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on
DECISION-MAKING ACROSS LEVELS, TIME AND SPACE: EXPLORING THEORIES, METHODS AND PRACTICES

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DECISION-MAKING ACROSS LEVELS, TIME AND SPACE: EXPLORING THEORIES, METHODS AND PRACTICES

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CONTEXT OF THE WORKSHOP

Decision-making is integral in virtually every aspect of our personal, social and working lives. Indeed, we make decisions every day, whether at an individual level or collectively in the organisations that we work in or interact with. It is therefore not surprising to find a wealth of literature covering various aspects of how decision-making takes place in an organisational context. The long-standing interest in researching the nature of decision-making probably dates back to the post-war era. Simon (1959), for example, reviewed developments in the theories of decision-making as he explored the intersections between the disciplinary traditions of economics and psychology when theorising about decision-making. According to Simon (1959), the law of maximising economic utility as the *sine qua non* for any decision-making exercise is confronted by the psychological challenge of satisfying human motivations. Interestingly, he alluded then to notions of power and bargaining and game theoretical positions to demonstrate that decision-making in business organisations is far from being rationalistic and that choices are rarely binary, as he suggested that the understanding of probabilities and expectations is crucial in determining the effects of decision-making.

Indeed, a fundamental theme associated with decision-making relates to uncertainty. For Pfeffer *et al.* (1976), the degree of uncertainty influences the way in which social structures deployed for allocation of rewards and resources, which are of primary concern to any organisational decision-making process. Akerlof (1970), in his seminal paper on 'The market for "Lemons"', also referred to uncertainty of the quality of information – which he termed as asymmetrical information – and how this influences the decisions made. Huber and McDaniel (1986) argued that the principles of decision-making should drive the design of organisational structures if organisations were to respond effectively to uncertainties of the external environment, whereas Duncan (1973) suggested that decision-making structures are in fact malleable as they adapt to environmental uncertainty. Others (e.g. Pettigrew, 1973, and; Eisendhardt and Bourgeois, 1988) have focussed their attention on how the political behaviours of actors internal to the organisation can influence the decision-making process. Van de ven and Delbecq (1974) looked at group decision-making as they identified the efficacy of different ways of getting people from a variety of backgrounds to come together to make effective decisions.

What makes a good decision is also subject to considerable debate. Early economists have framed this outcome as expected utility. Early economic explanations have attempted to simplify the outcomes of decisions in what is termed as expected utility, where decision-makers often make rational decisions between clear and discrete alternatives with some level of expectation on possible outcomes. Others have questioned such formulaic treatment of decision-making, especially given the risks associated with uncertainty. Kahneman and Tversky (1979) proposed an alternative prospect theory to analyse decisions in risky environments, whilst Prelec and Loewenstein (1991) argued that an added level of complexity relates to making decisions over time. Bell (1985) discusses disappointment and regret when intended outcomes of decision-making are not met. In the 1980s, with the advent of computer-aided tools, researchers have been concerned with the effects of technology on organisational design and decision-making (see e.g. Huber, 1990).

Notwithstanding the vast amount of work already done in the field of decision-making research, the construction industry presents a fertile opportunity to apply fresh theoretical and empirical insights as to how the complex landscape of stakeholders involved in designing, constructing, using and managing the built environment make decisions. This is especially pertinent given contemporary concerns with reference to delivering economic, social and environmental dimensions of creating a sustainable future for industry and society. Furthermore, much early research tended to treat the analysis of organisational decision-making as if this happens within a single, coherent entity of an organisation. Thus, there is scope for examining interorganisational relations that are so important in studying how we make decisions in the world of construction. Therefore, the focus of this research workshop is on the theories, methods and practices of decision-making associated with the construction industry. Without doubt, concepts of conflicts and trade-offs, power relations, risk and uncertainty, and information and knowledge management will be mobilised in the discussions that will develop in the workshop. Three dimensions are of particular interest here, including the notions of decision-making across levels, time and space:

- ***Across levels***: how do we make sense of decision-making processes that take place across the various layers of stakeholders? How do decisions made by policy-makers in the government and local authority shape the decisions made by design and construction companies and vice versa? How can decisions made at the individual level (e.g. end-users) inform decisions made by the professionals and vice versa that goes beyond current practices of user consultation? How are decisions made and enacted, and how do these connect between individual and collective levels? How do we distinguish between the levels anyway?
- ***Across time***: one explanation as to why we have to make decisions is because of incomplete information. Yet, the quality of decisions made depends on the quality of information, and the knowledge of the decision-maker(s), at a particular point in time. So, how do decision-makers gather the necessary information, especially information relating to future technologies and socio-cultural and behavioural trends? How do decision-makers exercise trade-offs of economic, social and environmental concerns when they take a long-term view? Are there trade-off issues that have not been thought of at the point of making decisions? How do decision-makers individually and collectively become aware of these issues? Also, how do decision-making for the future that is made in the present account for the legacy of the past? How do we set boundaries regarding the time frames?
- ***Across space***: how can we capture the inter-organisational and inter-sectoral dynamics that typify the way we make decisions about sustainability in practice? For example, decisions made regarding the design and construction of buildings are often influenced by, and impact upon, decisions made in the area of transport. So, how do decisions made in one sphere of influence inform and shape decisions made in another? Also, how are decisions made between physical and virtual space? Where are the intersections? And what are the power relations that need to be scrutinised?

THE PAPERS

The call for participation attracted seven contributions, which are included in this set of proceedings. Hindmarch, Gale and Harrison discuss the development of a tool that can help project participants manage the messiness associated with design changes in construction, with a view to facilitate effective decision-making. Volker, through three case studies in the Netherlands, argues that decisions made about the selection of architect tend to follow an intuitive process. Volker suggests that this is in tension with more rationalistic prescriptions of procurement law in the Netherlands.

Manu, Ankrah, Proverbs and Suresh explain the importance of integrating the expertise of the construction team at design decision-making so that matters relating to health and safety could be considered at the outset of any construction project. Awe, Stephenson and Griffiths also suggest the need for joined-up thinking across various stakeholders to secure future skills capacity for the Nigerian construction industry. Shahrin, Johansen, Lockley and Udeaja focus the attention on building information modelling (BIM) as a tool that can help build environment professionals make appropriate decisions based on effectively capturing, translating and ultimately delivering on customer requirements.

In the final two papers, Chen and Taroun discuss on methodological considerations in structuring the application of decision-making. Chen describes the use of Analytic Network Process (ANP) as a way for decision-makers to assess multiple perspectives according to the STEEP (Social, Technological, Environmental, Economic and Political) framework. Through a single case study, Chen demonstrates how ANP could be effectively mobilised to define options from which decision-makers can make a rational selection. Taroun criticises *inter alia* analytic hierarchical process of defining decision options, as he claimed that stakeholders in the industry often grapple with uncertain and incomplete information. He proposed the use of evidential reasoning methodology based on Dempster-Shafer theory as a plausible alternative to integrate practitioners' intuition and experience within the decision-making process.

PULLING THE STRANDS

Three key themes seem to emerge from the papers included here. Firstly, the contributors reinforce the recurrent themes of risk and uncertainty identified in the mainstream literature on decision-making. However, risk and uncertainty associated with decision-making in the construction industry are exacerbated in part by the dispersed nature of stakeholders involved and the inter-temporal complexities of the design and construction process. A broader view of the inter-organisational relations that matter in how decisions in the construction industry are made over time (see e.g. Manu and colleagues, and Awe and colleagues), and this needs to go beyond conventional perspectives of bounded rationality that has driven much early research in decision-making.

Secondly, there is often a tension between intuition and experience on the one hand and rational prescriptions on the other (see Volker). It seems that a major concern with many construction management researchers is the aspiration of defining a structured approach to decision-making. Whilst the fuzziness of professional judgement is acknowledged, there is often a desire towards the ordering of decision-making in formulaic terms. The question remains as to the purpose of such formal endeavours; should decision-making be framed in such rational terms or is this a sign of the discomfort among those making sense of decision-making in the field?

Thirdly, tools and methods seem to matter a lot! It is clear in some of the papers presented here (see Hindmarch and colleagues, Shahrin and colleagues, Chen and Taroun) that the researchers place a positive value on tools and methods in affording better decisions in the delivery of construction projects. Yet, there is much scope to research how these devices are being used in practice, and how efficacy of such tools and methods are being determined through the negotiation of power relations in construction. Perhaps the field of construction management is still a long way away from uniting perspectives of decision-making across levels, time and space.

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A PROPOSED CONSTRUCTION DESIGN CHANGE MANAGEMENT TOOL TO AID IN MAKING INFORMED DESIGN DECISIONS

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Current practice shows that construction design change management (CDCM) relies heavily on the experience of practitioners to assess the impact of proposed design changes. This UK government and industry (Arup) funded research is concerned with mitigating the risk associated with a practitioner making a judgment disproportionate to the true impact of a design change. Several design management tools and techniques have been reviewed (including the Analytical Design Planning Technique (ADePT) and the 'last planner' methodology) and suggestions have been made on how they can be adapted to apply to change management. A CDCM model has been proposed as a possible solution, enabling practitioners to make an informed decision regarding the true impact of a proposed change. The CDCM model incorporates a Design Structure Matrix (DSM) and process map generation to create a checklist of rework; it also records the reason for deviation if the true impact is different to the assessed impact. The cost, resource, deviation, and reason for deviation are stored in a database and are available when a similar change is required on a similar project, allowing compensation to be applied to the predicted impact.

Keywords: design change management, decision-making, 'last planner', impact assessment, risk.

INTRODUCTION

All projects can be represented by the project management triangle where, scope, cost and time are the project constraints represented on each corner. In all projects scope, time and cost are connected. Likewise, when a design change occurs there is a change to the scope of the project and therefore it is necessary to change the project cost and/or duration. When referring to the impact of the design change it is this change to the project cost and/or duration, which needs to be considered. In order to calculate the additional project cost it is necessary to know the additional resource needed to complete the rework or redesign. This research considers the deviation between the predicted impact of a change and the true impact once a design change has been implemented; this deviation is in terms of cost, resource and time.

Design changes during the detailed design phase, of a built environment project, usually have a negative impact on the design programme, in terms of additional resource, cost and project duration. Since design is iterative in nature, the consequences of a change can rattle through various engineering disciplines, making the impact difficult to predict. Current practice, within the project sponsor organisation, shows that project teams calculate the effect of a design change on the programme, using their experience of similar changes during previous projects. There

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is a risk in relying solely on a practitioner's knowledge, in that they could make an inaccurate assessment or they may leave the business, resulting in a reduction in specialist decision-making expertise. This risk is increased when decisions are made across multidiscipline teams, which are not co-located.

A number of design management models (DMM) and techniques have been reviewed such as the Analytical Design Planning Technique (ADePT) (Austin 1999(a); Austin 1999(b); Austin 1999(c)) and the 'last planner' methodology (Ballard 1998; Choo 1999; Ballard 2000; Choo 2003)). The authors of this paper suggest what can be done to adapt these tools/techniques in order to address change management. A CDCM model is put forward as a possible solution. This would support practitioners in making informed decisions with respect to the true impact of proposed changes.

PROBLEMS IN CDCM

Many practitioners believe construction design is being managed effectively using protocols documenting change requests. However, after deeper interrogation of such protocols it is evident that within each protocol, in order to aid the decision on whether to implement a change, an assessment of the impact, in terms of resource and cost, is required. After gathering data from industry specialists in an international design consultancy, it is evident that various protocols are used depending upon the project managers preference. There are two tiers of risk for any design change, each discipline team leader is asked to assess the impact of the change for their discipline. The first tier of risk occurs when the team leader decides which team members to consult. These team members are then asked how they will be impacted by the change. The second tier of risk occurs when the team member assesses the impact based upon their experience.

Some practitioners believe that on projects where teams are co-located, it may be acceptable to use experience to assess the impact of a change. However, in projects, which are complex in nature, where multidisciplinary expertise is drawn from non co-located project teams, the decision-making is more difficult since it is necessary to determine how other disciplines will be affected.

An accurate impact assessment of a proposed design change is essential; to enable an informed decision of whether it is worth implementing the change, to maximise efficiency in the design process and to prevent overruns. This research is concerned with mitigating the risk associated with a practitioner making a judgment disproportionate to the true impact of a design change. A CDCM tool is to be developed to aid design practitioners in assessing the impact of a change and to record the impact of changes for future reference.

The next section of this paper is a literature review summary of current design management tools, which can be adapted and developed to address the problem of solely using a practitioner's experience in assessing design changes.

A REVIEW OF SOME DMM

In 1965 Donald V Steward (Steward 1981) developed the Design Structure Matrix (DSM), a matrix representation of a process. The matrix can be reordered and interrogated to find the optimum order of carrying out tasks, through eliminating the amount of rework. Design tasks are carried out in the order they are listed in the matrix and are listed both down the left hand side and along the top of a matrix. Each marker in the matrix determines the relationship between two tasks, the task on the left of the marker is dependant upon information from the task above the marker. Any marker under the diagonal is reliant only on tasks, which have already been completed. Whereas, a marker above the diagonal represents design iterations, where the information/data required is initially estimated. The need to estimate and carry out design iterations can be reduced through reordering the matrix, hence changing the order in which tasks are carried out. When reordering the matrix, the aim is to eliminate the markers above the diagonal, if this can not be done; it is optimum to cluster the markers into groups as close to the diagonal as possible; this is called partitioning.

The DSM was incorporated into the Analytical Design Planning Technique (ADePT) during the late 1990s. Austin *et al* (Austin 1999(a); Austin 1999(b); Austin 1999(c)) identified that design is an iterative process requiring assumptions and rework until a suitable solution has been developed. Previous network analysis planning techniques (e.g. traditional programmes, made up of bar charts) do not account for the iterative nature of design and monitor progress based upon the completion of design deliverables. ADePT uses a DSM to identify the information required to carryout a task, the availability of this information is then monitored to facilitate more effective planning and management of building design.

ADePT management have recently used ADePT to assess the impact of design changes, through manipulating the DSM, on a commercial project (Paul Waskett, ADePT Management Ltd, personal communication, October 2, 2009). After identifying a task that requires re-evaluation because of an imposed design change, it is necessary to move that task to a future period in the schedule. This means moving the task down the matrix until it is below the task currently being completed. Once the task is in place, it is necessary to identify if any other tasks require rework by checking if the task has any dependencies in the upper diagonal. If other tasks require rework, they must also be moved down the matrix. The process is only complete once all rework is identified and there are no more dependencies in the upper diagonal (or the dependencies have been partitioned).

At a similar time to Austin *et al* developing ADePT, Choo *et al* (Choo 1999) developed the WorkPlan database program to aid in developing weekly work plans adopting the last planner methodology. The term ‘last planner’ refers to the individual or group of people who decide what tasks are to be carried out on a day-to-day basis. Traditionally the last planner will allocate work either based on “project schedule” or “whatever is generating the most heat”(Ballard 2000). Choo *et al* (Choo 1999) explains that, traditionally programme schedules are produced by a project manager who may not have a clear understanding of the work to be performed. For example, they may be unaware of what the constraints are on a task and whether the resources required to carry out the task are available at the required time. This traditional schedule identifies what task SHOULD be done at a given time, in order to satisfy the project objectives. The Last Planner System (LPS) proposes that the last planner also executes a schedule; their schedule should take into account both what the management believe SHOULD be done and combine this with what physically CAN be done. The last planners schedule represents what WILL be done. Ballard and Howell (Ballard 1998) suggest that the last planner should carry out this schedule on a weekly basis using a weekly work plan.

HOW CAN THE DMM BE ADAPTED TO ADDRESS CDCM?

Current practice within the sponsor company shows the most common method used for design planning continues to be the traditional project programme, usually using

MS Project or Primavera, software packages. Applying sections of ADePT in the reverse order will allow a traditional project programme to be converted into a DSM. Once a design change is proposed, this DSM can be manipulated as suggested by ADePT management to reorder the matrix and determine a checklist of design tasks, which require rework. This checklist can then be converted into an IDEF0v process map, which will allow the practitioners assessing the impact of a change to visualise the required rework.

The last planner philosophy applies to project planning; a similar philosophy can be used to analyse the impact of a change. Throughout this report, the authors will refer to this as the 'last practitioner' philosophy. The term last practitioner refers to the person or people asked to assess how a given change will affect them. The 'last practitioner' is aware of the physical constraints on carrying out the tasks; they can assess what physically CAN be done in addition to what the change dictates SHOULD be done. The 'last practitioner' can make a more informed impact assessment than someone higher in the hierarchal tree (for example a project manager) since the 'last practitioner' is aware of the physical constraints of a task. Current practice within the sponsor company, uses this last practitioner philosophy, where the 'team member assesses impact based upon experience'. The proposed CDCM model is concerned with supplying the 'last practitioner' with as much information as possible to allow them to make an informed decision and hence mitigating the risk associated with the practitioner making a judgment disproportionate to the true impact of the design change.

