ARCOM

Doctoral Workshop

Construction Process Research

Chairman: Professor Tony Thorpe

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Loughborough University

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ARCOM DOCTORAL RESEARCH WORKSHOP

Construction Process Research

David Collett Hall, Loughborough University.
Wednesday 16th February 2000, 11.00-17.00.

Chairman: Professor Tony Thorpe, Loughborough University

10.30 – 11.00	Coffee	
11.00 – 11.10	Welcome and introduction to the day	Dr Andrew Dainty, *Coventry*
11.10 – 11.20	Introduction to process research	Prof Tony Thorpe, *Loughborough*
11.20 – 11.50	*Communication and decision-making as a means to determine project organisation structure*	Mike Murray, *Strathclyde*
11.50 – 12.10	Discussion and questions	
12.10 – 12.40	*The process approach to project risk management*	Adam Greene, *Loughborough*
12.40 – 13.00	Discussion and questions	
13.00 – 14.00	Lunch	
14.00 – 14.30	*Stochastic planning of concrete placing operations*	Paul Dunlop, *Edinburgh*
14.30 – 14.45	Discussion and questions	
14.45 – 15.15	*Case studies in construction process improvement*	Matthew Finnemore, *Salford*
15.15 – 15.30	Discussion and questions	
15.30 – 16.00	Tea	
16.00 - 16.30	*Developing an expert system in order to improve the efficiency of building projects*	Joanna Poon, *Wolverhampton*
16.30 – 16.45	Discussion and questions	
16.45 – 17.00	Summary and conclusions	Prof Tony Thorpe, *Loughborough*
16.30	Close	

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COMMUNICATION AND DECISION-MAKING AS A MEANS TO DETERMINE PROJECT ORGANISATION STRUCTURE

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ABSTRACT

Communication has been described as the 'social glue' that ties members of project teams and other organisational subunits together. Indeed, the pattern of relationships that are planned or emerge during group interaction constitute a group structure. Moreover, communication and group interaction are commonly cited with reference to the quality, effectiveness and satisfaction of group decision-making. Construction project teams are commonly referred to as temporary multiorganisations and for the purpose of this research the 'key' design and construction team members (Client, Architect, Project Manager, Contractor, Quantity Surveyor, Services & Structural Engineers) communication profiles are investigated.

This paper discusses preliminary findings derived from a longitudinal investigation of twelve construction projects located in the central-belt of Scotland. Critical incidents (project problems) are used as a unit of data whereby the communication network is exposed following a study of team interaction (as a means to resolving the 'critical incidents') during the decision-making process. The twelve projects cover the various procurement routes (Traditional, Design & Build and Management methods) and the extent to which they inform Formal / Informal communication configurations and Decision-Making Schemes are discussed.

Keywords: Communication, decision-making, organisational structure

INTRODUCTION TO PROJECT ORGANISATIONAL DESIGN

The question to whether the construction process can be formally designed appears to be contentious. Tatum (1984) examined eight projects in the USA, concluding that project managers do not use systematic methods in designing organizations. Tatum observed that projects were structured primarily by using an 'adaptation process' where managers used experience because 'time limitations prevented [evaluation] of alternatives'. Indeed, McClellan (1994) observed that due to compressed 'lead-in' time many project managers have little or no opportunity to consider the organisational structure to be adopted for a project. Moreover Bryman *et al* (1987) in considering the construction project as a temporary system conclude that anecdotal evidence supports the proposition that project structures 'emerge'. This lack of formal project 'structuring' is seen by several authors to cause confusion within projects.

Gray & Suchoki (1996) examine the benefits of rapid project team integration, but conclude that people are poorly introduced to their specific roles on a project. Payne (1993) reiterates this point, stating 'incorrect project structures lead to frustration, low morale and poor motivation'. However the decision to 'pre-plan' a project structure requires significant input of resource, since construction projects are generally considered to be 'complex in nature' (Luck & Newcombe, 1996). There is evidence to suggest that project structures are designed, guidance being offered to would-be designers by Walker (1980), and latterly Hughes (1989). Both authors recommend project structures should be designed in advance, proposing prescriptive management tools and techniques for structuring projects.

Moore & Moore (1997), who again argue in favour structuring projects, emphasise flexibility and an open systems philosophy. This possibly confirms the findings of Morris (1972) who noted that project organisation flexibility increases when environmental rate-of-change and degree of uncertainty increases. However other authors suggest that projects should be formally designed using project management tools

and techniques. Aykas (1996) for example sees the use of Work Breakdown Structure (WBS) and Organisational Breakdown Structure (OBS) as means of integrating a project network structure. Ribeiro's (1998) case study based research found that a key element to the project structure was a procedure manual.

IS ORGANISATIONAL STRUCTURE COMPLETELY DEFINED?

