A FRAMEWORK FOR STRATEGIC DECISION-MAKING BASED ON A HYBRID DECISION SUPPORT TOOLS

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SUMMARY: *The performance of a contracting company is closely linked with the quality of the decisions at the strategic level. However, the increasing complexity of organizations' internal and external environments and the unstructured nature of decisions at the strategic level make the decision making a very complicated task. The number of influential variables is so large and their effects are so varied that any attempt to encapsulate them in a rational manner can indeed hinder the decision making process. To this end, this research explores the advantages of decision support tools and the benefit these tools can yield for the strategic management. Some of these tools are deterministic and structured: they rely on straightforward calculation or optimisation techniques. The solution to the unstructured problems, however, has relied on heuristic approaches and judgement of the decision-maker. While deterministic problems have to a large extent been addressed and appropriate models and algorithm have been developed for them, the unstructured problems have remained relatively unattended and the research works in this area tend to focus on single issues. This paper conceptualizes an umbrella framework using a "Viable Systems Diagnosis" VSD Model and a "Decision Framework", within which strategic decision making research applicable to construction can be coordinated and developed, thus avoiding wasteful duplication and gaps in knowledge. To this end, the research highlights the relevance and potential use of artificial intelligent techniques in assisting the managers with unstructured decisions. Further, it is argued that a strategic decision support system should assume an integrated structure, as many decision nodes, within the overall decision making structure, share common attributes and the inter-connection amongst these decision nodes has a complex structure. Therefore, the object oriented approach will provide an efficient structure for the development of the overall framework.*

KEYWORDS*: executive management, artificial intelligence, building, decision support tools, executive information system, management decision structure, artificial neural network.*

1. INTRODUCTION

Construction contracting is a high risk, dynamic and complex business, which is subject to a high level of uncertainty and features an industry that is fragmented and very susceptible to environmental influences. Typically a construction company survives on its ability to attract a sufficient number of profitable contracts that provide sufficient turnover to adequately cover the cost of fixed overheads.

Typically, construction companies survive by clients taking most of the risk. More recently the growing popularity of design and build and other more sophisticated forms of construction procurement has required construction companies to take more risk. Increasing emphasis on PFI projects by the public sector has also placed more responsibility and risk on contractors. The outcome of these developments is the importance of implementing the correct corporate strategies and exerting tight control in the achievement of performance benchmarks and profit objectives.

Contractors who take responsibility for design, construction and post occupation performance of built facilities require to be in possession of, or have access to sufficient capital to finance a portfolio of projects. Furthermore, contract responsibilities and obligations are increased with a commensurate level of risk. Reputation, credit worthiness and a track record of delivery are key factors in the ability to enter this type of business. Competent corporate policy and decision making are therefore vital to business success and profitability. Top level decision making must take into account the degree of dynamic change associate with the process, developments in technology and the influence of business factors such as globalisation. The scope for correct decisions based on experience and acumen of individuals has been degraded by the complexity of the business environment and the dynamics of change. It is therefore necessary to adopt a more reliable approach to decision making where more factors and circumstances can be considered in the light of what is already known from a multitude of sources, including retained corporate knowledge of the business.

It may be argued that the construction industry as a whole has been too preoccupied with the outcome of individual projects, which collectively produce corporate outcomes resulting in business success or failure. Hence the general level of corporate management is subsumed by the need to create as many individual project successes by whatever means are available. This approach has been shown to create adversarial practices and fragmentation within construction. Various studies of the construction industry in the UK have promoted the needs of the client as paramount, supported by teamwork, partnering and supply chain management (Egan 1998).

Major clients are insisting that contractors take more responsibility and share the risk associated with the delivery of construction projects and this has placed pressure on the need to develop robust corporate strategies supported by sound and well thought out decision making (Withycombe, 1996).

Reference to literature reveals the development of theoretical body of knowledge relating to both decision structure of corporate management and the use of decision support tools. There have been many works defining the structure of corporate management and the related decisions (Skitmore et al., 1992, Hick, 1990, and Langford and Male, 2002). There has also been significant work in the understanding of systematic approaches to corporate business management and decision making Ansoff & McDonnell (1990). Theories associated with organisation analysis (Jackson and Flood (1988) have been linked to systems theory. Initial work was undertaken by Checkland (1981) and Beer (1985) where systemic models were created to assist the understanding and analysis by relating the business world with the systems world. In this manner new methodologies can be development to improve business efficiency and performance. This work was further developed by Jackson and Flood (1991) and Fay & Yepes (2003) with the adoption of cybernetic principles associated with the notion of "Viable Systems Diagnosis" (VSD) leading to the development of a total systems model. There have also been many attempts to apply AI techniques to various aspects of management decision making (Moselhi et al., 1991).

This paper recognises the complexity of decision making at all levels of organisations' management and that the making of each decision is reliant on input from various other decisions at various levels. To this end, the paper proposes a framework that reflects the interrelations and interdependencies of decisions at strategic, tactical and operational levels, as well as incorporating inter-organisational variables and those external to the organisation.

2. STRATEGIC MANAGEMENT DECISION MAKING

Modern organisations operate in an increasingly complex environment and the magnitude of the consequences of decisions at the strategic level demands high quality responses from the management. The ever-changing and turbulent internal and external environments of the organisation demands extreme sensitivity from the management in their reactions towards change. This often requires rapid response and the consequence of one course of action could be dramatically different from an alternative course of action.