The 'last planner' philosophy uses 'Percentage Plan Complete' (PPC) and reasons to track the percentage of assignments completed in each weekly work plan (Ballard 2000). This can be adapted for tracking the deviance in assumed impact in terms cost/time/resource compared to the actual impact of a change. The reasons for any deviance can be recorded and feedback given to the 'last practitioners'. This deviance can also be stored in a database, so that compensation can be given for future changes on similar projects.

PROPOSED CDCM MODEL

The important factors in proposing a CDCM model is that it is of benefit to the practitioner who will use it. It is not possible to eliminate the risk of incorrect impact assessments being made. However, it is possible to supply those practitioners with as much data as possible, to enable them to make a more guided impact assessment; using both a checklist created from a DSM analysis of the current programme and a database of previous changes on similar jobs.

Figure 1, represents the proposed CDCM in visual form; this section summarises the model by describing each element of the model in turn.

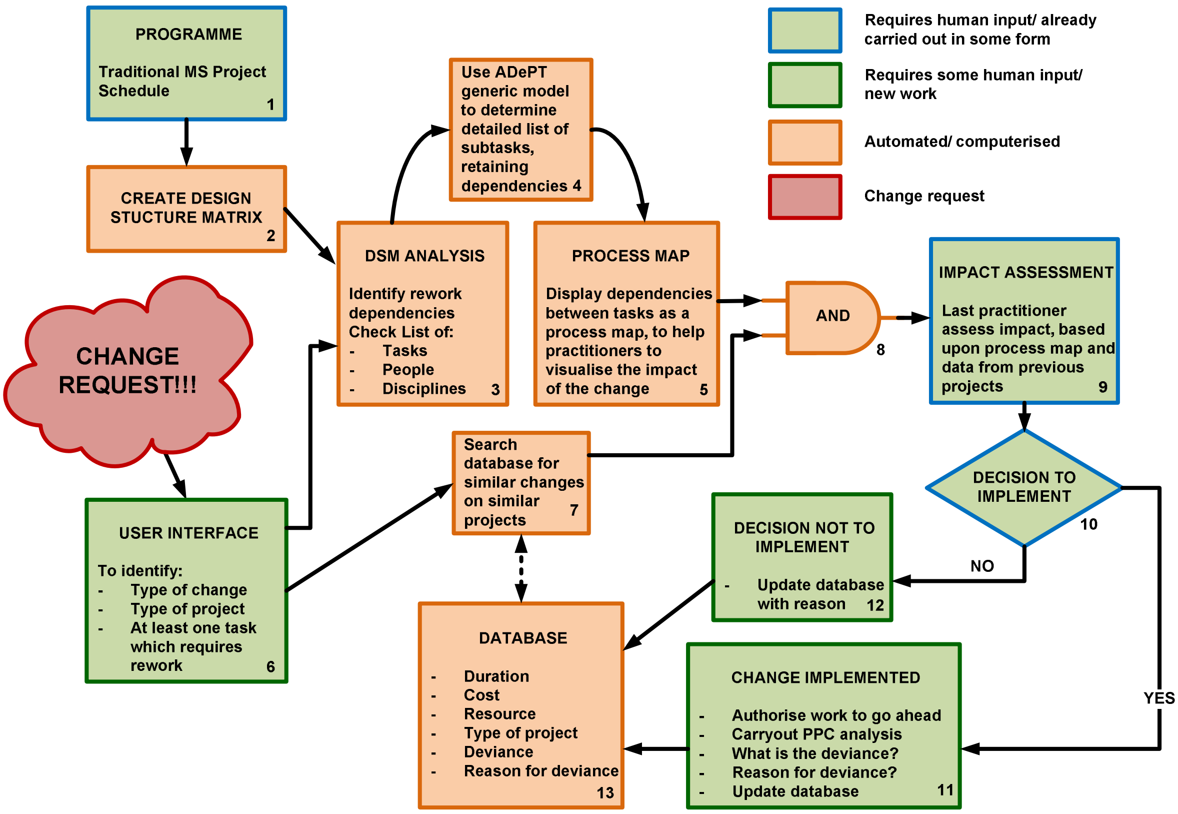

***Figure 1**: Proposed CDCM model*

The first stage of the CDCM model is to take the current project programme and convert it into a DSM. Once a change has been requested and some project characteristics have been inputted into the user interface, DSM analysis can be carried out to identify a list of tasks requiring rework. A generic model will be used to split the list of tasks into a more detailed list of subtasks. The list of subtasks will be converted into a process map, allowing the last practitioner to visualise the rework process, when making the impact assessment. The last practitioner is also supplied with historic data of similar changes on similar projects, from the database, to enable a more informed impact assessment to be made. When the discipline leader has collated the impact assessments from each affected last practitioner a decision on whether to implement the change is made (this decision may need authorisation from the client etc.). Once the decision is made, the last practitioners are informed whether to implement the change. If the change is not implemented, the reason is recorded in the database. If the change is implemented, PPC analysis is carried out; recording any deviance between the expected and actual cost and time to carry out the rework, the reason for any deviance is also recorded in the database.

CONCLUSIONS

In construction design, no single protocol is used to manage design changes. Very little is known about the consequence of design changes. Currently design practitioners use their experience to assess the impact on their specialist field. A CDCM tool is required to help mitigate the risk associated with a practitioner making a judgment disproportionate to the true impact of a design change.

The research carried out so far has clearly identified a need for the CDCM tool. Various design management models have been reviewed and suggestions have been made regarding how they can be adapted in order to help evaluate change. A CDCM model has been proposed, incorporating DSM analysis and process maps to create a checklist and visualisation of redesign tasks, in addition to creating a historical record of the impact of a change for future reference. The reason for any deviance between the real impact and the expected impact of a change is recorded in a database and recalled when a similar change on a similar project has been proposed.

The next stage of this research is to gain ‘buy in’ from the practitioners who will be using the CDCM tool. Once the practitioners have declared they would use the tool, production of the software model will begin.

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ARCHITECT SELECTION: RATIONAL OR INTUITIVE DECISION MAKING?

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During the selection of an architect clients attempt to make decisions about the 'best architect for the job'. Argumentations concern a mixture of judgements about the quality of the design, the capabilities of the designer and the capacities of design firm in question. In most cases procurement law applies which is based on the assumption that decisions are based on a rational consideration of weighted selection and award criteria. However, recent theories about decision making claim that, especially in the case of ill structured problems and uncertain information, intuition is used over analytic thinking. This paper argues that the current interpretation of procurement law in the Netherlands conflicts with the actual intuitive and holistic way of decision making of public clients during architect selections. Evidence from three empirical cases with observations, interviews and document analysis is used to describe how representatives of public clients make decisions in the illusive context of architectural design.

Keywords: decision making; experts; architecture; procurement; rationality

INTRODUCTION AND THEORETICAL BACKGROUND

The processes of a public client for the selection of an architect has its roots in three distinct systems of selection: 1) tendering for the design service, 2) the architectural design competition, and 3) the selective search to identify a suitable designer (Strong, 1996). These roots cause potential conflicts during the process of decision makers of public clients. Results of such conflicts become more visible every day. In the Netherlands disputes over rating points, a difference of a tenth of a percent, and calculations errors already led to several law suits between architects and public clients (e.g. Lybaart, 2008). This paper focuses on the origin of decisions in the elusive context of design and the seemingly rational structure of procurement law.

If public clients in Europe want to award a contract to an architect they have to comply with procurement law and its principles of transparency, objectivity, non discrimination and equal information (Arrowsmith, 2005). The legal requirement is that services above the amount of €125.000 for central governmental organisations and €193.000 for non central government should be tendered according to EU rules and regulations. Most of the Dutch public commissioning clients choose a restricted tendering procedure to select the economically most advantageous offer for the services of an architect. This means that a client selects at least five candidates out of all parties that showed interest in order to make a final decision about the firm they want to award the contract to. The client has to publish the selection and award criteria beforehand. If applicable, also the relative weight of the criteria should be mentioned. These kind of decision processes are based on the assumption that required information is available to make rational decisions, and people weigh the pro's and con's in order to choose the most optimal alternative. Research on actual decision making behaviour found that people do not make optimal solutions but that they choose an option that satisfies them (Simon, 1997). People tend to use heuristics (general rules of thumb) to reduce the time and effort to make reasonably judgements and decisions (Tversky & Kahneman, 1974). For example, the 'availability heuristic' describes how people choose the most frequently used option to apply on their situation. This means that sometimes criteria are not applied exactly the same way as they were announced. The criteria do become part of the frame in which decisions are made. In applying heuristics people tend to make systematic errors, called biases. Most of the research done in this field focuses on analyzing these biases instead of focusing on implications for practice (Beach & Connolly, 2005).

Competitions have a long history and play an important role in the field of architecture. Designs can be considered as ill-defined problems which require expertise to be solved. Because tradition suggests that experts are better at making judgements about design quality than novices, in most competitions a jury is appointed to judge the quality of the submissions. The area of Naturalistic Decision Making (NDM) (e.g. Lipshitz, Klein, & Carroll, 2006; Zsambok, 1997) studies how professionals make decisions in real life situations with time pressure, incomplete or unreliable information and ill-defined goals. These kinds off decisions are based on (unconscious) recognition of patterns and cannot be explained very easily to others because of the intuitive character (Klein, 1993). Often affect, mood and emotions play a role. The third root of the selective search for a suitable designer can be compared to areas as human resource management and the composition of project teams in the area of organisational psychology. In these areas the social context of a decision maker is very important. The image theory of Beach describes decision making as an social act in which the decision maker takes into account the options and preferences of other people (Beach, 1990). This means that organisations do not make decisions themselves, but decisions are made by individual members of an organisation by the use of three images: a set of values and beliefs, specific goals and operational plans. Research shows, among other things, that screening of suitable options seems more important than the actual choice, that compatibility of images is linked to the number of violations to the images (a violation threshold) and that the more members of an organisation agree about the principles, the more they agree about the appropriateness of a plan (Beach & Connolly, 2005). Decision making can therefore be considered as a process of sense making rather than choice making (Weick, 1995).

The combined roots of the current process of architect selections raise conflict in decision making processes of public clients. These conflicts are partly related to the fact that rational decision making procedures do not always reflect the way these procedures are implemented in practice. They also relate to the fact that a public client is in fact 'a many headed monster' as one of the architects involved my research case put it aptly. In Western societies rational(-istic) decisions appear to be more acceptable and easier to defend than decisions based on the intuition (Hogarth, 2005). Experiences from practice show that a matrix with the criteria is used to organize and ground the final decision to meet common expectations about the rationality of decisions. Most professionals in design disagree with this approach because they feel too restricted in their judgement. They rely on their expertise during judgement of design quality instead of the preset criteria developed by the client (Schön, 1991). During their intuitive judgement they process the preferences and requirements of others to reach a decision that would find support among the other stakeholder groups. The level of professional experience and the composition of the group of decision makers influence the process of decision making. Announcement of the decision criteria does therefore not guarantee that a process will fulfil the requirements of transparency, non discrimination and equal information. A matrix with segregated judgements could reflect the final outcome of the decision, but does not reflect the actual process of decision making. Transparency should not be interpreted as a criterion to evaluate the final outcome, but more so to construct the process of sensemaking among decision makers and their stakeholders. In this paper the findings of three tenders are reported on the issues of decision making about the selection process of a public client to find an architect. Three themes in decision making are distinguished: the social context of the client, the level of expertise of decision makers and the role of intuition in decision processes.

RESEARCH METHODOLOGY

The case study method was chosen to account for the fact that the research field is nascent, lacking both empirical studies and theories that address processes of decision making in this context. Building theory from case studies is a research strategy that involves using one or more cases to create theoretical constructs, propositions and/or midrange theory from case-based empirical evidence (Eisenhardt, 1989) and that typically answers research questions that address ‘how’ and ‘why’ in unexplored research areas particularly well (Edmondson & McManus, 2007). In this situation cases were selected because of opportunities for unusual research access and revelatory situations (Yin, 2009). Although Freedom of Information Act seems to imply otherwise, gaining access to tender situations proved to be very difficult. Tender situations appear to have a very sensitive and delicate nature. Next to that it is hard to trace clients preparing a tender before the official announcement is made to trace their motives. Within these limitations, and the available time, three instrumental cases were conducted in the context of a restricted tendering procedure: a School, a City Hall, and a Provincial Government House. The cases differed in the scope of the assignment, the type of tender and the characteristics of the selection process. This paper is based on the results of a cross case search for patterns across three cases.

A variety of data was collected for each case to allow for triangulation between self-report, observed behaviour and official justifications. In the School and Provincial Government House case the observations and formal and information interviews were the main source of information, while in the City Hall case the documents and interviews were most important. The cases were analyzed as separate identities first and then systematically compared on appearing constructs. The study was set up according to the principles of Yin (2009) and Stake (1995) in order to address the potential shortcomings of using a case study method in terms of limited generalisability, validity and reliability. The semi-structured interviews were recorded and transcribed. The coding and analysis of all documents was done in Atlas.ti by the author and validated with the supervisory team of the research project. A more detailed description of the analysis of the City Hall case can be found in Volker, De Jonge, Lauche and Heintz (2008). The cases of the School and Provincial Government House are described in Volker & Lauche (2008).

FINDINGS

The social context of a client

All cases show that the public character of a client led to a lot of stakeholders to involve in decision making. Because the built environment is something generally known and experienced by all kinds of people, a plethora of ideas and opinions could be found among the stakeholder with a differentiation of interests and ambitions. Table 1 describes the most important stakeholders that were somehow involved in the separate cases. Further analysis showed a distinction between the role of decision makers: as shareholders (with mainly financial involvement) or as stakeholders (with practical involvement), as decision makers (actively involved in the decision process) as represented stakeholders (represented by others in the decision process), and as decision maker with personal interests (with private responsibilities) or as decision maker with professional interests (with official or work related responsibilities). Most of the decision makers belonged to different stakeholder groups. The Provincial Executives were for example employees of the province, but also part of the representatives of the client body. Therefore they were stakeholders and decision makers at the same time with both professional as well as personal interests.

Table 1: *Overview of most important stakeholder(s) groups) per case*

Stakeholder category	School with sports facility	City Hall with library	Provincial Government House
Commissioning client body	Department of Education	City Council	Provincial Council (PS)
Representatives of the client body	School Board, Department of Sports	Board of Mayor and Aldermen	Provincial Executives, Queen’s commissioner
Shareholders and supervisors	Common Exploitation Company, Municipality	Province, Department of Interior and Kingdom Relations	Department of Interior and Kingdom Relations
Daily users	Teachers, Children	Local government servants and officials, Employees of the library	Employees of the province
Non-daily users	Parents, Neighbours	Citizens, Clients of the library, Tourists, Shop keepers in the city centre, Neighbours	Inhabitants of the Province, Visitors, Other companies in the business park
Representative groups of the users	Representative advisory body, Parents’ council	Employees council act, Historical interest groups, Political parties	Employees council act, Biological or environmental interest groups, Political parties

Analysis of the observations during the selection and award meetings showed that in the City Hall case the decision makers differed in their interests between the user needs, the integration in the context, the importance of financial means and political aims of the project. During the School case differences in the scale of the interests, the user levels, the input of means, the perspective in time, interests in the product and in the process, kinds of responsibilities and need for innovation were found. In the case of the Provincial Government House the perception of risks, the level of creating support, the responsibilities and the level of involvement differed between the stakeholders of the project. All together this led to the following overview of pairs of potential conflicting interests that should be addressed during the selection process of an architect (see Figure 1). The multiplicity of personal, client relates, process related and building relates issues makes it almost impossible to address them rationally during the decision process. The use of intuition enables decision makers to take the interests into account that appear to be relevant at the moment in order to deal with the interests of the different stakeholders. The following sections show the role of expertise and intuition in decision making processes of people representing a public client.

Client related issues		Building related issues	
Short term	Long term	Urban level	Building level
Certainty	Innovation	Personal use	Representation function
Political support	Existing policy	Innovation	Functionality
Permanent staff	Political parties	History	Future
Exemplary function	Accountability	City heritage	Personal remembrance
Personal interests	Professional interests		

Project related issues		Process related issues	
Quality	Time and money	Decision responsibility	Advisory rights
Construction	Maintenance	Supervisory function	Commissioning body
Process partner	Design partner	Political support	Content of decision
Primary budgets	Secondary budgets	Control	Risks

Figure 1: *Overview of decision issues in pairs of potential conflictive interests of decision makers found in the cases*

DECISION MAKING AND EXPERTISE

People experience the built environment as a daily user, but that does not automatically mean that everybody is an expert in architectural design. The same applies for architect selections in the context of European legislation – most people involved in the cases other than the consultants have been involved in a tender or selection procedure before, but only a few selected an architect by applying a restricted tendering procedure. Analysis of the findings in the cases displays different kinds of expertise on several levels and from multiple perspectives. Expertise tends to be domain and role specific: a civil rights lawyer does not know much about tendering regulations, an urban planner usually knows only little about climate design and a director of a primary school does not know everything about the needs of teenagers in secondary education. Expertise as decision maker, expertise about architecture and expertise in tendering regulations seemed to be most apparent during these architect selections. The findings suggest that the personality of the decision maker is important for the degree in which one is aware of these differences in expertise and therefore also the need for compensation by others. Especially the perception of someone's own level of expertise influenced the position he or she found him or herself in. For example, the School director indicated that he only passively attended the committee meetings:

'The whole day I sat there with my eyes and ears wide open. I am a layman; I did not find time to say anything useful about the entrants I saw. I just sat there for show.'