Perhaps the most appropriate starting point of this section would be to consider the analogy that Hall (1997) uses in comparing organisational structures to those of buildings. Although he recognises that this analogy is not perfect it is acknowledged that both 'buildings and organisational structures (and the explanations thereof) are subjects of fads and fashions'. Hall delivers a comprehensive view of what previous authors see as structure, referring to studies by the likes of Weber (1947), Burns and Stalker (1961), Hage (1965) and Blau (1974). Definitions of structure range from the macro, i.e. those describing bureaucracy vs authority, or mechanistic vs organic properties; to the micro, i.e. those detailing roles, formalization and centralization properties. Hall warns that multiple explanations of structure exist, and therefore welcomes a 'healthy and informed eclecticism' among the academic community. Hall outlines two views which are pertinent to any study of this nature and are worthy of keeping in mind for any 'structural' researcher. These are:-

1. The overwhelming majority of studies of organizational structures wittingly or unwittingly make an assumption that there is a structure in an organization.

2. There are multiple explanations of structure. When explanations are taken singly, in opposition to one another, or outside their historical and cultural context, they offer little. When combined and in context, we are able to understand how and why organizations take the forms they do.

The need to maintain impartiality and consider several views, without being swayed by current management 'fad', is highlighted by Vroom (1997). Vroom observes that 'both organisational processes and [thinking] are subject to ongoing development', therefore it is a 'waste of time' to lend permanence to empirically valid theories of organisational process. This appears wise advice given mainstream management research rarely considers application of theories and models to the construction process, this being left to the growing band of construction management academics. It gains further relevance in view of the UK construction industry's fascination with recent reports from Latham (1994), Egan (1998) and Reading Construction Forum (1999). All these reports propose utilising such panaceas for the construction industry as 'lean construction', 'concurrent engineering', 'partnering' and supply chain management. Uptake of any or all of these principles implies a significant reorganisation of project structures, which should be thought of as a forced requirement to design construction project organisational structures.

It is worth noting the evolving nature of construction management research as theories of organisational structure are proposed, validated, re-evaluated and replaced regularly. Green's (1999) review of the adoption of 'lean' philosophy in the UK construction industry is critical of the Egan Report's 'seemingly blind faith in the principles of lean thinking', going on to describe Womack and Jones' *The Machine that Changed the World* (1996) as 'guru-hype'. Strong words, yes, but Green is probably right in calling for more balance in research agenda, and one where the academic community ensure that counter arguments are heard.

Overall it would appear that there are a number of competing views that should be taken into account when analysing and describing organisational structure. However, it is undeniable that in any organisation, communication is its life blood. An analysis of the pathways that communications follow, their frequency and the decisions that result from them will define the structural characteristics of the organisation and it is communication as a surrogate of structure that will be discussed in this paper.

STRUCTURE 'MAPPED OUT'

It would seem that guidance is needed to allow the use of 'structural' and 'communication' theories to be applied to project environments which are not only 'temporary multi-organisational' but also multidisciplinary. This was sought in the work of Weinshall (1979) who introduces tools which can be used

to measure managerial relationships and interactions in organizations. Indeed Weinshall suggests that the 'most important problems confronting [organization leaders] are how to describe [their organisational structure] to themselves and others, and [to] decide when, where, and how to introduce changes in their organizationaal structures'. Weinshall critiques the various organizational charts that can be used to describe organizational structures (Fig. 1).

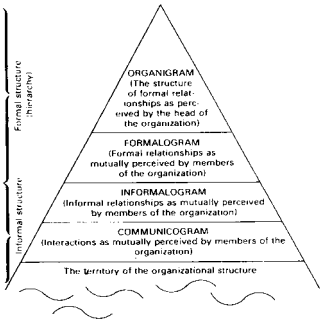

Fig 1: Tools used in measuring managerial relationships and interactions (from Weinshall, 1979)

The Organigram can be compared to a map or an aerial photograph where linkages between individuals are identified. The Formaligram and Informaligram (also known as a Sociogram) describe the relationships as viewed by the organisations participants. These are useful insofar that they can highlight disagreements and omissions between people as to their roles relative to each other. However Weinshall points out their shortcoming in that neither are capable of dealing with communication dynamics in the time dimension. Moreover, Weinshall examines other research in this field that indicates more serious shortcomings, the most important of which that, unless the meaning and character of a communication are perceived identically by those participating in the interaction, a break occurs in the communication network.

Weinshall developed a conceptual tool - a communication chart or communicogram - used to measure aspects of interaction among management employees in a manufacturing company. The findings of Weinshall's work was pertinent to the research described here. It found that when perceived interactions were checked against each other for a concensus of their occurrence, it transpired in only 25% of cases were the perceptions of one party reciprocated by the other. 75% of reported interactions thus registered in the mind of one party only, and therefore could be regarded as 'lost' from the communication point of view.