Strategic decisions are a reflection of the attitude, values and expectations of the decision-makers at the top level. They have a long term effect on the direction and future activity of the organisation, and have resource implications, affecting decisions at the lower levels and initiating a wave of other, often lesser decisions (Hickson et al. 1986).

The uncertainties and complexities of strategic decisions direct the decision makers to reduce the infinitely large problem into a manageable one. This conversion to a manageable model of reality inherently involves a great number of assumptions, many of which, rely on the judgement of the decision maker. But the scale of the complexity and variety of variables surrounding the decision is such that some of the assumptions are ill-defined and possibly wrong. To combat these problems the managers categorise the uncertain decisions into a number of criteria: Laplace, insufficient reason to believe otherwise; Minimax, making the best out of worst possible conditions; Maximax, the best out of the best alternatives; Savage, the best of the regrets for not taking the right actions; and Hurwicz, giving a range of attitudes from optimistic to most pessimistic (Turban 1993). The choice of the approach is linked to decision-maker's conservatism.

The strategic decisions such as expansion, consolidation, diversification, revision, etc., require an extensive analysis of numerous issues independently and in combination. The industry has been somewhat conservative, resisting to explore and exploit a range of available techniques and apply them at higher decision making levels. This is partly due to management's reluctance to recognise the need for scientific management. Also, there is a lack of appreciation as to the extent to which the application of management science can be useful. This often leads to a poor allocation of resources to areas of management science, hence, the technical capabilities to implement the science does not develop adequately. Where applied, the management science techniques are poorly located within the organisation. Their use is often scattered and undefined rather than being integrated as part of organisation's structure and culture. Indeed, there have been formidable forces of opposition to the management science activity within many organisations (Forgionne, 1983).

3. DECISION SUPPORT TOOLS

Management decision making is considered as an art because it is dependent on the experience, intuition and creativity of the decision maker. The successful solution of a single problem can be achieved by a variety of approaches. However, the complex nature of today's managerial decisions, at the executive level, demands high quality information and the use of scientific decision making tools. These tools exist in various forms each suitable for a particular type of problem.

The scientific revolution of early 1900, introduced by F. W. Taylor, took a major turning during the 2nd World War. Since then there have been further advancements in the modern tools of decision making. Such techniques can be broadly categorized under the heading of "Operational Research" and include typically linear programming, network analysis, dynamic programming and queuing theory. However, in general, the contracting organisations do not seem to take full advantage of the modern scientific techniques. Studies by Shannon et al (1980), Morgan (1989) and Anderson et al (1994) suggest that only a handful of techniques are being used. More importantly, the techniques are often used in isolation rather than in an integrated manner because they typically provide specific solutions where the variables are known. Whereas, an integrated approach to the use of various decision tools will prove to be more flexible and powerful: the enhanced capabilities of individual models will complement each other, hence, the capability of the whole will be greater than the summation of its individual components.

Also, the development of management science was paralleled with the advancements in computer-based information management systems. These fields of management support merged during 70's to form the Decision Support Systems - better known as "Interactive Computer-based Systems". In order to provide support for complex decisions and to enable managers to exercise control over their decisions, fields such as Decision Support Systems (DSS), Group Decision Support Systems (GDSS) and Executive Information Systems (EIS) were develop. To this end, various techniques have been developed and exploited.

4. ARTIFICIAL INTELLIGENT TECHNIQUES

The concepts surrounding AI emerged in the 1950's, resulting in the development of many techniques, which ranged from addressing basic human logic reasoning to replication of humans' neural system and genetic inheritance. The streams of artificial intelligence include expert system, natural language processing & semantic modelling, robotics & planning, intelligent computer-aided instruction, and machine learning consisting of neural computing, genetic algorithm, case-based reasoning, inductive learning, and explanation-based learning. These techniques have complementary characteristics with their individual strengths and weaknesses.

Artificial intelligence (AI) is a science associated with intelligent software programs or machines that are capable of making inferences and solve problems in much the same way as humans do (Minsky, 1968). It relates to the part of computer science that focuses on designing intelligent computer systems that are similar to what is recognised as intelligence in human behaviour (Barr and Feigenbaum, 1981). AI aims to study mental faculties through the use of computational models (Charniak and McDermott, 1985). In doing so, AI attempts to make machines smarter, understand what intelligent is and make machines more useful. In simple terms, AI is about the study of the thought process of humans and representing them via machines. In some ways they advance over natural intelligence: their ability to sustain operation; ease of duplication and dissemination, and consistency. The primary advantage of AI techniques is their ability to deal with non-deterministic situations where a given problem is likely to have several possible outcomes. Further, AI is capable of doing this without the need for the expert to be present. These characteristics make AI highly relevant to management decision making, particularly at the strategic level, where the decisions are extremely uncertain and far from being deterministic: in the absence of the expert, management decisions could be replicated, thus offering cost effective and time saving solutions. They have the ability to deal with problems where an algorithm or procedural problem solving approach can not be adopted. It has the ability to exploit the range of knowledge needed to emulate intelligent behaviour and exercise a problem solving process Again, this is very similar to the characteristics of many management decision makings at the strategic level, where the processing primarily involves reasoning and intelligence rather than computing and algorithm; the input components are often incomplete and made of knowledge rather than just data; the search methods are usually heuristic; and the outcome is probabilistic and incomplete..