But the project manager who chaired the meetings indicated that his perception of the contribution to the discussion differed from his own:

'Novices are very often very capable to convey a coherent image. He [the School director] heard terms he did not know but he surely could make a judgement. They know what design quality is about. Then intuition counts.'

The level of expertise appeared to depend on the position and role of the decision makers in the tender. One of the board members of the School – a real estate management consultant in daily live - explained the differences between the position as a consultant and as a board member:

'It is totally different. As a client we do not only have the authority but also the responsibility and that is why one is more aware of the choices one makes. Now I understand why clients have difficulty with decision making…. It is definitely harder...

I feel responsible. As consultant I am responsible but I do not have physical influence on the decision. That freedom, you do not experience that as a manager because you have to act as you decided.'

A similar phenomenon was found in the City Hall case. For most council members being a politician is not their primary profession – they usually have other daily jobs. However, this does not mean that people with less specified expertise are automatically bad decision makers. Or as the process manager of the City Hall indicated about the decisions taken in the award committee (consisting of council members):

'I think it is really clever of the award committee how they considered all advises. Although a pharmacist is not an urban planner, it did turn out well.'

The observations showed that a lack of expertise can be counterbalanced by involving other experts. In the case of the City Hall and the Governmental House the politicians made use of special committees with employees that focused on a specific item. Like the clients in this research, nowadays more and more municipalities hire expertise from outside because they do not have the means to have the expertise 'in-house'. But even management consultants involved in architect selections do not always have specialized expertise. In these cases the background of the consultants varied from civil engineering until real estate management and architecture. Juridical consultants belonged to another category of advisors, but their level of specific knowledge about architect selection also varied. The authority level of the consultants acting in a project team usually differed from the authority of the actual decision makers and the other advisors.

A jury panel (selection and/or award committee) usually consists of people with different backgrounds, levels of experience and expertise, acting from different positions and with diverse interests. The jury panels of the City Hall and the School consisted of a mixture of architects (in the School case only on advisory basis), administrators and managers with different decision rights. The analysis in the data in the City Hall case showed differences between the stakeholder groups in number and type of aspects they used in their argumentation (Volker, et al., 2008). The project team and the external financial consultant reviewed only the aspects they were assigned, such as possible conflicts with the zoning plan or budget, and did not express a preference. The prospective building users with no professional background in architecture, the citizens and the employees, used only half of the criteria that the expert committee and the selection committee used. It was the expert committee that considered the highest number of design aspects, focusing on feasibility and the contribution of the design vision of the quality of the city, but excluding finances, performance, and building services. The award committee seemed to have followed the expert committee in their judgement but also stressed the financial limitations. In their public defence, almost all aspects of the fourteen design quality distinguished in the case analysis were mentioned as criteria for their final decision. This implies that experts were better able to take more balanced decisions with long term perspective while novices focused more on the direct consequences of a decision.

The observations and interviews of the cases suggest that the ongoing discussions between the decision makers increased the appreciation of other interests, raised the awareness of the importance of a valid judgement and exposed more qualities of the submissions. Discussions also seemed to have supported knowledge transfer between the panel members. They sometimes complemented each other in expertise. The composition of the panel does need to fit with the criteria that will be assessed and the sources of information that are provided by the participants, for example regarding the issues of sustainability. In the Government House case sustainability was a major theme of the project. During the selection meeting, the panel discovered that none of the available panel members or available experts had enough expertise to make a proper judgement on this aspect. Also in the School case sustainability was to be an important theme, while none of the panel members proved to be an expert. In both case sustainability was not mentioned very often in the argumentation during final decision making.

THE ROLE OF INTUITION IN DECISION PROCESSES

During the process of decision making a frame of references was built among the decision makers of the group. This frame of references seemed to be influenced by the characteristics of the group members, the content of the submissions and the design of the tendering procedure. The observations suggest that during discussion the selection and award criteria were used to build the frame and steer the direction of process. Selection and award criteria mentioned in the official tender guidelines seem to cover only the basic requirements to be judged by the client. Priorities shifted during the process. The findings also suggest that by building a frame of references within the group, interpretation of the criteria increased. The criteria were being interpreted more widely or narrowly during the process. Sometimes additional aspects, such as previous experience of a panel member with certain firms or architects, were used in the argumentation of the decision. The panel members of the School used the argument of educational experience most frequently during their judgement, while the official selection criterion was not that specific for education. In case of the City Hall the change in perception and use of the criteria was clearly shown during the public debate and also confirmed by the interviewees. First functionality and aspects like requirements, budgets and social skills of the designers dominated the discussion among the stakeholders in the award phase. By the end the political parties discussed the overall judgement without referring often to the 'physical boundaries'. Emotional responses to the designs came into play, and arguments became more general but also more subjective and based on intuition. Because the client could not express some of their criteria in objective terms, they referred to the criteria of 'most appealing design' as their main decision criteria. And the 'most appealing design' seems to include 'intangible' criteria such as personal connection, faith in and affinity with the architectural firm, design and designers. Also in the School case the main argument for decision making seemed to be the 'click with the architect' whereas officially it would have been the economically most advantageous offer.

In case of the School and the Provincial House the criteria were used very explicitly during the beginning and the end of the process but very implicitly during the discussion in between. One of the School panel members explained:

'You only use the criteria because you have to be transparent and because you have to explain later on. But I have not looked at the criteria during evaluation [red: in the award phase], I would lie if I would say so...'

The matrix form they used in the School case strengthened the effect of the criteria structuring the decision process. The ease in which the results of the matrix sheet with judgement of parties involved in the School case was accepted, indicate that the weighing factors that were incorporated in the sheet were not applied explicitly but taken as a given during the decision process. The decision about the weight of the criteria therefore has important but implicit implications on the decisions. After the ranking in the matrix, original judgements seemed not important anymore. Everybody trusted the excel sheet made by the consultant and focused on the total scores. Then the discussion pursued on a more general level to find a balance between the selected firms and the personal interests of the decision makers.

In the award phase the impact and functionality of the design proposals led to a definite 'click with the design product' in the City Hall case. The personality and shown competences of the architect seemed to be most important in the final decision of the School case. Almost all decision makers in the School case reported in retrospectives interviews that the final decision in the award phase was based on their intuitive judgement about the person and their potential competences, which led to the 'most convincing party' and a 'click with the architect'. Communication skills and sympathy seemed more important than the content of the proposal, or previous personal experience with the designer. This 'click' however, was not an official award criterion, but can be seen as part of the aspects of 'communicative skills'. According to an advisory panel member of the School the current winner presented a weak vision in comparison with other firms but the choice of the School Board is comprehensible:

'The architect had a very charming personality and focused on the needs of children instead of architecture in general'.

Because the fee of the most preferred architect in the School case turned out to be the lowest afterwards and the City Hall used a fixed price, the influence of price on final decision making cannot be retrieved in these cases. Also in the City Hall case 'true excellence' did not seem to be about answering to all functional, durable and aesthetical requirements but about the potential of the full package of the design proposal, the designer and the firm they belong to. Therefore the winner of a tender reflects the design firm which the client believes will best fulfil their needs and provide them with the right architectural value. These findings indicate that building trust between the project partners is one of the main motives during tendering procedure. One of the participating architects in the City Hall case explains this client behaviour in tender situations:

'One always selects people who one trusts, which make one feel right. They will just see what would happen next.'

CONCLUSION

The findings of all cases show that it is difficult to apply the pre-announced criteria and their relative weight during a group process of decision making. Criteria are not part of a rational decision method but part of a process of sensemaking of decision makers that represent a public client. The final decision about the 'winning architect' appears to be a common effort between the members of the award committee. Would the kind of naturalistic decision making be against the law? The law implies that there is only one decision maker who rationally applies clearly defined criteria. In practice decisions are made by administrators and committee members the represent several stakeholder groups. Decision makers usually have different levels of expertise and different interests. They need time to interpret the criteria, the brief and the procedure that were usually built by others that were not part of the actual award committee. In a political and democratic arena sense making is important for support in the implementation of the decision. The observations show that the ongoing discussions between the decision makers increased the appreciation of other interests as well as the perception of the submissions. Discussion also seemed to increase satisfaction, acceptation of the decision process and acceptation of the decision itself. These effects contribute to the transparency of the decision process and future outcomes of the project.

The results indicate that the award criteria triggered the process of giving meaning during the tender process, but that decision makers did not directly refer to the official formulations in their discussions. The appliance of the criteria was mainly done intuitively and discussed with the other members of the group. At the same time the argumentations that were used to justify the decision corresponded to the criteria identified in the call for tenders. Therefore it can be concluded that the criteria did create the structure in which the decision had taken place. The criteria acted as a steering method which enabled the client to stay within the rational context of the law. Another scenario could be that in the final stage of decision making, the arguments were reduced to the official criteria because a need existed for an 'objective' justification of the decision. This kind of justification in numbers and apparent importance of criteria in a matrix form support the perception of objectivity to the outside world. This does not, however, mean that decisions were made according to the principles of objectivity, transparency and non-discrimination. This raises the issue of then to reflect and justify group decisions of public clients about quality assessments of design proposals. Ill-defined problems often have ill-defined answers. The tradition in architecture seems to accept these inadequacies, and recognizes that sometimes expertise and intuition is needed to make decisions. It also accepts that not everything can be rationalized and predicted beforehand. In the case of tender decisions the traditions of two professional fields, law and architecture, clash with each other in their expectations about the amount of rationality during decision making. All we need is a way to deal with it…

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THE CONTRIBUTION OF CONSTRUCTION PROJECT FEATURES TO ACCIDENT CAUSATION: AN INSIGHT FOR INFLUENCING THE HEALTH AND SAFETY OUTCOMES OF PROJECTS THROUGH PRE-CONSTRUCTION DECISION-MAKING

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Health and safety (H&S) studies indicate that pre-construction decision-making has a significant impact on the H&S outcomes of construction projects. To enable project participants involved in pre-construction decision-making to greatly and positively influence the H&S outcomes of projects they therefore need insight into construction accident causal factors, especially those factors that emanate from decision-making at this critical stage of project procurement. Among such causal factors are construction project features such as the nature of project, method of construction, site restriction, project duration, procurement system, design complexity (buildability), level of construction, and subcontracting. A critique of H&S literature within the UK construction industry reveals that these construction project features emanate from the client's brief, design decisions and project management decisions to contribute to accident causation on projects. However, the extent of their contribution to accident causation, and consequently the H&S risk implications remain unknown and requires further investigation. The emerging research questions relating to this knowledge gap together with the research methodology to be adopted in an empirical investigation aimed at unravelling the knowledge gap are subsequently put forth. It is argued that the insight to be obtained from this study will assist construction project participants who are engaged upstream of the project procurement process to positively influence the health and safety outcomes of projects through their decision-making.

Keywords: accident causation, construction project features, decision-making, health and safety

INTRODUCTION

Like other construction project outcomes such as cost, the H&S outcomes of projects are greatly influenced by pre-construction decision-making (cf. Szymberski, 1997; Entec UK Ltd, 2000; Macmillan *et al.,* 2001; Bartolo, 2002). It is therefore important for project participants who are engaged in decision-making at the pre-construction stage to have insight into construction accident causal factors that emanate from decisions made at this critical stage so that they can be well informed to make good decisions that will help in preventing accidents during the construction phase. Among such accident causal factors that emanate from pre-construction decision-making are construction project features such as the nature of project, method of construction, site restriction, project duration, procurement system, design complexity (buildability), level of construction, and subcontracting. However, H&S studies have mainly made only passing references to the accident causal role played by these construction project features without providing insight into the extent to which they contribute to accident

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causation and consequently the H&S risk implications. This study provides the initial step towards attaining this insight so that pre-construction decision-makers can understand the H&S implications of such decisions for them to be able to positively influence the H&S outcomes of projects. The study achieves this by first exploring the impact of pre-construction decision-making on H&S followed by a critique of H&S literature to demonstrate the mentioned knowledge gap. The study then poses the key research questions that are needed to interrogate the knowledge gap and subsequently outlines the research aim and objectives, and the research methodology which is to be adopted in an empirical study being conducted towards unravelling the knowledge gap.

THE IMPACT OF PRE-CONSTRUCTION DECISION-MAKING ON H&S OUTCOMES OF PROJECTS

"There is a time when we must firmly choose the course we will follow, or the relentless drift of events will make the decision" (Franklin D. Roosevelt, as cited in Adair (2007)). In this quotation, the Former US President, Franklin Roosevelt does not only underscore the importance of decision-making but more so, timely decision-making. Decision-making, being the process of evaluating alternative choices to achieve a course of action (Genest, 2007), cuts across several disciplines (cf. Hansson, 2005) and this process has been identified to reflect three major theories of decision-making: *descriptive, normative and prescriptive* (Bell *et al.,* 1988; Dillon, 1998; Martin, 2005). The descriptive and normative decision theories, which are earlier theories, are concerned with how people (actually) make decisions, and how people should (theoretically) make decisions, respectively (Bell *et al.,* 1988; Dillon, 1998). The prescriptive theory, which is more recent and is based on the theoretical foundation of the normative theory in combination with observations of the descriptive theory, is concerned with how to help people to make good decisions (Bell *et al.,* 1988; Dillon, 1998; Ryu *et al.,* 2007). The differences in these theories are further illustrated in Table 1 below.

Table 1: *Decision-making theories (Bell et al., 1988; Dillon, 1998)*

Decision-making theory	Definitions
Descriptive	Decisions people make How people decide What people actually do, or have done
Normative	Logically consistent decision procedures How people should decide What people should do (in theory)
Prescriptive	How to help people to make good decisions How to train people to make better decisions What people should and can do

Underpinning this study is the prescriptive decision theory, as this study focuses on how to assist construction project participants to make good decisions concerning H&S at the pre-construction stage. Drawing on the quote by Franklin Roosevelt, this study emphasises the pre-construction period as the opportune time for decision-making regarding H&S on projects since this period offers the greatest opportunity to influence the H&S outcomes of projects (cf. Szymberski, 1997; Entec UK Ltd, 2000). Szymberski (1997) illustrated this by his time-safety influence curve (Figure 1) which shows that safety can be influenced to the greatest extent in the early phases of projects. Szymberski (1997) indicated that the ideal situation is for construction worker safety to be a prime consideration of the project planners and designers at the conceptual and preliminary design phases in the procurement process and that a considerable portion of the ability to positively and effectively influence site safety is lost when its consideration is absent until the construction phase. The influence of decision-making at the early stages of projects on the H&S outcomes of projects is also acknowledged by Sir John Egan (Strategic Forum for Construction, 2002), the Office of Government Commerce (2004) and the Construction (Design and Management) Regulations 2007 (CDM 2007) (HSC, 2007).

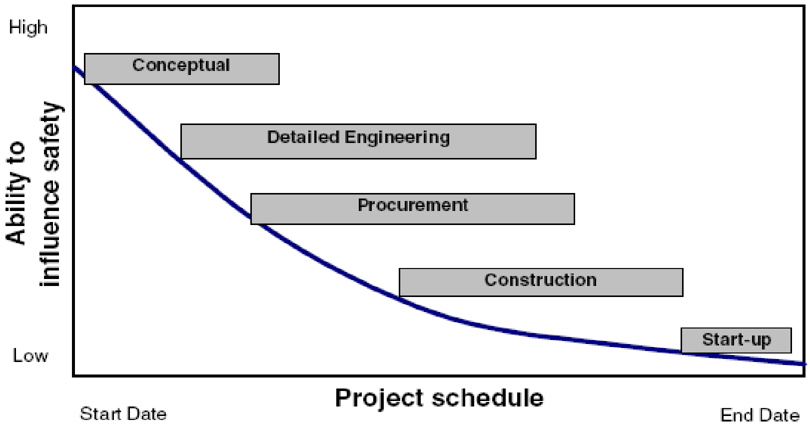

Figure 1: *Time/safety influence curve (Szymberski, 1997)*

In this regard Sir Egan (Strategic Forum for Construction, 2002) said;

"***Pre-planned***, *well designed projects,* ***where inherently safe processes have been chosen***, *which are carried out by companies known to be competent, with trained work forces,* ***will be safe***: *they will also be good, predictable projects*".

