	(Kumaraswamy & Dissanayaka, 2001)
Operation & Maintenance	Knowledge Graph	Preservation for civil infrastructure DSS	(Shen & Grivas, 1996)

3.3 Challenges for DSS in Infrastructure Planning

Much research on DSS in planning has been conducted to date (Ibrahim et al., 2002; Kahraman et al., 2003; Shapira & Goldenberg, 2005). Yet, most of the models were impractical as it is complicated and difficult for a layman such as project managers to use. It is desirable that those complexities in the models and be easily hidden by an advanced DSS which can offer simplicity, effective and efficient tools towards better decision making. Some research only concentrates on model development and discards few important computer science fundamentals i.e. software engineering, information management and human centred computing. There is also research that attempt to adopt computing essence in their model development (McCowan & Mohamed, 2002). However, it often imposed incorrect terms which led to wrong concept of software development modelling. As a result, most of the model and method were not being used or they have limited impact for real world decision making (Qijia et al., 2005).

Based from arguments in previous sections, from Grigg's, Howes & Robinson to H. B. Eom et al. models, we developed a framework which is desirable for a better DSS implementation in construction project management (see figure 3).

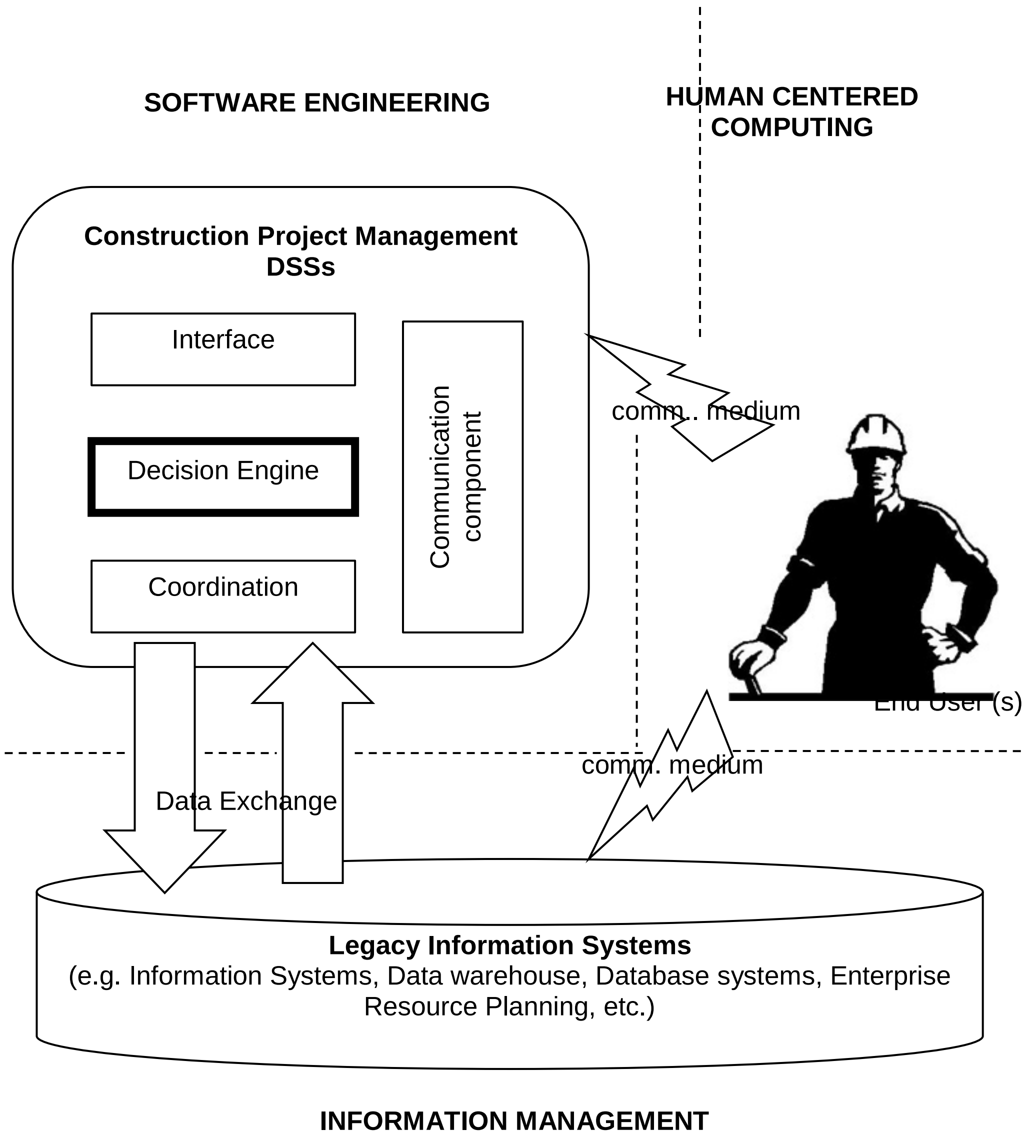

Figure 3 A desirable settings for construction project management's DSS implementation and its contributing computing fields

The above framework proposed three components dedicatedly for DSS implementation i.e. *interface*, *coordination* and *communication* components. Interface is important for software development as it can bridge and hide the complexity of decision engine, which may comprise decision method such as AHP, fuzzy logic or any artificial intelligence and operational research techniques. Continuing this idea, the interactivity of input/output process may enhance user perception and motivation to use the system. The main purpose of this module is to get acquired concise data and display the processed information back to the user.

In the mean time, the concept of coordination is also important as data may available extensively and need to retrieve, filter and manipulate from the existing databases or data warehouse. In other words, coordination is useful as a pre-processing or data preparation before reverts the clean data to decision engine.

If the DSS are targeting a group of end users, therefore, communication component is useful as it can support knowledge sharing and reduce the conflict within group indirectly. Communication may range from traditional distributed application to an advanced grid computing or from web based system to ubiquitous mobile applications. Similarly, the usage of communication medium varies and it depends on the type of communication component used. The medium might consist of distributed networks, internet, or wireless.

In spite of concentrating within the core of DSS components, the proposed system should also consider on how to integrate DSS with the existing Information System. Otherwise, DSS will stand alone and would not achieve its full capabilities with the rich and usefulness of databases in the legacy system. In addition, the legacy system needs to be updated with the knowledge created by DSS.

On the contrary, implemented system should no isolate the human factor of computing as it is the main objectives of DSS to support in decision making. Therefore, system usability should be emphasis as a part of DSS development. Usability will measure how good the delivered system can be used by end users. In brief, the proposed features as described in this section are essential to be considered for better DSS development particularly for construction project management. In other words, this model can be generally applied to all construction project management applications including infrastructure project management planning.

4. CONCLUSIONS AND FUTURE WORKS

Making decisions in a complex environment such as in infrastructure project planning often strains our human cognitive capabilities. Because in many situations ranging from strategic to operational level, the quality of decisions is important, aiding the deficiencies of human judgment and decision making has been a major focus in a modern infrastructure project. The variety of uncertainties and alternatives can be modelled and managed by using useful tools such as DSS. However, most of available DSSs in construction planning do not provide a good platform to produce better decision making due to complexities of decision models. As a result, a better framework of DSS implementation and environment is proposed. This will become our trigger for future research to conduct and construct an in depth DSS frameworks and its components specifically for selection problem. The expected result with a concise definition and framework implementation will sit in between software engineering and construction project management area.

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