AI is a science and as well as a technology. To develop machines or systems that exhibit intelligent involves many sciences and technologies (eg. linguistics, psychology, philosophy, computing hardware and software, mechanics, optics, etc.). AI provides scientific foundation for several growing commercial technologies. Examples of interaction include those with Psychology leading to cognition and psycholinguistics; electrical engineering leading to image processing, control theory, pattern recognition and robotics; philosophy leading to logic, philosophy of language and philosophy of mind. Other Intersections include computational linguistics, psycholinguistics and sociolinguistics. Relevance to management notably includes management theories (e.g. decision making, implementation), statistics, mathematics, management science (heuristic programming and cost-effectiveness), and management information systems (MIS).

The main areas of AI include knowledge-based systems (KBS), expert systems, computer vision and scene recognition, and intelligent computer-aided instruction. In the current work, the choice of the AI methods is primarily determined by the characteristics of each management decision node within the overall decision structure. Expert systems offer computerised advisory programs that attempt to imitate the reasoning processes and knowledge of experts in solving specific types of problems. These are very popular for where experts are difficult to find and retain. They have the potential to enhance productivity and to augment decision making capabilities. A gradual shift towards highly specialised programs encoding narrow areas of expert knowledge gave rise to the concept of KBS. There are three distinct components to KBS; the knowledge-base which ccontains information about the domain (factual knowledge, heuristics/rules of thumb and control strategies); the inference engine which forms the heart of the knowledge base system applying logical inference through backward chaining (where the conclusion is given and the conditions are checked) or forward chaining (starting at the condition and working towards the conclusion); and finally, the user interface, facilitating the means of communication between the user and the knowledge-based system.

Despite their success and applications in several areas, KBS tend to suffer form what is known as *knowledge elicitation bottleneck.* (e.g. Ahmad and Minkarah, 1990 and Brandon, 1990). There have been attempts to resolve problems such as those by (Watson et al., 1992a, 1992b), though, solution shave been fund in various forms. One such solution is the case-based reasoning (CBR), where expert rules are replaced by those from examples of similar historical situations. Examples of early applications of CBR include CYRUS (Kolodner, 1984), JUDGE (Bain, 1986), COACH (Collins, 1987) and CHEF (Hammond, 1989). As far as decision making is concerned, CBR offers a tangible way of modelling, as it tends to operate on a more logical way of problem solving which is closer to the way the mind works. Furthermore, it relates to cases that have already existed rather than expert KBS where on every attempt the problem is initiated form the scratch (Kolodner, 1992, and Kolodner and Mark, 1992).

Due to the scale of the problem and diversity of decision types, the research will rely on the use of several AI techniques. However, it is envisaged that those techniques associated with biological analogy have grater potential of use within the domain of this work, as these techniques form the basis of thinking and intelligent behaviour. In particular, the work will benefit form the use of the artificial neural network technique. This is an intelligent system which is capable of modifying its internal structure to improve its performance. In a pragmatic manner, the system works towards a solution. The output is elaborated by the ability of the system to learn from the past and recurring experiences in much the same manner as the neural system within human body. As far as the construction industry is concerned, the advancement in this area has been rather slow. As a complementary method, genetic algorithm (GA) is a type of learning algorithm which learns through trial and error, hence, search methods aim to find optimum solutions in a random, yet directed, manner. GA adopts mechanisms of natural selection and genetics. It is a rule-based system, where each rule has a certain associated probability. At each cycle those rules which meet a condition are collected. Rules are fired (by random/chance) and those with higher probability are fired more often, until such time that certain rules always fire.

5. RESEARCH AIM AND OBJECTIVES

The proposed research will build on the outcome of all previous works. However, the novelty of the research rests on the identification of the decision structure of a contracting organisation moulded into an object-based structure, and determination of the attributes of the comprising decision nodes (objects).

The research is founded on a holistic and fully integrated VSD Model that provides a generic strategic system based structure capable of adaptation to specific corporate requirements. Within the VSD Model will be a Decision Framework with an integrated decision support system. The proposed decision support system, which for a given situation, assists the management at the executive level to make more effective strategic decisions. The outcome of the work can be utilised by corporate managers to enhance their abilities rather than replace their judgmental input. Therefore, it will be a tool for the decision makers to improve the quality of their decisions by complementing their intellect. Since, corporate decisions rely on information and decision from other levels of the organisation, the final product will also be a decision support tool for management at other levels.

6. CONCEPT OF THE VSD MODEL

Decision-making at the strategic level affects the whole organisation (as well as its external environment), hence, it encompasses, in one form or another, all functional and operational activity and decisions within the organisation. Instead of focusing on a specific area, perhaps in isolation from the rest of the organisation, as maybe the case for functional problems, the strategic decisions require an integrated approach to managing the organisation. Therefore, in order to enhance the efficiency of the organisation, decision making is structured in such a way as to cross the operational and functional boundaries and serve the strategic goals of the organisation. Also, the decision-makers are made aware of the links between their decisions and company's strategic goals.