With the intent of further buttressing the influence of pre-construction decision-making on the H&S outcomes of projects, it is worthwhile to also mention that pre-construction decision-making has a similar influence on cost. Macmillan *et al.* (2001) highlighted that decisions taken at the conceptual design stage of a building project can significantly reduce costs and increase client satisfaction. This is corroborated by Bartolo (2002) who indicated that it is critical to make the correct strategic decisions in the early stages, as it becomes increasingly expensive and unrealistic to make any significant changes as design progresses. Ashworth (2004) gives a graphical illustration of this (as shown in figure 2) which is similar to Szymberski's time-safety influence curve.

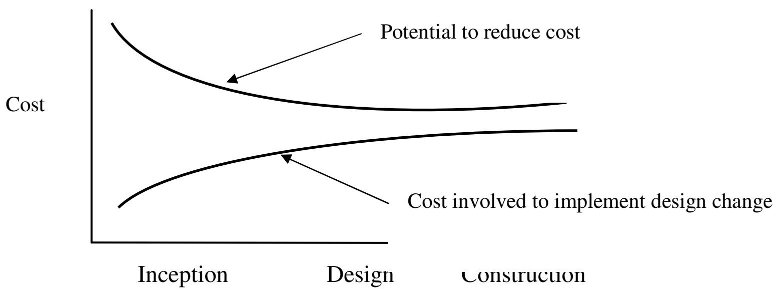

Figure 2: *Chart illustrating a declining influence on cost along the stages of project procurement (Ashworth , 2004)*

Seeing that decision-making at the pre-construction stage has a significant influence on the H&S outcomes of projects, it is thus imperative for project participants involved at this stage to be equipped with insight into accident causal factors, especially those causal factors that emanate from the decisions they make at this stage. Given that reliable, relevant information (insight) is an essential ingredient for making good decisions (Drummond, 1996; Adair, 2007), the insight into accident causal factors which emanate from pre-construction decisions will undoubtedly be very useful to project participants engaged in decision-making at this stage. A critique of accident causation literature reveals that construction project features such as the nature of project, method of construction, site restriction, project duration, procurement system, design complexity (buildability), level of construction, and subcontracting are among accident causal factors that emanate from decision-making at the pre-construction stage of projects (cf. Mayhew & Quinlan (1997), Health and Safety Laboratory (HSL) (1999), Entec UK Ltd (2000), Gibb (2001), McKay *et al.* (2002), Loughborough University and UMIST (2003), Loughborough University (2006, 2009), HSE (2009) and Manu *et al.* (2009)). These features are attributes (organisational, physical and operational) that characterise/describe construction projects and to a large extent emanate from the client's brief, design decisions and project management decisions during the pre-construction phase of project procurement.

Having established the impact of pre-construction decision-making on H&S and the need for insight into accident causal factors that emanate from it, it is thus important to explore the accident causal role played by the identified construction project features to have an understanding of how they contribute to accident causation, the extent to which they contribute to accident causation and the resulting H&S risk implications. As emphasised by Suraji *et al.* (2001), such insight is essential for accident prevention. In view of this, the subsequent section of this study critically examines the contribution of construction project features to accident causation. The review aims at obtaining an understanding into this phenomenon and also aims at revealing the knowledge gap that still exists and the benefits of the insight that is currently shrouded by the knowledge gap so that research can be directed towards obtaining that insight to facilitate pre-construction decision-making.

EXPLORING THE CONTRIBUTION OF CONSTRUCTION PROJECT FEATURES TO ACCIDENT CAUSATION

As demonstrated by the accident causation models of Suraji *et al.* (2001) and Haslam *et al.* (2005), construction project features (emanating from the client brief, design decisions and project management decisions at the pre-construction stage), contribute to accident causation by the introduction of proximal accident causal factors into the construction phase, and this contribution to accident causation consequently has H&S risk implications (cf. McKay *et al.* (2002), Chua and Goh (2005), Loughborough University (2006)). As explained by Suraji *et al.* (2001) and Haslam *et al.* (2005), the proximal accident causal factors are factors that can directly lead to accidents and these factors are also introduced by distal (root/underlying) causal factors. This process by which construction project features contribute to accident causation is illustrated in figure 3.

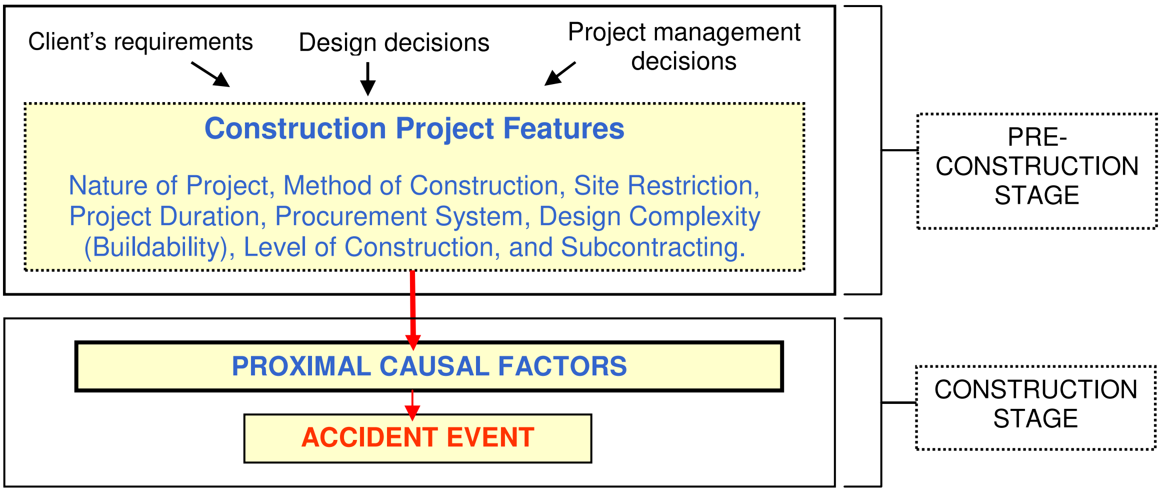

Figure 3: *The contribution of construction project features to accident causation (in line with Suraji et. al. (2001) and Haslam et. al. (2005))*

H&S literature indicates that construction project features contribute to accident causation to varying extents depending on the extent of prevalence of the relevant proximal factor(s) within/associated with construction project features. In view of this, the insight into the extent of contribution of construction project features to accident causation provided by literature is only limited to the extent of contribution to accident causation among construction project features of the same kind. This insight does not provide the actual extent of contribution to accident causation which would also allow for relative comparison among construction project features of different kinds. To explain this limitation, for instance literature indicates that conventional-onsite construction contributes greater to accident causation than pre-assembly due to the greater extent of manual handling (i.e. the proximal causal factor) that is associated with conventional on-site construction than pre-assembly (cf. McKay et. al. (2002), Wright et. al. (2003) and Loughborough University and UMIST (2003)). Literature also indicates that management contracting contributes greater to accident causation than design & build procurement due to the greater extent of fragmentation of the project team (i.e. the proximal causal factor) that is associated with management contracting than design and build procurement (cf. HSL (1999) and Loughborough University and UMIST (2003)). However, literature does not provide the extent to which conventional-onsite construction contributes to accident causation in relation to management contracting (the two project features being of different kinds i.e. method of construction and method of procurement, respectively). Such insight is however important for providing a basis for making decisions regarding the prioritising of accident prevention measures.

It also follows that the H&S risk evaluation (in the extant literature) associated with construction project features as a result of their contribution to accident causation is only the risk in relation to construction project features of the same kind and not a holistic risk evaluation which would also allow for comparison among construction project features of different kinds (cf. McKay *et al.* (2002), Chua and Goh (2005), Loughborough (2006)). When construction project features interact on a project, some project features potentially mitigate or aggravate the risk associated with other project features as noted for instance by Wright *et al.* (2003). Also, concerning this potential risk mitigating-aggravating interaction effect amongst construction project features, literature again provides limited insight. Clearly, these constitute a considerable knowledge gap which demands investigation in order to facilitate pre-construction decision-making.

The insight into the extent of contribution of construction project features to accident causation and consequently the H&S risk implications is vital, as by it the ability of the project participants to positively influence the H&S outcomes of projects through pre-construction decision-making will be greatly enhanced. Project participants (i.e. client, design team and project management team) who determine these construction project features (through the project brief and their decisions) at the pre-construction stage would by such insight be able to take into consideration the H&S risk implications of construction project features when making decisions. Low-risk construction project features could be chosen over high-risk ones where there is the opportunity to do. Also construction project features that potentially mitigate the risk associated with other construction project features could be chosen to reduce the risk associated with such project features where those project features have been selected or they are inevitable as may be dictated by the client's requirements. In preparing the construction phase plan as required under the Construction (Design and Management) Regulations 2007, the insight could also be useful to the construction team when making decisions regarding the planning and prioritising of accident prevention measures to be implemented during the construction stage. Ultimately, these will facilitate the achievement of good health and safety outcomes on construction projects as noted by Sir John Egan (Strategic Forum for Construction, 2002), and by that also contribute towards improvement in the construction industry's poor H&S performance (cf. Health and Safety Executive (HSE) (2009)).

Having demonstrated the knowledge gap in literature concerning the contribution of construction project features to accident causation and consequently the H&S risk implications, and the importance of such insight for pre-construction decision-making, the subsequent section of this study takes the first step towards bridging this gap in knowledge so that the benefits of the insight can realised.

IMPLICATIONS FOR FURTHER RESEARCH

Building on the above discussion, the fundamental research questions that need to be addressed in order to unravel the knowledge gap are;

- To what extent do construction project features contribute to accident causation? and;
- What are the H&S risk implications as a result of their contribution to accident causation?

These questions are key research questions for interrogating the knowledge gap since such questions help to define the aim and objectives of a research work and they also inform the choice of an appropriate research approach (Ahadzie, 2007; Fellows and Lui, 2008). Drawing on the research questions, this study outlines the research aim and objectives, and the research methodology which is to be adopted in an on-going research being conducted towards interrogating the knowledge gap.

RESEARCH AIM AND OBJECTIVES:

The aim of this research is thus to establish empirically the extent to which construction project features contribute to accident causation and consequently the H&S risk implications, and to develop a H&S risk evaluation model based on the contribution of construction project features to accident causation.

To achieve the above aim, the research is pursuing the following objectives;

- To undertake a critical review of construction accident causation literature highlighting the causes of accidents in the construction industry and pointing out the contribution of construction project features to accident causation;
- To undertake a critical review of health and safety risk and risk assessment methods with the aim of identifying a suitable method for evaluating the H&S risk associated with construction project features as a result of their contribution to accident causation;
- To develop a clear conceptual model that maps out the relationship between the extent to which construction project features contribute to accident causation and the health and safety risk resulting from their contribution to accident causation;
- To develop an instrument (questionnaire) that will enable data collection to investigate empirically the conceptual model;
- To collect data and analyse the data to determine the contribution of construction project features to accident causation and the H&S risk associated with construction project features as a result of their contribution to accident causation;
- To develop a H&S risk evaluation model to assist project participants with pre-construction decision-making in relation to construction project features and also decisions regarding the planning and prioritising of accident prevention measures to be implemented at the construction phase;
- To evaluate the usefulness of the model from practitioners' perspectives; and
- To draw conclusions from the findings of the study and on that basis make recommendations for industrial H&S practice and for further research.

RESEARCH METHODOLOGY:

The research paradigm to be adopted for the research will largely be positivist (quantitative), which implies that the reasoning of the research will largely be deductive involving the development of a conceptual and theoretical structure prior to its testing through empirical observation (Loose, 1993). Within this general positivist framework, elements of interpretivism (qualitative) will also be incorporated to provide deeper insight into the contribution of construction project features to accident causation. The research methods to be applied will include (in the order of their application):

1. Literature review – An exploratory literature review of the H&S performance of the UK construction industry will be conducted followed by an in-depth literature review of the causal factors in construction accidents. The review will accentuate the role of construction project features in causing accidents, pointing out the scope for further research in relation to the extent of contribution of construction project features to accident causation and the H&S risk resulting from their contribution. The in-depth literature review will also focus on H&S risk and methods of assessing H&S risk with the aim of identifying a suitable method for assessing the H&S risk associated with construction project features as a result of their contribution to accident causation. In line with deductive research, the literature review will underpin the development of a conceptual model which presents the two related facets

of the knowledge gap (i.e. the extent of contribution of construction project features to accident causation; and the H&S risk implications) in a unified coherent piece.

2. Interviews – Semi-structured interviews will be conducted with UK construction contractors (the focus being the site personnel/professionals, such as construction managers, site managers, site engineers, H&S managers, etc) and H&S experts/consultants (such as CDM Co-ordinators) to refine the conceptual model. To achieve this, the interviews will further explore the contribution of construction project features to accident causation to obtain further understanding of the accident causation process, and also to identify other construction project features that contribute to accident causation but have not been reported in literature. It will also provide additional empirical evidence in support of the literature underpinning the conceptual model.
3. Questionnaire – The refined conceptual model together with the interviews will inform the development of a questionnaire which will be administered in a cross-sectional survey to the same category of respondents as in the interviews. The questionnaire will solely be the basis for determining the extent of contribution of construction project features to accident causation and the H&S risk implications.

The sequential application of the above research methods constitutes a robust research approach which will allow the knowledge gap to be initially explored in-depth in a qualitative manner (through interviews) to learn more about it, followed by a quantitative investigation with a large pool of construction professionals (through a questionnaire survey). This is a mixed method approach which Creswell (2009) describes as sequential exploratory strategy, which involves a first phase of qualitative data collection and analysis, followed by a second phase of quantitative data collection and analysis. Since in the case of this research, the quantitative data collection and analysis will solely provide the basis for determining the extent of contribution of construction project features to accident causation and the H&S risk implications, this particular mixed method approach prioritises the quantitative facet over the qualitative facet in line with the allocation of weight when planning mixed methods design (Creswell, 2009). Creswell (2003) provides an example of a scenario in which this approach can be situated *viz*; where for instance the researcher wants to both generalise the findings to a population and develop a detailed view of the meaning of a phenomenon or concept for individuals, the researcher may first explore generally in a qualitative manner to learn about what variables to study, and then study those variables with a large sample of individuals quantitatively. Again, the sequential exploratory strategy enables the researcher to develop an instrument (which in the case of this research is a questionnaire) to be subsequently administered to a sample of population (Creswell, 2009). These scenarios reflect this research and demonstrate the suitability of this approach to be adopted. A flow diagram of the entire research process is shown in figure 4 below.

Having laid out the research aim and objectives and subsequently a robust research approach to be applied in interrogating the knowledge gap through the research being conducted, what then remains is to pursue the research objectives by following research process outlined above and illustrated below to enable the attainment of the full insight into the contribution of construction project features to accident causation.

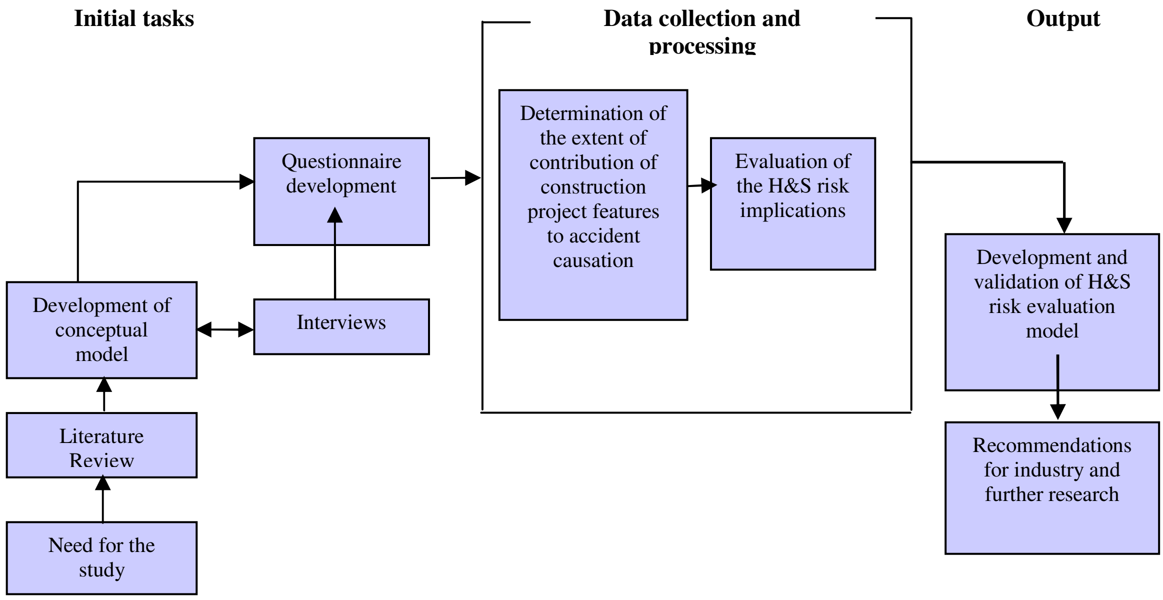

Figure 4: *Research process (adapted from Creswell (2003, 2009))*

CONCLUSION

The above critique of literature has demonstrated the impact of pre-construction decision-making on the H&S outcomes of projects. By that the critique has also demonstrated the importance of having insight into accident causal factors that emanate from pre-construction decision-making in order to assist project participants to be able to influence positively the H&S outcomes of projects by making good decisions concerning H&S at this crucial stage. Underpinned by the prescriptive decision-making theory (i.e. how to assist people to make good decisions), the study has focused on construction project features which emanate from pre-construction decision-making and by the introduction of proximal causal factors contribute to accident causation, the aim being to obtain insight into this accident causal phenomenon. It is argued that this insight is necessary to assist project participants in decision-making regarding the choice of construction project features (on the grounds of H&S) and also regarding the planning and prioritising of accident prevention measures to be implemented at the construction phase. The study has however demonstrated that the insight within the literature of the contribution of construction project features to accident causation and consequently the H&S risk implications remains elusive and therefore demands investigation. As an initial step towards unravelling the knowledge gap through an on-going research, the study has put forth the key research questions, the research aim and objectives, and a robust research approach to be applied in the research. Given the significant influence of pre-construction decision-making on the H&S outcomes of projects, the eventual outcome of this research will be a major contribution towards achieving H&S improvement in the UK construction industry.