Decision making relies heavily on the availability of relevant information in the right format and at the right time. The decisions at the higher levels encompass all the information generated by the activity within the organisation and the external factors such as the economy, competitors and the politics. Despite today's complex nature of decision structure of companies, the importance of the need for an integrated decision support system has not received adequate attention. By its nature, the object oriented approach facilitates integration while yielding a high level of flexibility which is required to accommodate these complexities

By taking a view involving the adoption of cybernetic principles associated with the notion of 'viable systems diagnosis' (VSD) it is possible to develop a model comprising of subsystems that define an organisation as a total system and provide it with identity (Beer, 1985 and Jackson and Flood, 1991). By adopting the principle of recursion the whole system is replicated in its parts so that the same viable system principles apply throughout. Furthermore, operational subsystems are integrated and controlled through a higher level of management subsystems, taking into account influences from the environment. This effectively identifies strategic management and corporate decision making and clearly defines the relationship and links with operational subsystems and the control thereof. Emphasis is also placed on learning from experience and dynamic change with a view to creation of new knowledge and skills to effect continuous improvement. This places importance on the need for intelligence gathering, auditing and feedback.

Building on the work of Jackson and Flood (1991) and Fay and Yepes (2003) a 'viable systems' model is proposed for the purpose of addressing the need for a structural system to support and promote sustainable business infrastructure. Using this approach gaps and weaknesses can be exposed and the robust nature of the total system can be judged when exposed to trend scenarios and unexpected events.
Figure 1. illustrates a 'viable systems' model that identifies institutional/organisational subsystems located in an operational domain (Howes and Robinson, 2005). Each subsystem will be managed and controlled according to the traditional system concept of input-transformation-output that is subjected to influences from total and local environments. The model provides four high level corporate functions acting as subsystems that form a meta system responsible for oversight, regulation, coordination and direction. The meta system provides high level thinking resulting from gathering intelligence from the total environment and audit reporting on the performance of the operation subsystems, both individually and collectively. Information collected is analysed and evaluated to establish what actions should be taken and to initiate learning processes where the body of corporate knowledge is enhanced. The outcome of this process may result in policy changes at both the meta level and operational levels to effect improvement as part of a continuing process of enhancement.

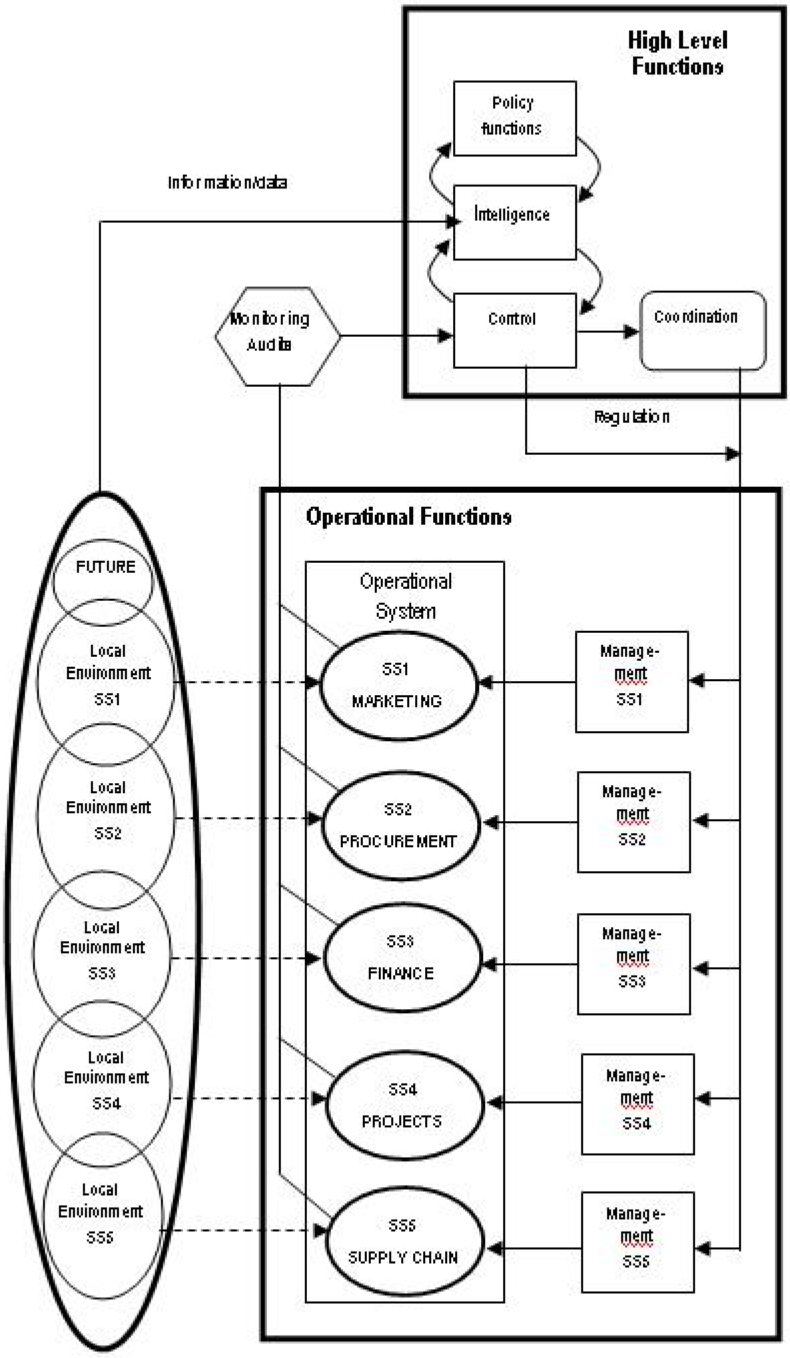

FIG. 1: VSD Model for Strategic & Operational Management

7. THE DECISION FRAMEWORK

The decision framework must be encapsulated within the VSD model. At the top level will be an intelligent Executive Decision System in support of strategic management decision making. The structure of the later will be object oriented making use of a hybrid of decision support tools.

The development process involves identification of the totality of the structure of management decision framework at the enterprise level as shown in Figure 2. It also requires identification and definition of all decision nodes (objects) at strategic, mid-management and operational levels. The construction of the overall model of the executive information support system will require development of individual object models.

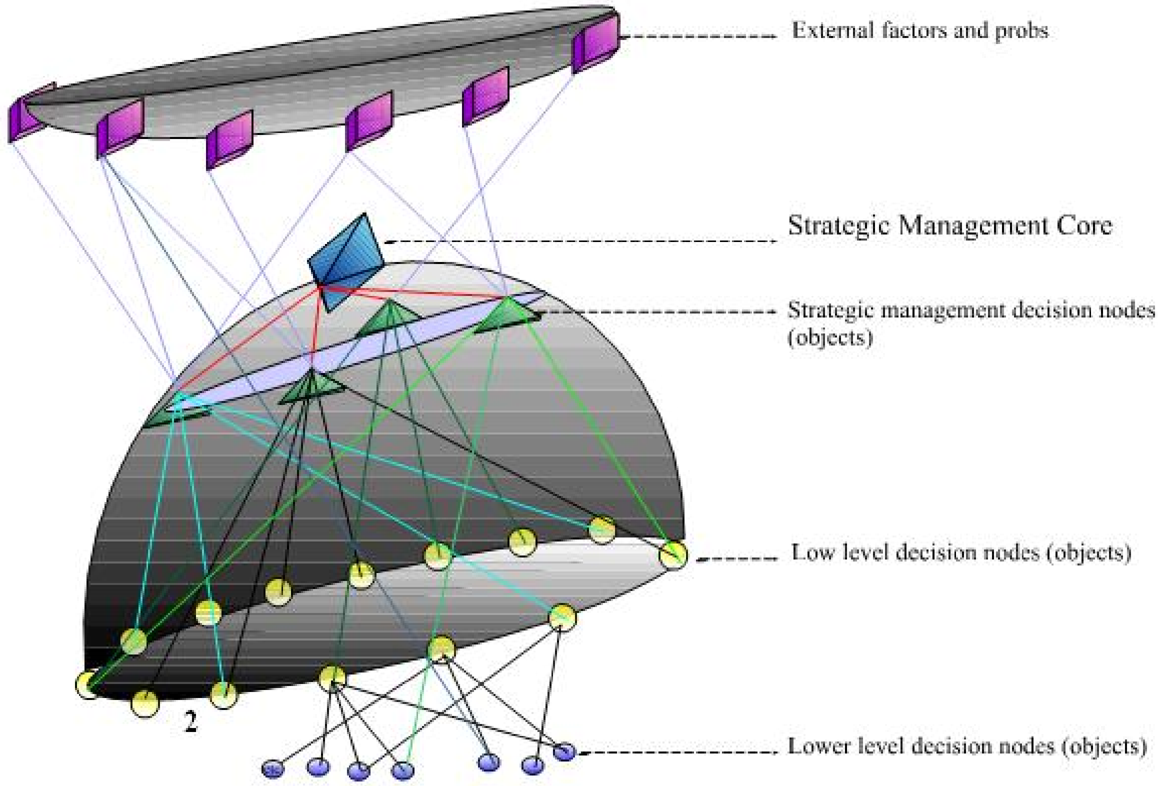

FIG. 2: Strategic Management Decision Structure

The research is carried out in two phases in a more or less sequential manner. Phase one consists of development of the structure of management and the establishment of an associated decision making framework. Appropriate decision making tools will be identified for each type of decision. Phase one is the product of marriage of two separate investigations which are carried out in parallel. Initially, as in traditional hierarchical structure, the decisions at the executive level are identified. Once the Decision framework is established and the support tools are identified, phase 2 will commence with the development of systems underlying database. Ideally, the proposed database will grow to encompass all aspects of management decision making. However, integrated databases are best suitable for definable environments such as projects (see Tanyer and Aouad 2004). Whereas, for the subject of this research, in view of the diversity of decision nodes, it is necessary that the structure must be flexible to allow inputs from distributed objects.

The AI decision support techniques will play a central role in manipulating data relevant to the to the nature of decision nodes and the generation of intelligent decisions and solutions. As the database generates new knowledge continuous improvement will be achieved resulting in greater efficiency and less waste.
As shown in Figure 3, in order to make strategic decisions, management requires certain information and knowledge some of which are external and others are organisation-related (here each decision is referred to as a decision node). The strategic decisions are allocated in the first instance to functional decision nodes representing the primary subsystems of the organisation, each with a specific set of decision attributes. These are then broken down into lower level decision nodes with associated attributes. The lines connecting the objects represent influence and effects in either direction. Many decisions at the strategic level are envisaged to share one or more decision nodes. These decision nodes form the components of the objects of the overall structure. The nature of each decision node is determined by its attributes that are in turn influenced by the information available from the corporate database and the external environment.