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EFFECTS OF DECISION MAKING ON ARTISANS' TRAINING PROBLEMS IN THE NIGERIAN CONSTRUCTION INDUSTRY

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The Nigerian construction Industry has experienced changes over the years since the oil boom of the early seventies, both in terms of volume and complexity of work. Projects such as construction of roads, buildings, bridges, dams, sewage plants, have been executed on large scales. It has, however, been observed that, in recent times, the stock of skilled manpower has not been able to match the level of economic activities and development. It is therefore imperative that efforts are directed at tackling the manpower development challenges and more particular those that relates to training and education of the construction site skilled operatives. Defective approach to decision making on the part of the policy makers has been identified as one of the main influences of the present predicament. Problem solving and decision-making are important strategies for business; problem-solving often involves decision-making, and appropriate approach to decision making regarding skills and vocational training is very relevant in tackling the present problem. This paper aims at eliciting ideas and generating discussion on how decision making across levels and time can positively impact on Artisans' training and thus influence the formulation of a 'best practice framework' for the training of craftsmen in the Nigerian construction sector.

Keywords: decision making, labour shortages, skilled operatives, technical education, vocational training.

INTRODUCTION

Leaders make solid decisions and commit to seeing them materialize. A key skill in becoming a successful leader is the skill of decision making. Decision making is also one of the best developmental tools at the disposal of the leaders. In order to create momentum around decisions the leader must cultivate commitment. Asking for input, especially from key stakeholders, is critical for momentum and effective implementation (Taylor, 2008; Harris, 2008).

Successful leaders have learned that action is vital, they know that procrastination can have a devastating effect, but decision making on how to get the Nigerian youth mobilized into profitable skills acquisition, which would benefit them as individuals and move the country forward both economically and socially, seems to be left un-attended. As a result, the younger generation take to loitering and loafing (Nwagwu, 2004). Neglect on the part of the nation's leadership in evolving a positive decision making and problem solving strategies, which could redeem the present awkward situation; may result in a whole generation of able-bodied citizens being wasted or squandered on the platform of indecision occasioned by selfishness and corruption. At present, young people seem to eschew the high-end construction trades in exchange for the lure of promising positions in technology or other emerging fields, leaving a shortage of skilled workmen in the construction industry. The cream of the nation’s youth no longer shows interest in skill acquisition (Dike, 2006; Bolaji 2007).

Many who would have been trained to acquire profitable skills take to petty or even serious crime. Some of the artisans that are engaged on construction sites are essentially incompetent. Some of the trained craftsmen who should be engaged on construction sites have taken to other supposed financially lucrative businesses such as 'okada' commercial motor cycle transportation (Awe, 2006). Emphasis on skill instruction in technical colleges and vocational training centres has become secondary, due to poor funding and a misplaced emphasis and misdirected focus (Awe, 2004 and Akindoyeni, 2005).

Obiegbu, (2005) also observed that problems of low wages, absence of a clear-cut career path; and a lack of organized apprenticeship training schemes are evident in the construction industry at the present time. Most of the Nigerian technical school students see themselves as being trained to perform supervisory roles on completion of their training; the Polytechnics and Universities are producing middle level and high level manpower respectively. If this trend goes unchecked; a period will come when there will be many graduates of construction related fields but few or insufficient number of craftsmen to carry-out the actual work; a situation that will be catastrophic for the Nigerian construction industry and the nation's economy as a whole.

Construction work, as at the present time in Nigeria is labour intensive, unlike in some advanced countries such as the UK where a great percentage of site operations have been mechanized thus requiring fewer numbers of operatives on the construction sites (VanDoren 2008). The goal of this paper therefore, is to generate discussion with the view to eliciting ideas on how decision making across levels and time can positively impact on tackling the identified problems with training and development of Artisans; thus influencing the formulation of a 'best practice framework' for craftsmen training and development in the Nigerian construction sector.

ARTISANS' TRAINING PROBLEMS IN THE NIGERIAN CONSTRUCTION INDUSTRY

Nigerian seemingly well structured and closely monitored educational system should normally have enabled and encouraged the nation to produce sufficient number of seasoned craftspeople to meet the needs of the local industries and the challenges in the global economy but the reverse seems to be the case. Bolaji (2007) notes that the Nigerian educational policy has not been capable of providing the needed manpower development to stir the nation's socio-economic exigencies left by the colonial masters. The policy issue though seems well laid-out but non-directional due to incessant changes. It has become a tradition to abandon policy mid-stream.

Okafor (2000) observes that there is total decline in the quality of training facilities at all levels of Nigerian education system. Many technical and vocational training institutions do not have the necessary facilities for effective teaching and learning. Odia and Omofonmwan 2007; Olaitan 1996; and Essien, 1998; identify lack of necessary facilities such as tools and adequate workshops to hinder in-depth practical instruction. Akindoyeni, 2005; Awe, 2005; and Obiegbu, 2005; highlighted reduced emphasis on skills instruction due to poor funding and a misdirected focus. The industrialization of the nation is being delayed due to the inefficiency of the technical education system. Akpan (1999) submits that technical and applied skills would not be effectively acquired by mere reading of handout and pictures of simulated tools and equipment. Oni (2007) advocates the need for proper funding of technical and vocational education. Acute shortage of suitable, trained and qualified vocational teachers is another identified bane of Nigeria Technical and Vocational Education (Aina 1991 and Okorie 2000).

Other challenges of the Nigerian vocational educational system as identified by Oranu (1998) include problems related to curricular which include inadequate emphasis on pre-vocational subjects at the primary and junior secondary levels, shortfall in recruitment and exodus of teachers, low student morale, examination-oriented approaches to curricular implementation and inadequate political will. The general orientation of the Nigerian educational system seems to lay more emphasis on paper qualification than on acquisition of marketable skills; hence the trainees concentrate on accumulation of qualifications at the expense of acquisition of skills.

Since the era of oil boom of the early seventies, the Nigerian construction industry has experienced progressive transformation both in terms of complexity and quantity of projects. Vast construction projects such as buildings, roads, dams, bridges, sewage and power plants has been executed (Adeniji, 1994; Akindoyeni 2005). Since construction technology involves both local and imported, it is imperative that workers are constantly trained and developed locally to acquire and adapt the available technologies (Nwagwu, 2004; Onjewu, 2005).

DECISION MAKING PROCESS AND ITS IMPLICATION FOR SKILLS AND VOCATIONAL TRAINING IN NIGERIA

Decision making in any venture has been viewed to follow a structured process or procedure (Hogarth, 1990; Ranyard, Crozier and Svenson, 2001; Harris, 2008). The decision making process involve:

- Defining and clarifying the issue - to determine if it warrant action; if it does, is it urgent, important or both?
- Gathering all relevant facts and understanding their causes.
- Thinking about possible options and solutions.
- Considering and comparing the pros and cons of each identified options.
- Selecting the best options.
- Explaining the decision to those involved and affected, and following up to ensure proper and effective implementation.

Akin to the above process is the traditional six-step problem solving process highlighted by Orth and Yoe (1997) which are:

- Identifying and selecting the problem
- Analyzing the problem
- Generating potential solutions
- Selecting and planning the solutions
- Implementing the solution
- Evaluating the solution

These decision making and/or problem solving processes are relevant and have implication for skills and vocational training in Nigeria for the following reasons:

- The Nigerian workforce training; seems to have defied solution over time. There has been programmes targeted at addressing the problems but the projects are either abandoned mid-stream or sabotaged.
- The lack of interest of the up-coming generation in skills acquisition calls for critical definition and painstaking clarification so as to know how best the

younger generation could be re-oriented, re-directed and re-focused to pick-up interest in skills acquisition; with the view to making them gain economic freedom and contribute to economic growth and national development.

- The myriad of problems confronting vocational education and training require critical analysis and corresponding urgent and positive actions.

DISCUSSION

The crux of this write-up and presentation is, actually, to elicit ideas; from academic researchers on how decision making across levels and time can positively impact on Manpower training and development in the Nigerian state. The goal is to influence or give a 'lead' towards the formulation of a 'best practice framework' for mobilising, training competent workforce and developing the younger generation; with the view to tackling the menace of skilled labour shortage in the nation's construction sector.

The question then is: How appropriately or effectively can the decision making process be adopted as a strategy to solving the skills training problem and tackling labour shortages challenge?

- Across levels: How can the relevant stakeholders - the policy makers, construction sector, labour unions, construction and allied professional bodies unite to make decisions that could positively impact on the younger generation to effect a change of attitude towards skills acquisition?
- Across time: the decision necessary in this regards relate to the future of the younger generation, the construction sector, national economy and development. How best could decision-makers gather relevant, necessary and quality information and what are relevant trade-offs to ensure a long term effect?

CONCLUSION

The contributions and positive input from the Researchers at this workshop would give a clue towards possible solutions that could be proffered towards tackling the identified problems.

Issues raised would also immensely facilitate the formulation of a 'best practice' framework for manpower training and development in the Nigerian construction sector.

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EFFECTIVE CAPTURE, TRANSLATING AND DELIVERING CLIENT REQUIREMENTS USING BUILDING INFORMATION MODELLING (BIM) TECHNOLOGY

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The construction industry has long identified the importance of addressing client requirement in order to achieve project performance. However, the industry has a poor record of addressing these requirements owing to the complexity and uncertainty of the project brief. Various procedures have been adopted in the past, with varying levels of success or failure for those involved. As the current economic crisis effect major clients, the position has become more complex (i.e. there is huge pressure on the clients' spending powers). Clients are beginning to demand quality and value for their money. It is suggested that a fresh view might be required as to how the clients' requirements could be captured and delivered to achieve quality and value for money. The introduction of Building Information Model (BIM) in the construction industry is considered to increase the ability to deliver better and enhanced products to the clients. The usage has been increasing worldwide but research is still required as to how this tool might be most effectively employed. BIM is an emerging technology that has been used to provide virtually images of what likely the client would have containing with all the data throughout the building life. The main issue here is how BIM can be used to capture, translate and deliver client requirement during project? The aim of this research project is to examine the process of translating client requirements (CR) into a finished product using the Building Information Modelling (BIM) approach by evaluating how client requirements can be translated into BIM to maximize client satisfaction. It will consider client requirement related to five (5) different attributes; types of client, types of needs, types of procurement, types of project and types of building.

Keywords: building information modelling, client requirement, translating process and construction industry.

BACKGROUND OF THE RESEARCH

The realization of the Government vision to improve the construction industry through various efforts can be achieved if the team shares a vision that construction is beyond the narrow concept of construction (Wolstenholme, 2009). The problem within the industry is the failure to deliver the client requirement due to inadequacy within the briefing process including among other issues, lack of systematic and structured methodology, less focus towards clients' real needs, ineffective usage of information technology (IT) and most importantly ;failure to provide clarity and traceability towards client requirement (Kamara et al,2002) . All these attributes provide vague and implicit client requirement which could be improve through an integrated process which clarified what the client values and delivering client requirements that reflects their needs. Client is the key to the whole construction process and understand their needs is paramount (Latham ,1994) and it can be done by getting the brief right in order to meet client expectations and having an effective project delivery(Egan,1998). In 2001, the NAO (2001) noted the importance of capturing client requirements as an area to be focussed upon in improving construction performance. Based on Wolstenholme's review (2009) of what industry had achieved regarding client satisfaction matters it seem that, the focus on the customer remained important but the focus on integrating the process and the team around the product had not yet engaged the industry and it still has a situation where it is often unclear how clients requirements should be fed into the design process.

Improvement in the delivery of public services has been a major policy theme in successive British Governments. Schools and hospitals are fundamental to public service, and require great care during the briefing process. The 2003 Government report, '*Improving project and programme delivery: Increasing the Civil Service's capacity and capability to deliver'* urged project teams to meet Government's objectives to improve the public services. Research on improving briefing process was widely carried out. The briefing process involved expressing clients' wishes and it is important for client to have clear view of what their project should achieved (Boyd & Chinyio, 2006).This is where BIM may be useful as it is able to virtually construct clients' requirements into a model and to provide opportunities for both client and project team to examine the 'what if' scenario' without great effort. The introduction of BIM in the construction industry is considered to increase the ability to deliver better and enhanced products to the clients (Lamb, 2009; Smiffs & Tardiff, 2009; Singh *et al* 2009). Building information modelling can be acknowledged as a collaborative tool (Salmon,2009;Singh *et al,*2009) as everyone has the same accessibility to the project information (Curtis *et al*,1992). It produces better coordination of project details (Klotz *et al*, 2007) within a 'single source' model(Eastman *et al*,2004). And it also allows the client and stakeholders of the project to link their requirements to live data(Salmon 2009).

It is suggested that a different viewpoint might be required as to how the requirements could be captured and delivered. It is worth mentioning that other methods, methodologies or tools such as Facility Programming Product Model (FFPM), SEED-Pro, Brief Maker, Auto Brief and Quality Function deployment(QFD) has been developed to assist in defining client requirement. Kamara and Anumba (2000) for example developed a computer based tools to support early stages of construction process by removing ambiguities and provide precise definition and the opportunity to trace the design decisions to original intention of client. But, this tool would not be able to provide data through the building lifecycle compared to what is offered by Building Information Modelling (BIM). However, this further raises an issue as to whether or not Building Information Modelling (BIM) is able to capture, translate and deliver what is required by the client. This raise further question whether the 3D model that is produced is correctly reflects what is wanted by the client in his project as 3D model sometimes can be misleading particularly to those from outside construction.

The usage of BIM has been increasing worldwide but research is still needed as to how this tool might be most effectively employed. Senescu & Haymaker (2009) suggests that due to differences in client background and level of understanding of the process and application of BIM it cannot be seen as a miracle tool. BIM would not be able to integration and collaboration among client and project team if everyone in the network does not understand their role in their project(Linderoth 2009). The maximum benefit of BIM is also related to the level of commitment given by the client (Howard & Bjork, 2007;(Linderoth 2009) and training received by the staff (Kaner *et al*, 2008). The main point that needs to be established here is; BIM should be seen as a tool which needs both parties (the client and constructors) to have the same vision of what they are getting (Kaner *et al*, 2008).

There is also considerable uncertainty concerning the interoperability issue. The question of the capability of BIM to hold the virtual project from the initial stage up to the end within a single file and the issue of data transfer could become another barrier to adopting BIM (Gu *et al*, 2008). Despite a number of research projects being carried out on BIM, research on contractual and procurement and the roles and obligations of each project team member are not widely done. Much of the work to date is heavily on the technical features of BIM rather than looking at it from the human resource or contractual/organisational points of view. Gu *et al* (2008) stated that the project team are rather more focussed on the technical aspects, the process and the method of carrying out the BIM.

BIM is believed to offer opportunities for more effectively deal with client in capturing, translating and delivering client requirement issues and particularly in its use to clarify project objectives, assist collaborative working and the clarification of objectives. This research will examine whether BIM can be used as a tool for capturing, translating and delivering clients' requirements and if it is suitable, manageable, and effective in delivering them the final product (refer figure 1).