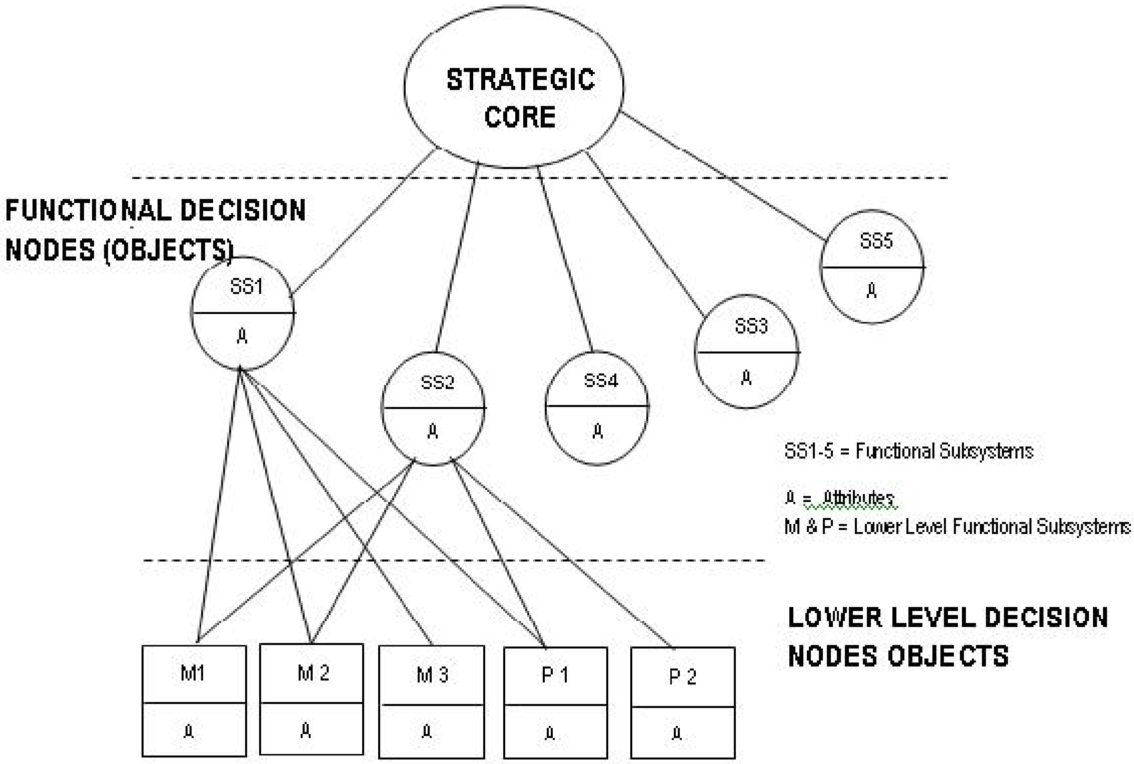

FIG. 3: Structure of Decision Nodes and Influences

Figure 4 demonstrates the interrelations and interconnections of objects through functions. Also, objects obtain information via 'probes'. The final output can assume a yes/no or it can produce a fuzzy output with a chance of occurrence. The outputs also generate a risk analysis associated with the relevant decision.

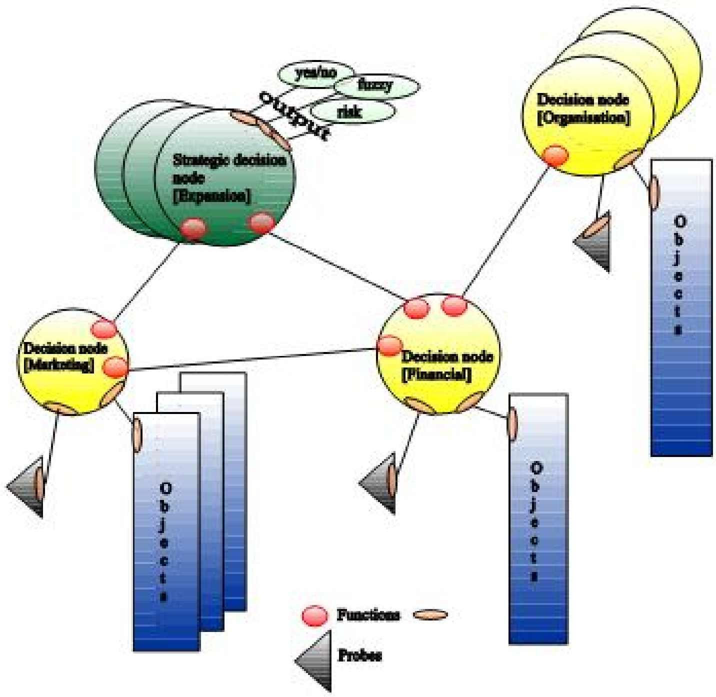

FIG. 4: Example of structure of object-based decision

The outcome of this section is the development of the structure of management decisions. Parallel with this development will be an investigation to identify the variety of available decision support tools. The analysis will commence by categorising the support tools (methods) according to whether they are classified as operational research, statistical/financial or founded on artificial intelligence concepts as shown in Figure 5. It is argued that the overall system will benefit from all types of decision tools, thus lending itself to a hybrid form of decision system.