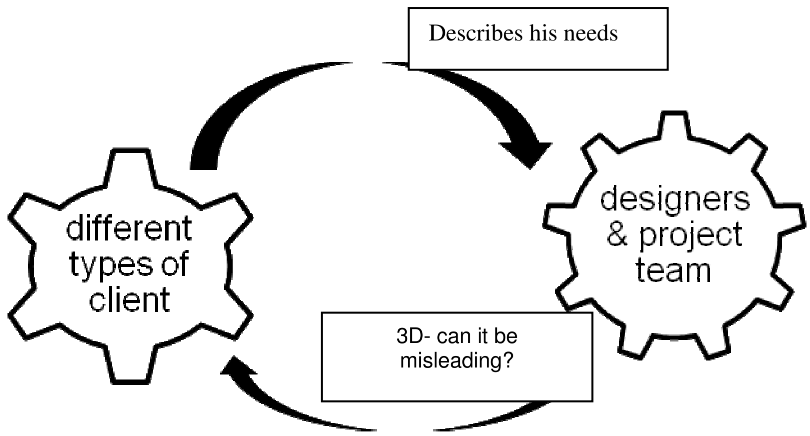

***Figure 1**: Relationship between client and project teams during the process of capturing, translating and delivering the clients' requirement.*

AIM OF THE RESEARCH PROGRAMME

This research sets out to evaluate how client requirements can be translated into building information modelling to maximise client satisfaction and to establish a methodology that reflects the usage of building information modelling within the design and delivery process to produce greater 'value' to the client.

Within the above aim, the research will address a number of questions:

1. What are the main factors that really help and hinder the client in communicating to the project teams what they want and need from a project and how are these affected by Building information modelling?
2. What are the problems faced by project teams when adopting BIM in their projects as problems could affect the process of capturing, translating and delivering client requirement?

3. Can BIM reduce misunderstanding and misinterpretation between clients and designers and project team?
4. What are the main benefits gained by both project owner/client and the project teams while BIM is used in the project?
5. How might BIM help clients in decision making on determining what they want from the project?

The following table captures the objectives and the methods and approaches to achieving them.

***Table 1:** Objectives and approaches*

	Details of research objectives	Methods
1	To examine the features and the application of Building Information Modelling (BIM) and to investigate whether BIM can reduce misunderstanding, misinterpretation in the communication process.	1. Literature Review 2. Industry case study
2	To evaluate the process of communication and interpretation that happens during the communication process between the different types of client and the designer and project team compared to with the production of 3D Forms produced by BIM	1. Observation on the case study 2. Interviews with project participants. 3. Closed questionnaire
3	To consider the implication of BIM on contractual issue.	1. Data derived from case study, interviews and questionnaire survey.
4	To model a practical client requirement methodology for construction project.	1. Industry Case study 2. Results from survey (questionnaires & interviews)
5	To test the methodology and evaluate the effectiveness of using BIM to deliver better client requirements within UK construction industry.	1. Web hosted questionnaire

RESEARCH STRATEGY & METHODOLOGY

As an exploratory-descriptive research, this research will employ appropriate methodology compatible with our objective to examine and understand the issues relevant to the building information modelling (BIM) as a tool to capture, translate and deliver the client requirements within Government projects; specifically schools and hospitals. In more detail; the researcher is keen to explain the observed changes which happen during the application of BIM in projects and to consider the benefits, problems and contractual issues encountered.

In order to achieve the aim, objectives of this research project and to answer the above questions the following strategies and research methods will be adopted:

i. *The use of published sources*- where the literature review will be used to practice the knowledge and look for links between client requirement and building information modelling in delivering client satisfaction.

ii. *Case study*- of current organization or companies that employ BIM within their building process. The knowledge gained from the case study will provide 'depth of insight' of what is actually happening in employing BIM in the construction process. The selection of the case study will be 2 single case study which using the BIM and same procurement method. In this case studies, the project that will be limited to school and hospital. The case study also will be using the set of attributes as shown in figure 2 as to set boundaries to guide the research process and as the criteria to look in the case study
This case study will adopt a mixed research, due to the need to get better response from the project participants but also to obtain richness of qualitative data from the in-depth analysis of the field data (Bryman, 1989).
Initially, closed questionnaires will be used to seek general and overall ideas of what project members think and to avoid low responses from the project members. This closed ended questionnaire is actually will act as the pilot study to assist and refine researcher's research design and strategy. The range of answers from the closed questionnaire, will allow the open ended and semi-structured interviews to be closely targeted to clients and project members to gain meaningful comments and insights from them.

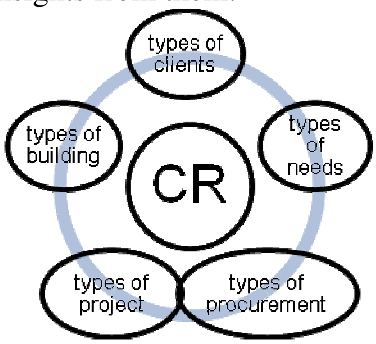

Figure 2*: Attributes contributing to the context within client requirement*

This case study also will involve embedded multiple-case design as illustrated in figure 3. The research will be focussing on hospitals and schools in UK, preferably within the north east of England. Thus, each hospital and school that will be selected as the case study will involve more than one unit of analysis (see figure 3). For example, in the case of hospital, analysis would include outcomes from the clinical staff and managerial staff employed by the hospital.

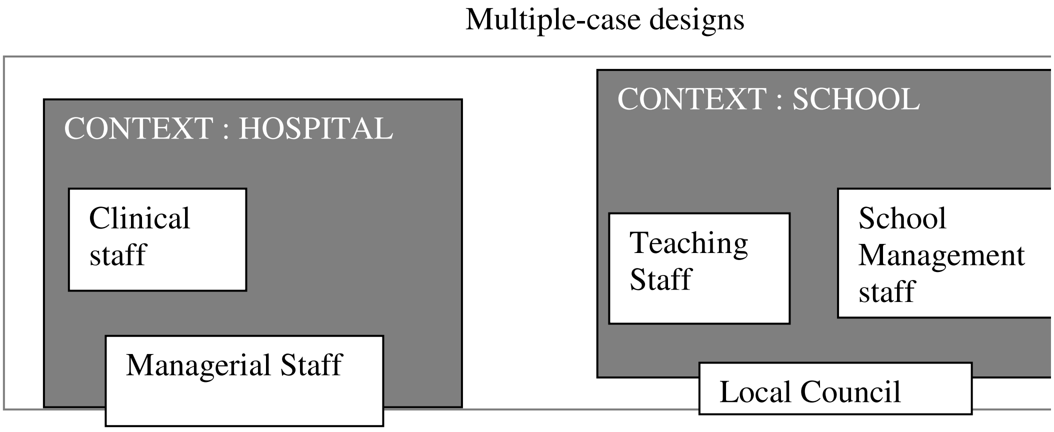

Figure 3: *Type of design for case study for this research*

The data collected from this case study will be use to answer the questions no 1 and number 2 in Section 2.0. Then, the data will be interpreted and analysed to develop the methodology to achieve research objective no 4.

iii. *Action research*- the methodology will be tested to see whether BIM can be used to capture, translate and deliver the various client requirements that will be identified during the course of study. Thus, eventually the methodology will be developed, and then it will be tested and refined to ensure it is working comprehensively.

Figure 4 will summaries all the research process that will be taken during the course of study.

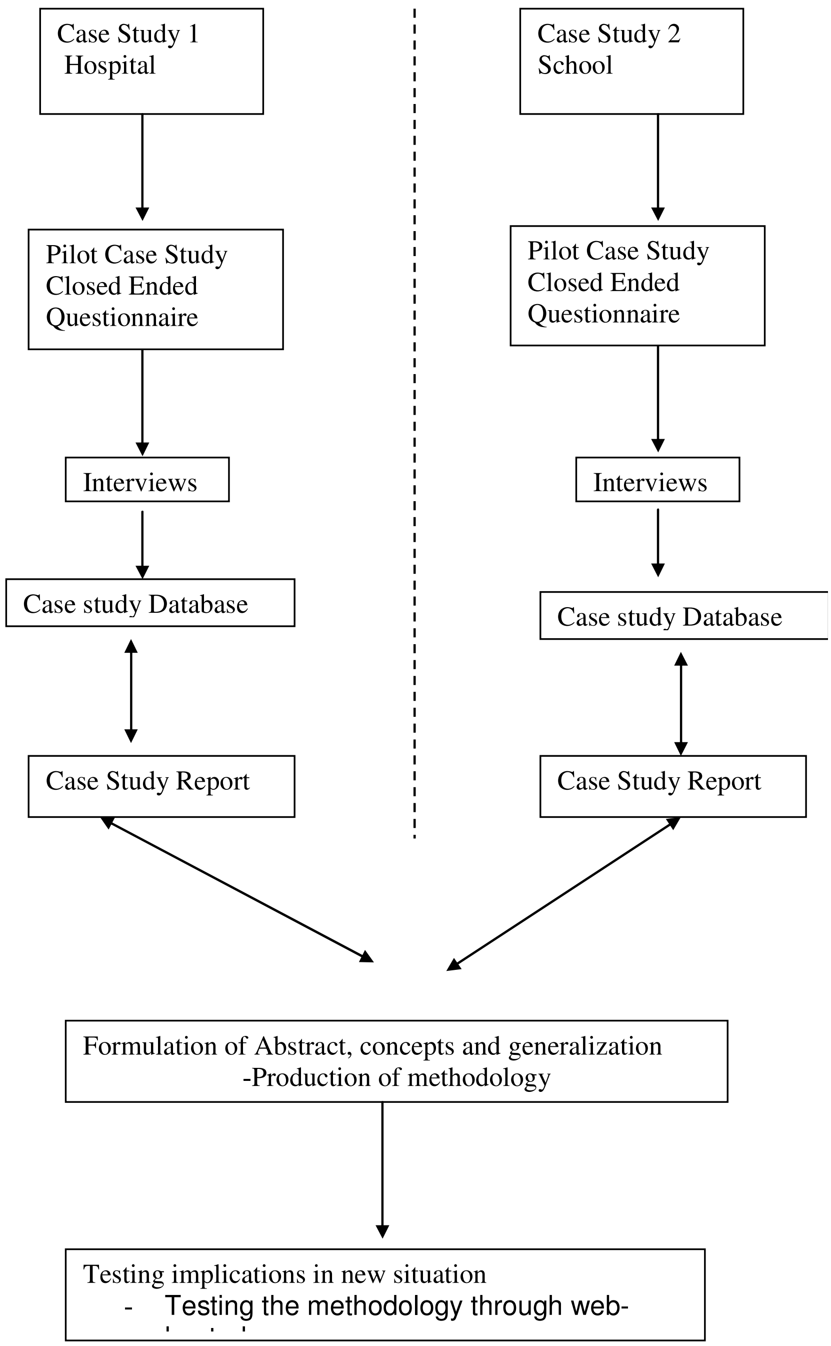

Figure 4*: shows diagram on the research plan for capturing, translating and delivering client requirement using Building Information Modelling (BIM) technology*

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ANP MODELS AND STEEP CRITERIA

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This paper and presentation aim to make a summary of research into the theory and application of Analytic Network Process (ANP) in multi-criteria decision making in construction and development since 2003 when the new area of ANP applications was initially explored by researchers in Hong Kong and UK. The paper and presentation focus on two main issues including the framework of ANP applications and the adoption of a novel set of decision-making criteria to cover social, technical, economic, ecological, and political (STEEP) issues related to project decision targets. In terms of ANP applications, a framework is introduced to summarise and further guide five progressive levels of contemporary research and development related to ANP in the construction sector. The entire relation between general needs and associated contents of assessment across stages of construction and development projects is then discussed based on industrial guides given by CIOB and PMI in order to highlight the importance and relevance of intruding a generic set of assessment criteria. An example based on the Royal Liverpool University Hospital project is given to demonstrate the feasibility of incorporating a set of STEEP criteria in an ANP model to deal with real world problem. It is expected to attract some interest in further research and collaboration in ANP applications.

INTRODUCTION

The application of analytic network process (ANP) (Saaty, 2005) for construction and development started around 2003 respectively from the Research Centre for Construction Innovation at the Hong Kong Polytechnic University (Chen, Li and Wong, 2005; Cheng and Li, 2005a) in China, and the School of Construction Management and Engineering at the University of Reading in UK, and two of first pieces of research were presented at the ARCOM Doctoral Workshop (Chen, Li and Wong, 2003; Huang, 2005), which was held at Glasgow Caledonian University on 18 June 2003. Since then, more publications have been turned out by pioneer researchers, and these include

- Aragonés-Beltrána, et al. (2008): valuation of urban industrial land
- Chen and Li, et al. (2005/09): risks assessment of commercial real estate development, vendor evaluation, construction plan evaluation, life cycle value assessment, construction knowledge management, evaluation of IT solutions, location selection, and buildings assessment, etc.
- Cheng and Li, et al. (2004/06): contractor selection, project selection, location selection, and performance evaluation, etc.
- Dikmen, Ozorhon, and Bu-Qammaz, et al. (2007/09): project appraisal, performance assessment, and risk assessment of international projects.
- Lu, et al. (2007): risk assessment.

Literature review reveals a progressive development, summarised in Figure 1, of using ANP for construction and development projects, and it has been noted accordingly that current research into ANP applications are approaching to its higher levels comparing with the contents of early research at the first level, called Adoption, which focuses on simple ANP models that were roughly set up but left with some confusions for applications with a horizontal expansion into possible areas in construction and development, and at the second level, called Integration, which focuses on integrative ANP models that were innovatively set up but still left with some further confusions for applications with a traverse expansion with one of more other possible approaches such as artificial neural network (ANN), fuzzy logic, and quality functional deployment (QFD), etc., which are deemed to be integrated with ANP. In terms of the integration of ANP with other relevant approaches, there are examples of incorporating fuzzy logic with ANP in evaluating environmental sustainability (Liu, 2007), safety risks (Peng, et al., 2008), and environmental impacts (Liu and Lai, 2009), and there are attempts to integrate ANP with artificial neural network and knowledge base system (Chen, Chung, and Li, 2008). And the purpose of using such integration is to facilitate either front-end or back-end process in decision making. For example, the QFD can be used as a front-end processor to collect data for an ANP model, whilst the ANP can also be used as a front-end processor to generate inputs to a QFD model. In terms of those confusions, which are based on the author's numerous discussions with both professionals and academics through presentations at meetings, workshops, seminars and conferences, and emails as well as publications in the past more than five years, they may include

- What is the gap between academic research and professional practice in using ANP?
- What is the confidence level of ANP results in terms of each specific decision-making question for construction and development?
- How can ANP be popularly used by practitioners in the construction sector?

These questions provide some essential requirements regarding potential demand of using ANP in construction and development practice, and therefore research and development should go ahead to achieve a higher level, and there have been some progresses from research dealing with those confusions.

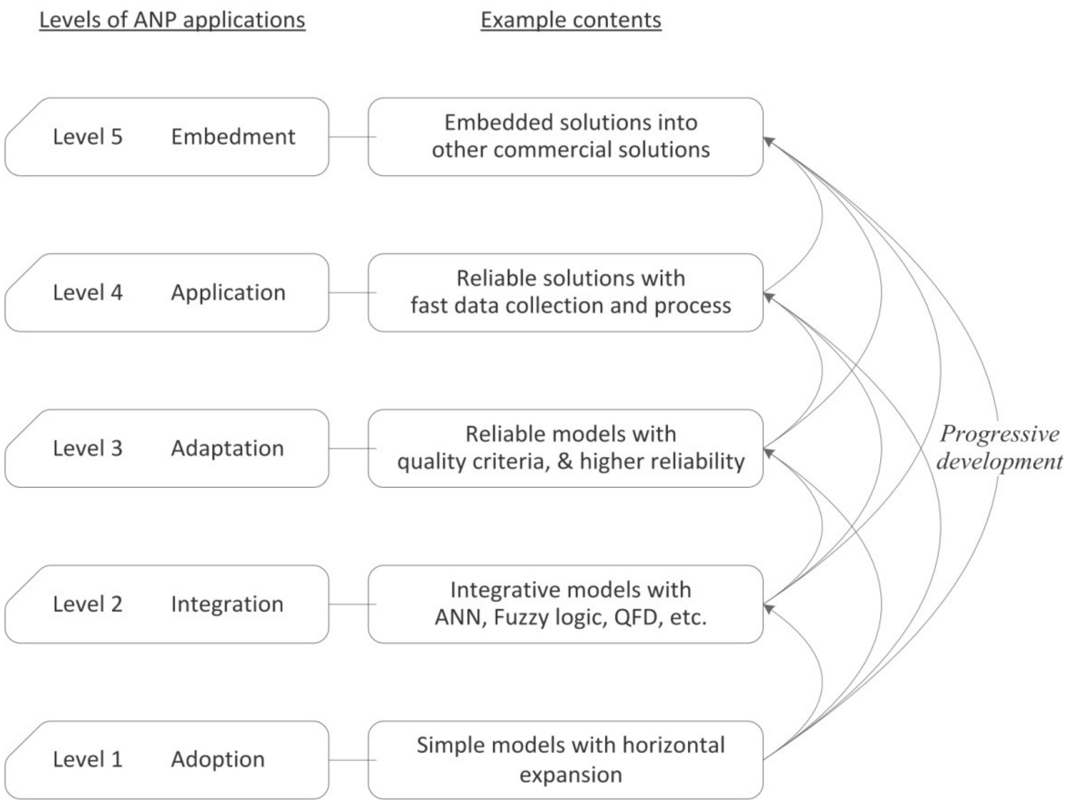

Figure 1: *Levels of ANP applications and example contents*

The third level of research into ANP applications, called Adaptation, focuses on reliable models in regard to the quality of criteria for ANP models, and the reliability of ANP models in decision making. In terms of the quality of criteria for ANP models, there are examples of using evaluation techniques such as the environmental impact index (EII) (Chen, Li, and Turner, 2008) to select appropriate criteria, and there are attempts to adopt a generalised classification of criteria regime such as the STEEP (social, technical, economic, ecological, and political) criteria (Chen and Khumpaisal, 2009a&b) for decision making in construction and development; and it has been proved through several case studies such as Liverpool One (Chen and Khumpaisal, 2009a) and the new Royal Liverpool and Broadgreen University Hospitals (Chen, 2008) as feasible approaches. In terms of the reliability of ANP models, there is an attempt to quantitatively measure the reliability of evaluation such as the reliability of facilities' evaluation (Chen, 2009) derived from ANP.