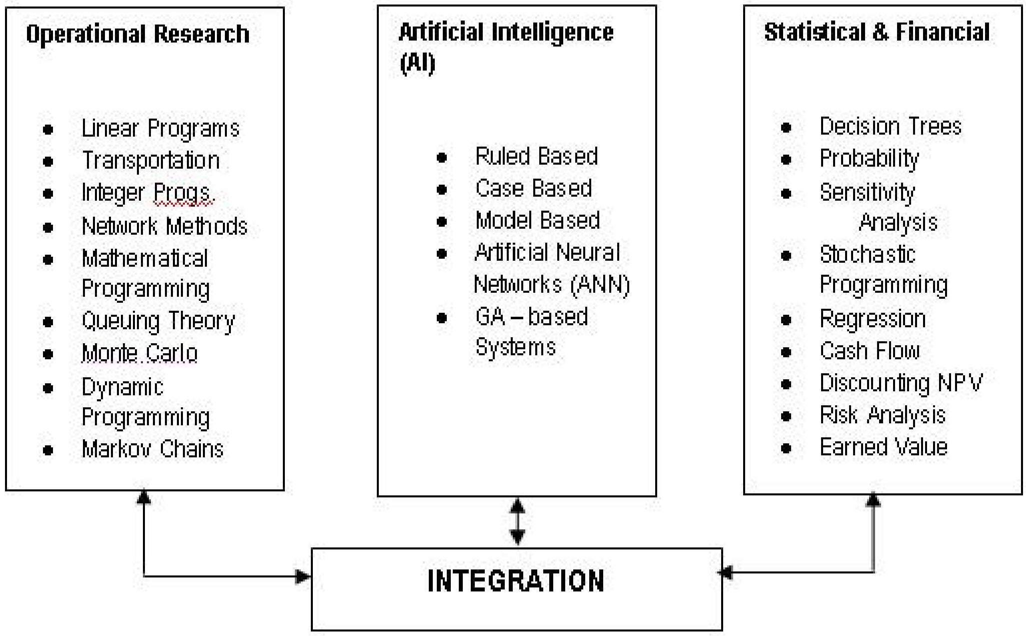

FIG. 5: Categorisation and Integration of Decision Support Tools

8. CRITERIA FOR MAPPING DECISION TOOL TO DECISION NODES

The identification of the variety of decision tools will pave the way for their adoption within the proposed system. However, in order for decision tools to be mapped to each decision node, there must be a set of criteria to which both the tools and nodes can relate. Therefore, in the next stage, the support tools are defined in terms of their *attributes* and their *characteristics*. While the *attributes* are associated with the inherent nature of each decision tool the *characteristics* provide a more descriptive account of each method which will help to simplify the selection of the relevant tool for each decision node.

The attributes are differentiated with respect to deductive consequences, time dimension, degree of uncertainty, dynamism in run-time, development practicality, need for user intervention and data requirement. In Table 1, these attributes are cross-referenced against a popular list of decision tools.

TABLE 1: Categorisation of the models based on their attributes

Model Attributes	Linear Programming	Transportation Linear Programming	Integer Programming	Network Methods	Calculus	Queuing Theory	Monte Carlo Simulation	Dynamic Programming	Markov Chains	Decision Tree	Stochastic Programming	Regression	Rule-based Systems	Case-based Systems	Model-based Systems	Artificial Neural Networks	GA-based Systems	Fuzzy ANNs
Deductive consequences																		
Normative	✓	✓	✓	✓	✓			✓		✓	✓	✓			✓	✓	✓	✓
Descrpitive				✓	✓	✓	✓		✓				✓	✓	✓	✓		✓
Time dimension																		
Static	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓		✓	✓	✓	✓	✓	✓
Dynamic	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Degree of uncertainty																		
Deterministic	✓	✓	✓	✓	✓			✓					✓	✓	✓			
Stochastic				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Dynamism in run-time																		
Static	✓	✓	✓	✓	✓	✓				✓						✓		✓
Dynamic							✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓
Self dynamic																✓	✓	✓
Development practicality																		
Low	✓	✓	✓		✓	✓	✓	✓		✓	✓	✓	✓	✓	✓			
High				✓	✓				✓							✓	✓	✓
Need to user intervention																		
Design time	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓
Runtime																✓	✓	✓
Data requirement for model justification																		
None	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓			
Data required														✓		✓	✓	✓

On the other hand, the model characteristics focus on another set of variables that are used to determine the suitability of each decision tool for each decision node. These characteristics consist of processing procedure, decision alternatives, solution quality, required information and application. In Table 2, the characteristics of each decision tool are identified.

TABLE 2: Model categorisation based on their characteristics

Model Characteristic	Linear Programming	Transportation Linear Programming	Integer Programming	Network Methods	Calculus	Queuing Theory	Monte Carlo Simulation	Dynamic Programming	Markov Chains	Decision Tree	Stochastic Programming	Regression	Rule-based Systems	Case-based Systems	Model-based Systems	Artificial Neural Networks	GA-based Systems	Fuzzy ANNs
Procedures																		
Single pass					✓								✓	✓	✓			
Iterative	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓				✓	✓	✓
Decision alternatives																		
Continuous	✓				✓						✓		✓					
Discrete		✓	✓	✓		✓	✓	✓	✓	✓		✓		✓	✓	✓	✓	✓
Solution quality																		
Optimal	✓	✓	✓	✓	✓			✓		✓	✓	✓		✓		✓	✓	
Satisfactory				✓		✓	✓		✓				✓	✓	✓	✓		✓
Required information for justification																		
Model parameters definition	✓	✓	✓		✓			✓	✓		✓		✓	✓				
Supportive data				✓		✓	✓				✓	✓		✓		✓	✓	✓
Knowledge				✓	✓		✓		✓	✓		✓	✓	✓	✓			
Application																		
Analysis	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓					✓	
Optimisation	✓	✓	✓			✓	✓	✓	✓		✓		✓	✓			✓	✓
Decision support	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓		✓		✓	✓	✓	✓
Instruction				✓	✓					✓			✓					
Diagnosis				✓					✓			✓	✓		✓			
Planning			✓				✓			✓			✓	✓		✓		✓
Interpretation						✓				✓		✓	✓					
Monitoring					✓				✓						✓	✓		✓
Control				✓	✓									✓		✓	✓	✓