The fourth level of research into ANP applications, called Application, focuses on reliable solutions in regard to fast data collection and process for model construction prior to ANP calculation. It has been realised through research that it is time consuming to use questionnaire to complete all pair-wais comparisons for any ANP models and sometimes it may be not realistic to get enough inputs from questionnaire survey, especially when the number of criteria is bigger. In terms of fast data collection from questionnaire survey, the key is to reduce the entire number of pair-wise comparisons for setting up the whole ANP model instead of the number of participants whose expertise is valuable for knowledge reuse in ANP. In terms of fast data collection, there are several examples to adopt an advanced technique called PairWiser (Chen, et al., 2008) to fundamentally change the way of getting data of pair-wise comparison through questionnaire survey so as to significantly reduce the total number of inputs from experts in the survey, and this change makes it possible to regulate any questionnaire with reasonable number of assessment criteria within one or two pages, which makes it very convenient to answer by experts and possible at the end to have a good response rate from questionnaire surveys. Although PairWiser tool enables fast data collection and process, there are still further requirements in regard to a wide range of applications. For example, there should be a solution to accelerate data transfer from the PairWiser led questionnaire survey.

The fifth level of research into ANP applications, called Embedment, focuses on embedded solutions into other commercial or professional solutions for construction and development. In terms of embedded ANP solutions into other possible systems to support decision making in construction and development, there has been some research initiatives in the past several years. For example, the ANP model can be embedded into an experts system (Chen, 2007a&b) for remote management against problems happened during either construction or operation of facilities, and the ANP embedded solution for such a remote experts system was designed according to systemic analysis using cybernetics, which is an ideal tool for strategy analysis of embedded system development. The embedment of ANP and other related solutions aims to create synergy environment for higher level of powerful decision making, and ANP can therefore play a crucial role in the chorus.

The ten *Progressive development* connectors between paired levels in Figure 1 indicate possible routes for research into contents related topics at upper levels, and it is a summary based on literature review of research into ANP applications related to construction and development since 2003. For more ANP applications in this domain, Figure 1 provides a generic guide in terms of the scope and distance of research and development and can be used as a framework of further deployment. However, it has also been noted that the adaptation of reliable ANP models with quality criteria at middle level is the connection from basic models at two lower levels to advanced models at two upper levels, and it is extremely important to define a set of high quality criteria in regard to their relevance and accuracy in any specific evaluation led by ANP.

Based on the review into ANP applications in construction and development projects, this paper aims to make a further study on a generic set of criteria for ANP models, and this is conducted in a scenario, according to preliminary research into risk assessment (Chen and Khumpaisal, 2009a&b) and facilities evaluation (Chen, 2008, 2010), that there is a generic set of criteria that can be selectively adapted for any ANP models for decision making in construction and development. To achieve this target, this paper first provides a general discussion on the proposed generic set of criteria against STEEP issues related to construction and development, and then describes an example set of criteria developed for specific evaluations, led by ANP, in real projects.

NEEDS OF ASSESSMENT

The needs of assessment or evaluation are obvious for any construction and development at different stages of its lifecycle. Examples of various needs of assessment are summarised in Figure 2. The needs of assessment are defined according to client's objectives for instance at different construction and development stages (CIOB, 2002), whilst the contents of assessment to fulfil those needs are defined by the areas of construction project management (PMI, 2003). From a generic point of view, Figure 2 provides a framework of the needs and contents of assessment across stages of construction and development, which is developed according two leading professional guides for project management in construction and development, and this makes the framework more meaningful in conducting assessment tasks for different projects. As the relationship between the needs and the contents of assessment is built on general objectives of stakeholders and general areas of management respectively in regard to the characteristics of construction and development projects, Figure 2 also reflects the necessity of incorporating a generic set of assessment criteria for decision-making models so that all influential factors could get a systemic involvement in each specific assessment such as project risk assessment and vendor evaluation and the involvement of influential factors could be justified according a selection mechanism such as EII (Chen, Li and Turner, 2008) against all optional influential factors under a generic classification such as the STEEP regime. In this regard, the STEEP criteria system is one solution to fulfil the needs of assessment in construction and development project management.

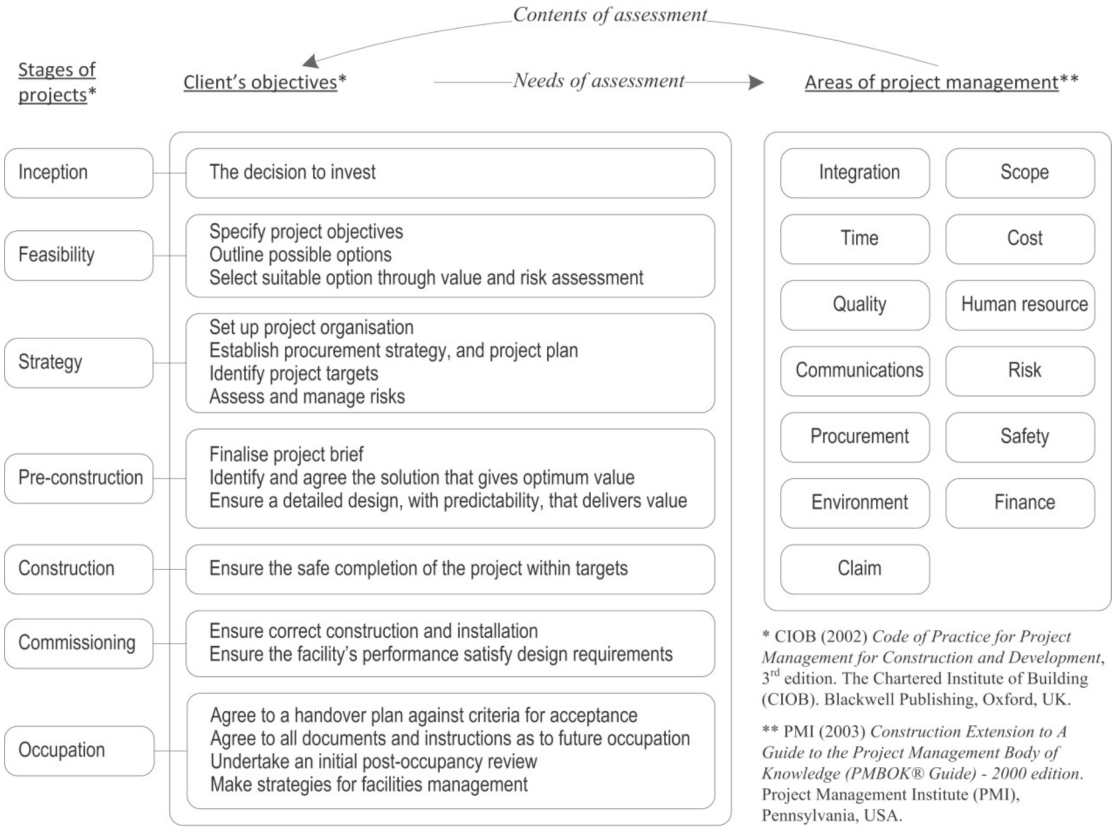

Figure 2: *The needs and contents of assessment across stages of construction and development*

STEEP CRITERIA

As mentioned above, STEEP stands for Social, Technical, Economic, Ecological, and Political. The STEEP criteria system is regarded as a generic form of associated evaluation criteria, which consist of a set of standard evaluation criteria for specific assessment purposes, and the STEEP criteria reflect the five aspects of assessment, which can be adopted with selected sub-criteria in assessment models such as ANP models. Although all assessment problems can be evaluated by using STEEP criteria, the set of sub-criteria is different from problem to problem under the STEEP framework in regard to various internal and external characteristics and circumstances of specific scenario of decision making. Namely, it is necessary to generate a specific set of STEEP sub-criteria for individual decision-making problem. In terms of the advantages of using the rationale of STEEP criteria to generate assessment criteria and associated sub-criteria to fulfil specific requirements in decision making, it can increase not only the relevance but also the effectiveness and efficiency to format such a set of criteria.

Generally speaking, factor selection is crucial in regard to the accuracy of results in any decision making. In another word, it is essential to select a set of appropriate criteria prior to making a decision-making model. If this scenario is acceptable, it therefore puts forward a task to define a set of criteria for a specific decision target. In regard to establish STEEP criteria, a three-step process is recommended below:

- Step 1. Factor finding
- Step 2. Factor evaluation
- Step 3. Criteria establishment

Step 1 aims to collect a number of factors, which may influence the target of decision making, as comprehensive as possible no matter they are highly or less relevant to the problem. In order to find those required factors, literature review and questionnaire survey are two main methods, which can get benefit from an intended brain storming process. In regard to the intention of finding a large group of factors with comprehensive coverage to a specific decision making target, it is not appropriate to use these raw materials without any further process to set up a decision making model. Therefore factors collected from the first step need to be evaluated.

Step 2 aims to evaluate all factors collected in Step 1 by using a quantitative measurement process. In regard to setting up STEEP criteria, a new evaluation method is proposed in this paper. It is called STEEP gravity coefficient, which is a relationship measure of factors to become one of STEEP criteria. Table 1 gives a further explanation regarding how to use the method in factor evaluation. The scope is subjectively set up from 0 to 100 for each STEEP profile, and the scope is accumulated accordingly from 0 to 500 for the total STEEP gravity coefficient for each factor under evaluation. All profile scores can be subjectively achieved.

Table 1: *STEEP gravity coefficient for factor evaluation*

Factors	STEEP gravity coefficient (GC)					
	Social GC [0,100]	Technical GC [0,100]	Economic GC [0,100]	Ecological GC [0,100]	Political GC [0,100]	Total [0,500]
Factor 1						
Factor 2						
…						
Factor n						

Step 3 aims to select a number of factors based on the total scores they have got in factor evaluation In Step 2. It is easily a normal way to choose factors that have higher scores to set up a set of STEEP criteria. Despite the reasonable measurement conducted in Step2, there are further two concerns in the process of criteria establishment. The first concern is how many factors should be finally chosen in regard to the rank derived from Table 1, whilst the second concern is whether it is necessary to further introduce a mechanism to give either a functional weight to each factor or a proportion weight to each STEEP profile in regard to the nature of the decision target, and this leave a way forward for research into ANP applications at level 3 (see Figure 1). Therefore a modification to the results achieved from Table 1 is given in equation 1 and 2.

$$S_i = \omega_i \times \sum_{j=1}^{5} GC_j \quad (1)$$

$$S_i = \sum_{j=1}^{5} \lambda_j \times GC_j \quad (2)$$

Where S_i is the final score of factor *i*, ω_i is the entire functional weight of factor *i* in regard to the nature of the decision target, GC_j is the gravity coefficient of STEEP profile *j* ($j \in [1,5]$) subjectively decided by experts using Table 1, and λ_j is the proportion weight to each STEEP profile in regard to the nature of the decision target. Theoretically speaking, the selective use of any of the two equations can make it more objective in terms of the relation between factors and decision target although all scores are subjectively given.

AN EXAMPLE ANP MODEL

As summarised in Figure 1, there have been a number of ANP models developed for decision making in constriction and development since 2003. In regard to the use of STEEP criteria to set up ANP models, this section aims to present an example ANP model recently developed to demonstrate the feasibility.

In 2008, the Royal Liverpool and Broadgreen University Hospitals NHS Trust conducted a consultation (Chen, 2008) on plans for a new hospital to replace the Royal Liverpool University Hospital, and the following two options are proposed for the future provision of the hospital services in Liverpool:

- Option 1 - developing a new hospital building next to the existing Royal Liverpool University Hospital
- Option 2 - refurbishing the existing Royal Liverpool University Hospital

A report was prepared accordingly to provide result from an ANP model for life cycle value oriented assessment against a set of STEEP criteria for the two options.

In order to set up an ANP model for the proposed assessment between the two options, it is essential to define a list of assessment criteria and their measurements so as to facilitate the use of ANP in practice. In order to improve the quality of decision-making using ANP, it was noted that the criteria for assessment should be comprehensive and practical with regard to the sustainability requirements for the new hospital project. In this regard, literature review was conducted to form an initial list of assessment criteria as shown in Table 2 to cover general issues related to for life cycle value oriented assessment. There was not a further evaluation to filter initially collected criteria. Table 2 also provides related measurement approaches adopted to quantify those criteria, which are prepared for the ANP model. Figure 3 provides the ANP model set up based on the STEEP criteria.

CONCLUSIONS

This paper and presentation are prepared for the ARCOM doctoral research workshop 2010 on decision making. In regard to the STEEP criteria and ANP models, this paper and presentation first provide an extensive review into different levels of research accumulated since 2003 when the use of ANP in construction and development was originally explored. A framework to guide further research and development in ANP applications is therefore put forward according current research and potentials. The needs of assessment in construction and development are then discussed based on general needs of stakeholders such as the clients. Contents of assessment across stages of construction and development are also summarised in order to clarify the link between the reasons and the details of assessment. In addition, this discussion also aims to clarify the importance of introduce a formal set of STEEP criteria for ANP models. An example ANP model set up for the Royal Liverpool University Hospital project is used to demonstrate the effectiveness of further discussion on details of STEEP criteria and ANP model construction. In addition to a comprehensive review into STEEP criteria and ANP models in construction and development, this paper and presentation also leave space to discuss further research into related areas.

Table 2: *STEEP criteria for the Royal Liverpool University Hospital (Chen, 2008)*

Clusters	Nodes	Valuation methods
Social factors	Workforce availability	Degree of Developer's satisfaction to local workforce market (%)
	Cultural compatibility	Degree of business & lifestyle harmony (%)
	Community acceptability	Degree of benefits for local communities (%)
	Public hygiene	Degree of impacts to local public health & safety (%)
Technological factors	Site conditions	Degree of difficulties in site preparation for each specific plan (%)
	Designers and Constructors	Degree of Developer' satisfaction to their professional experience (%)
	Multiple functionality	Degree of multiple use of the property (%)
	Constructability	Degree of technical difficulties in construction (%)
	Duration	Total duration of design and construction per 1,000 days (%)
	Amendments	Possibility of amendments in design and construction (%)
	Facilities management	Degree of complexities in facilities management (%)
	Accessibility & Evacuation	Degree of easy access and quick emergency evacuation in use (%)
	Durability	Probability of refurbishment requirements during buildings lifecycle (%)
Environmental factors	Adverse environment impacts	Overall value of the Environmental Impacts Index
	Climate change	Degree of impacts to use and value due to regional climatic variation (%)
Economic factors	Interest rate	Degree of impacts due to interest rate change (%)
	Property type	Degree of location concentration (%)
	Market liquidity	Selling rate of same kind of properties in the local market (%)
	Confidence to the market	Degree of expectation to the same kind of properties
	Demand and Supply	Degree of regional competitiveness (%)
	Purchaseability	Degree of affordability to the same kind of properties (%)
	Brand visibility	Degree of Developer's reputation in specific development (%)
	Capital exposure	Rate of estimated lifecycle cost per 1 billion pound (%)
	Lifecycle value	25-year property depreciation rate (%)
	Area accessibility	Degree of regional infrastructures usability (%)
	Currency conversion	Degree of impacts due to exchange rate fluctuation
	Buyers	Expected selling rate (%)
	Tenants	Expected annual lease rate (%)
	Investment return	Expected capitalization rate (%)
Political factors	Political shifts	Probability for rapid political shifts (%)
	Regulatory Impact	Probability of regulatory impact (%)

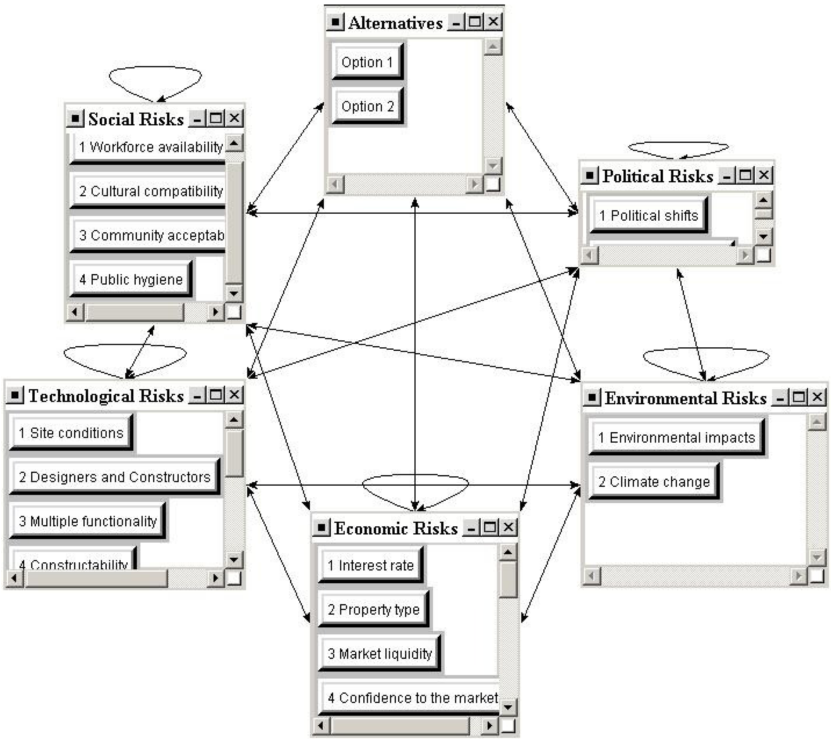

Figure 3: *The ANP model for the Royal Liverpool University Hospital (Chen, 2008)*

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DEMPSTER-SHAFER THEORY OF EVIDENCE IN CONSTRUCTION INDUSTRY; APPLICATIONS IN DECISION MAKING AND RISK ANALYSIS

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Decision making is an on-going task along the project life cycle. Decisions have in most cases multi-criteria to be considered in the case of uncertainty. They are also affecting different stakeholders and different project objectives. Researchers have researched different decision making theories and have come up with different tools to assist practitioners in making more informative decisions. There are many Decision Support Systems (DSSs) available for practitioners. Unfortunately, in reality they are rarely used. Instead, practitioners used to relay upon their personal judgment, past experience, intuition and gut feeling. The author argues that decision making in construction industry can be better handled by following an Evidential Reasoning (ER) methodology based on Dempster-Shafer Theory of Evidence. Incomplete information and ignorance, which are typical problems in construction industry, could be better handled by using distributed belief assessments. The limitations of the existing assessments' aggregation methods can also be overcome by deploying Dempster rule of evidence combination. The author argues that such approach can help in bridging the gap between theory and practice. It can also help in producing usable DSSs by structuring practitioners' past experiences and focusing on their believes for making more informative decisions for the future. An extensive literature review conducted by the researcher shows that it is the first time that such an approach is ever used for handling decision making in construction industry.

Keywords: decision making, construction project, evidential reasoning, D-S theory of evidence, Dempster rule of evidence combination, past experience, belief & gut feeling

INTRODUCTION

Construction industry has a very risky and complex nature. Risk is associated with every project and each process and decision throughout the project life cycle (BS IEC 62198:2001). Along the project life cycle (PLC) there are many decisions to be made. Unfortunately, the most crucial ones are to be made in the early stages where very limited precise information is available to support the decision maker. Gradually more information become available and uncertainties decrease. Having appreciated that, researchers have worked hard to create models and decision support systems to support the decision makers in the critical early stages. They have focused their works on main decision making tasks like: bid/no bid, mark-up estimation, project cost and duration estimation, contractor/ subcontractor qualifying and project risk analysis and assessment. Several DSS development techniques have been used in construction industry. The choice of an appropriate technique depends mainly upon the difficulty at knowledge acquisition, required data, explanation capacity, difficulty at development and the appropriate domain (Baloi and Price 2003). Fuzzy Set theory (FST) and the Analytic Hierarchy Process technique (AHP) are extensively used for dealing with risk assessment and decision making in construction industry. They have been used by many researchers like: [(Lai *et al*. 2008), (Zeng *et al*. 2007), (Zhang and Zou 2007), (Mahdi and Alreshaid 2005), (Shang *et al*. 2005), (Al-Harbi 2001), (Leu *et al*. 2001), (Carr and Tah 2001), (Ziad and Ayyub 1992)]. Both FST and AHP have their own limitations. Although there is no best theory of uncertainty (Baloi and Price 2003), the author argues that decision making under risk and uncertainty in construction industry can be better handled by following an Evidential Reasoning (ER) methodology based on Dempster-Shafer Theory of Evidence. It will be more suitable for decision making and risk assessment in construction industry in which practitioners are mainly depending on subjective probability and personal judgment.

In addition to the technical limitations of any decision making methodology, there is a question about its usability and popularity among practitioners. There are many Decision Support Systems (DSSs) available for construction practitioners. Unfortunately, such DSSs are not widely used. The usual practice, however, is to make decisions on the basis of intuition, derived from a mixture of gut feeling, experience, and guesses (Ahmad 1990). The author believes that this reality has to stimulate efforts towards producing more applicable and usable DSSs. Besides the reliability and the accuracy of the obtained results, practicality of the DSS, which includes the users' perspectives and their experience, should be a main feature of any DSS.

In this paper, the author is aiming at illustrating the suitability of using Dempster-Shafer theory of Evidence to handle the task of decision making in construction industry. First of all, there will be a brief summery of the limitations, as stated in literature, of the widely used FST and AHP for decision making in the case of uncertainty. This will identify the required features of an alternative approach in order to be an original contribution and a vital alternative to the existing ones. Then, there will be a separate section for highlighting the merits of the proposed methodology and its specific features, advantages and possible limitations.

THE LIMITATIONS OF FST AND AHP

FST and AHP have been widely used by researchers in attempt to tackle the problem of ill-defined and ill-structured problems of decision making and risk assessment in the presence of subjectivity and lack of precise information. These two techniques have shown accepted performance. However, they have their own limitations and shortcomings.

The limitations of FST

According to Dikmen *et. al.* (2007), FST provides a useful way to deal with ill-defined and complex problems in a decision-making environment that incorporates vagueness. However, they claimed that one of the reasons why FST is not widely used in practice may be attributed to its computational complexity. Kangari and Riggs (1989) mentioned another three limitations of the FST. These limitations are:

1- a problem of how to assign the membership values of a fuzzy set to represent a linguistic variable. The author believes that this problem reflects the difficulty in interpreting or understanding the actual meaning of linguistic variables by different people. It is by itself composes another dimension of uncertainty.
2- A of how to perform arithmetic operations
3- And a problem of associating the final fuzzy set in a series of calculations with a linguistic variable. They mentioned that a generally used technique involves calculating the Euclidean distance between the fuzzy set under question and a set of benchmark fuzzy sets. The fuzzy set under question thus takes on the linguistic characteristic of the closest of the benchmark fuzzy sets.

Tah and Carr (2001) mentioned the limitation of FST when aggregating assessments. The existing methods produce an average assessment. The averaging methodology may not be suitable for producing reliable overall assessment. The author believes that this limitation in FST is very critical especially when the decision making aim is, for instance, not to assess a risk by itself but to assess the risk level of a project as a whole. Hence, there is a real need for a suitable aggregation rule to suite the decision making task and not to only average the initial assessments.

The Shortcomings of AHP

In one of the earliest attempts to use AHP in construction industry, and the first use of it specifically for assessing construction risk, Mustafa and Al-Bahar (1991) applied the concept of value and weight in AHP for assessing risk probability and impact. They found it providing a valuable support for decision making process especially because of the systematic thinking environment it offered. However, they mentioned two concerns regarding the efficient usage of it. These concerns are:

1- Building the hierarchy with (7 ± 2) elements under any node in order to preserve consistency as recommended by the founder of AHP himself. This raise a question of how to handle cases where the number of elements is greater than 9. Mustafa and Al-Bahar (1991) illustrated a solution to this case by grouping the elements in clusters and then merging these comparable clusters.
2- The number of judgments required to derive relative priorities. It seems that AHP needs (n - 1) judgments to relate one element to the remaining (n - 1) elements. From these judgements, one can construct all other comparisons by forming ratios. This approach could be used when assessing tangible criteria. However, when one is dealing with intangible criteria it is much difficult. Mustafa and Al-Bahar (1991) argued that in such circumstances, one is no longer certain of the precise correspondence of the strength of a judgment to a numerical value, which represents that judgment, nor he/she is certain of the judgment itself.

According to Sen and Yang (1998), the large number of judgments required often causes inconsistency problem. Belton and Stewart (2002) argued that conducting sensitivity analysis in AHP is not practical because of the huge number of judgments involved and also because of the use of eigenvector method to derive preference vectors.

These concerns have been mentioned be researchers from AHP practicality point of view. However, there are other concerns from theoretical point of view. According to Belton and Stewart (2002) one of the concerns about the AHP is the Rank Reversal Problem. Rank Reversal refers to the fact that in certain situations, the introduction of a new alternative which does not change the range of outcomes of any criterion may lead to a change in the ranking of the other alternatives (Belton and Stewart 2002). Xu and Yang (2001) argued that when new alternatives are added to AHP, the assessments done on the old alternatives have to be discarded. A new assessment procedure has to start from the beginning, taking into account the whole alternatives. Belton and Stewart (2002) stated that some concerns have been expressed in literature concerning the appropriateness of the conversion from semantic to numeric scale used to measure the strength of preference. According to them, the general view, supported by experimental work, seems to be that the extreme points of the scale defined semantically as “absolute preference” is more consistent with a numeric ratio of 1:3 or 1:5 than the 1:9 used in AHP. Sen and Yang (1998) mentioned another theoretical limitation of AHP. According to them, AHP has a limitation as it implicitly assumes that elements at any single level in the hierarchy except the bottom one, the alternatives, are preferentially independent. They argued that an evaluation of an attribute in real MCDM problem may most probably depend upon the achievement level of other attributes.

D-S THEORY OF EVIDENCE IN CONSTRUCTION INDUSTRY:

D-S Theory of Evidence

The Dempster-Shafer theory of evidence was established by Shafer (1976) for representing and reasoning with uncertain, imprecise and incomplete information (Smets 1988). Dempster proposed his new system of dealing with uncertainty because of two shortcomings he saw with probability theory:

1- the difficulty of representing ignorance. In probability theory, ignorance is represented by assigning equal prior probabilities to all events which is surrounded with difficulties and limitations. In such representation, there is no distinction between randomness and ignorance.

2- the requirement of subjective belief in an event and its negation to sum to one. Dempster claimed that in many situations evidence that supports one hypothesis should not necessarily decrease the belief in all others (Dempster 1969). In D-S theory, there is no requirement that belief not committed to a given proposition must be committed to its negation. This makes the total allocation of belief can vary to suit the extent of knowledge of the decision maker.

According to Denoeux (1999), D-S theory of evidence distinguishes between uncertainty and ignorance by introducing belief functions that satisfy axioms that are weaker than those of probability functions. Thus, probability functions can be looked at as a subclass of belief functions, and the theory of evidence reduces to probability theory when the probability values are known. In addition, the theory of evidence provides appropriate method, Dempster rule for evidence combination, for computing belief functions for combinations of evidence.

Liu *et al* (2003) summarized the advantages of the Dempster-Shafer theory as follows:

1) It has the ability to model information in a flexible way without requiring a probability to be assigned to each element in a set,
2) it provides a convenient and simple mechanism (Dempster's combination rule) for combining two or more pieces of evidence under certain conditions.
3) It can model ignorance explicitly.
4) Rejection of the law of additivity for belief in disjoint propositions.

Liu *at al* (2003) also listed the disadvantages of the D-S theory as follows:

1) The theory assumes that pieces of evidence are independent which is not always reasonable to assume independent evidence.
2) The computational complexity of reasoning within the D-S theory could be one of the major points of criticism if the combination rule is not used properly.
3) D-S theory only works on exclusive and exhaustive sets of hypotheses.

As mentioned earlier, there is no best theory to handle uncertainty. D-S theory of evidence is, in comparing with fuzzy set theory and probability theory, richer in terms of semantics. It allows an expression of partial knowledge. However, its main shortcoming is the elicitation and interpretation of belief function (Baloi and Price 2003).

Evidential Reasoning for decision making in construction industry

The ER approach is the latest development in (MCDA) area (Yang 2001). It is based on D-S theory which is powerful evidence combination rule and well suited for handling incomplete uncertainty (Yang and Singh 1994). It uses an evidence-based process to reach a conclusion which differs from traditional MCDA methods (Xu and Yang 2005). Also, ER approach is different from most conventional MCDM modelling methods in that it employs a belief structure to represent an assessment as a distribution [(Xu and Yang 2001), (wang and Elhag 2007)]. It uses an extended decision matrix, in which each attribute of an alternative is described by a distributed assessment using a belief structure. Each belief structure in the belief decision matrix can be transformed into a basic probability assignment (BPA) by combining the relative weight of the criterion and the degrees of belief. Each BPA is viewed as a piece of evidence. The pieces of evidence are subsequently combined into an overall BPA by the Dempster's rule of evidence combination (Wang and Elhag 2007).

In the extended decision matrix, each attribute of an alternative is described by a distributed assessment using a belief structure (Xu and Yang 2001). Hence, each figure in a decision matrix is actually a distributed assessment, i.e. a set of figures.

For example, Suppose there is a decision making problem with *M* alternatives, *Ai (i=1, …, M)*, to choose from and *N* criteria, *Cj (j=1, …, N)*, to consider. The assessment of each alternative according to different criteria is to be conducted using, for instance, four evaluation grades *G = {G1 , G2 , G3 , G4 }*. These grades are to be deployed in each cell of the decision matrix to provide the distributed assessments.

Hence, the assessment of an alternative *A1 on* a criterion *C1* can be represented using the following belief structure:

S(A1(C1)) = { (b11,G1), (b12,G2), (b13,G3), (b14,G4)}

Where *b11, b12,b13,b14* are the degrees of belief that the alternative *A1* is assessed to the evaluation grades *G1, G2, G3, G4* when considering the criterion *C1*. These degrees of belief are expressed by the decision maker and the value of each of them fall in the rang [0-1].

The author argues that an *evidence-based* MCDA framework could provide better alternative to the widely used AHP and FST. Moreover, having reviewed the literature, the author argues that till now an ER approach based on DST has never been used for decision making in construction industry away from one research for qualifying contractors conducted by Sonmez *et al.* (2001). Such approach will have a maximum deployment of the cumulative practical experience of the decision maker. These feature will satisfy the practitioners and respond for their aspirations. It can be an original contribution to knowledge and a step forward in the field of decision making in construction industry.

CONCLUSIONS AND COMMENTS ON THE ER APPROACH BASED ON DST

To summarize, the existing tools for supporting decision making in construction industry have not fully appreciated the special nature of this industry. The available tools or theories maybe very attractive however, the special nature of construction industry and the type of decision making tasks in it require different approaches. Personal experience, gut feeling and intuition still the key methodology adopted by practitioners. The author argues that researchers have to satisfy these stakeholders by providing usable tools based on sound theoretical bases. The author argues that an ER approach based on D-S theory of evidence could be vital response to these aspirations. The author believes that the illustrated approach is a sophisticated and detailed one which can provide a very accurate and reliable tool to suite the ever growing complexity in construction industry. Besides the parametric picture of the obtained assessment, an average assessment score can be easily obtained by applying weighted averaging operations. The number of evaluation grades can be determined according to the complexity of a project and the level of detailed analysis required.

Although it looks very effective way for capturing a reliable assessment, the author is concerned about the usability of the proposed approach due to large number of required assessments and inputs. This issue is to be dealt with by making a fair compensation and trade off between accuracy and practicality.

Other concerns may be raised by experts or practitioners when the approach is tested with real cases. The researcher is aiming to discuss this approach with experts in order to get their feedback. Moreover, he is planning to adopt the case study research methodology in order to validate and test the approach by applying real cases with practitioners in construction industry. It is very important to get the feed back of the practitioners and to respond to their concerns in order to achieve the ultimate aim of this research project which is trying to help in bridging the gap between theory and practice in construction decision making and risk assessment.

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