Although, it is intended to exploit deterministic decision tools to their full potential, it is anticipated that, due to the nature of management decisions particularly at the executive level, the use of AI techniques will be significant. To this end, Table 3 will provide further insight into the nature and relevance of a number of AI techniques. It is envisaged that the artificial neural network will be most useful due to its self-learning ability and the extended ability due to the introduction of the 'learn-on-demand' methodology (Namatollahi and Khosrowshahi 1998) which enables it to cope with the ever- changing nature of the problem, and situations where relevant data are lacking in number.

TABLE 3: Comparison of Artificial Intelligence techniques.

	Rule-based Systems	**Case-based Systems**	**Model-based Systems**	**ANNs**	**GA-based Systems**
Difficult at knowledge Acquisition	High	Medium	Medium	Low	Low
Required data	Generalised knowledge	Cases	Designated models	Examples	Examples
Explanation Capacity	Excellent	Good	Good	Poor	Poor
Difficult at development	Low	Medium	Medium	High	Medium
Appropriate application domains	Instruction, diagnosis, planning, interpretation, management	Planning, management	Diagnosis, monitoring, control	Cost-estimation, forecasting, prediction	Optimisation, forecasting

9. FURTHER DEVELOPMENT

The product of phase one will be a framework model for management decision making at the strategic level based on the use of a hybrid of decision support tools. This comprises an integrated network of, sometimes interrelated, decisions at the strategic and tactical management levels.

Having identified the most appropriate decision tools for the decision nodes in phase I, working models will be developed for the decisions at the strategic level. This phase of the research relies significantly on the availability and access to relevant data. These include the independent data entities and the information contained in form of knowledge base of various applications.

The final model will consist of integration of individual decision models and these models will be placed in their context within the overall framework. This integration is inherent within the structure of the object-based model: following a strategic decision, a series of related decision nodes (objects) will be automatically fired to and each rattled object will in turn trigger a series of related objects.

This process relies on the development of an appropriate object design platform supported by an appropriate repository that combines the benefits of both relational and object oriented databases. To this end, the AI core of functions needs to be acquired or developed and then supported by an appropriate interface.

Finally, at this stage the adaptability of the framework, over time, will be investigated. The framework and its constituent models should have the flexibility to promptly adapt to the changing conditions. This consists of the ability to rearrange, add, delete, combine or change the constituent elements of the system. This is secured by the flexibility offered by using distributed object technology. This approach will also have the advantage of utilising (reusing) the existing models rather than having to generate new models. These include several models such as those for mark-up calculation (Moselhi et al 1993), bankruptcy evaluation (Khosrowshahi and Taha 1993), cash flow forecasting (Khosrowshahi 1991), planning (Al Shawi et al 1990), MASON masonry estimating system by Hendrickson et al., (1987), ESCHEDULER by Moselhi and Nicholas (1990), HISCHED by Shaked and Warzawki, (1995), project planning and monitoring by Tah et.al.,(1998) and CONSTRUCTION PLANEX by Zozaya-Gorostiza et al., (1990), architectural design (Faltings et al., 1991, Pearce et al., 1992, Maher and Balachandran, 1994 and Flemming, 1994), application in structural design by Zhao and Maher (1988), and Wang and Howard (1991), and other areas of application in construction (Moselhi et al 1992).

10. CONCLUSION

The performance of many construction organisations has been undermined by the quality of the decisions by the management. While recognising the importance of decision making at the strategic level and its significant impact on the performance of the organisation, the paper lays the foundation for development of a framework of executive decision support.

The paper discusses the structure of management decision system and suggests that the object oriented approach to the analysis and modelling will yield the necessary flexibility required for such a complex problem.

Although, many decisions are addressed through the use of deterministic and other established methods, inevitably, due to the nature of decisions at strategic level, the use of AI was seen as an imperative and the potentials of the a number techniques were highlighted.

In order to identify the most appropriate decision model for each decision node, it was necessary to produce a common set of criteria against which both, models and decision nodes could be contrasted. These criteria are instrumental in the identification of the right decision tool for each decision node. While these criteria are descriptive of the nature of the decision model, they also reflect the nature of the decisions. To this end, the paper categorises these models in terms of their attributes and characteristics and a further comparative analysis is produced for artificial intelligent methods.

This paper provides the framework for the development of an integrated decision support system for the benefits of the management at the strategic level of a contracting organisation. The system will help to avoid duplication and gaps in knowledge. The VSD framework provides for this area of research to be developed over time with sufficient flexibility and adaptability to accommodate change.

11. REFERENCES

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