INTERORGANIZATIONAL STRUCTURE

The field of interorganizational analysis has been described by Hall (1987) as a 'complex and potentially confusing enterprise'. Moreover Oliver and Ebers (1998) note that the richness and variety of research in this over recent years is 'breath-taking'. However they are critical of this growth in the number of studies in that it has not ensured a clear accumulation of knowledge or conceptual consolidation. It is interesting, although not unusal, to note that no studies concerning construction interorganisational teams can be found in 'mainstream' management journals. This would appear to be a wasted opportunity as construction teams also provide the researcher with added factors such as 'interdisciplinary' and 'sentience' variables to investigate. Notwithstanding this, the construction research fraternity have produced acadenmic papers, both in journals and at symposiums which have examined variuos interorganizational topics such as power, political behaviour, trust etc. Moreover, current concerns with both project and strategic partnering, supply chain management and concurrent construction emphasise the importance of interorganisational analysis witthin the construction process. One aspect of interorganisational relations which concerns our research is that of communication between the project participants. O'Toole (1997) , having reviewed the 'scholarly literature'on interorganisational relations concludes that the subject of interorganisational communication has received relatively little sustained attention.

COMMUNICATION & DECISION-MAKING STRUCTURE

An analysis of communication patterns within organisations is now widely accepted as a means to determine the organisations structure. Several authors have demonstrated its significance, Conrath (1973) for example posits that organisational communication data may provide the essential ingredient for the study of organisation. Roberts and O'Reilly (1978) concluded that organisations can be described as complex, overlaid communication networks, while Weick (1987) confirms communications importance by stating that 'it is the essence of organisation because it creates structures'.

This approach to determining organisational structure sees interpersonal communication between individuals and groups within an organisation as a core variable rather than using other structure determining variables such as specialisation, formalisation, centralisation (Pugh et al, 1968). An alternative approach, but which can be closely allied to this approach is that of decision-making structures. Wofford *et-al* (1977) note that group communication is more frequently directed toward group decision -making than toward any other type of group objective. Hirokawa *et-al* (1996) in conducting a literature review, reveal conflicting views regarding the relationship between group communication and decision-making performance and note that 'a very confusing state of affairs' exist. They do though provide future researchers with an 'avenue to follow'and direct them towards answering questions including 'under what particular circumstances and conditions is group communication related to group decision-making performance? In light of this advice it is pertinent to investigate whether construction project organisations can be formally designed as either communication structures or decision-making structures, or indeed a combination of both.

FORMAL AND INFORMAL COMMUNICATIONS

The degree to which formal communication is made explicit within construction projects is commonly thought of as being dictated by a combination of procurement route and its associated contractual form. Formal project communication patterns are imposed on the project team and therefore considered to be pre-designed, rather than evolving. However anecdotal evidence would seem to suggest that project participants bring their own preconceived ideas to new projects regarding frequency and mode of communications they intend to adopt. These ideas are tempered by whether they have cooperated with other team members on previous projects and indeed how amicable those relations were. Furthermore, current interest in project partnering and its inherent philosophy of cooperation would tend to indicate that the divergence between contractually prescribed and actual 'on site' communication structures will continue to broaden.

One approach which emphasizes this dicotomy is examined by Dow (1988), who refers to two conceptual schemes of organizational structure; configurational and co-activational. The configurational view is represented by an organisational chart, or what Dow refers to as an 'archetypical' image. The organisational chart uses vertical lines, and hierarchical relationships to imply management authority. This is the view taken by those construction academics and practitioners who believe that project structures can or are formally designed. The coactivational view is that structure is inferred from regularities in the behaviour of project participants over time. A view reinforced by Wofford *et-al* (1977), whose examination of informal communication observed that 'people communicate… because [of] their own psychology, situational circumstances and because they want to… not because the organization tells them to communicate'. The research described in this paper seeks to expose the 'myth' that procurement routes and contractual conditions establish 'concrete' structural attributes (i.e. configurational) and that 'real life' communication and decision making behaviour can be used as a determinant of project structure (i.e. coactivational).

Informal communication practices within organizations have been widely examined in mainstream management literature. Krackhardt and Hanson (1993) provide an excellent metaphor for distinguishing between the formal and informal system. The formal being the 'skeleton' of a company, and the informal being the 'central nervous system' which drives the collective thought processes, actions and reactions of an organization's business units. It is perhaps the evolution and adaptive nature of these processes which lend credence to the concept of the 'evolving structural' perspective. Fisher (1980) suggests that communication should be thought less a structural entity and regarded more as a sequence of events which occur over time. The sequences become familiar as certain reactions tend to follow specific acts, and are repeated so often that an organization's actors come to expect the next act in sequence even before it occurs. However Fisher warns that past interaction sequences constrain future interaction of those communicators familiar with the appropriate sequence. To further emphasise the point, Wofford *et-al* (1977) use the

analogy of a learning curve for a football team, in which early season performance tends to be exceeded later in the seaon as team members' ability to 'read' one another improves.

This would tend to reinforce the position adopted by the proponents of strategic partnering. Benefits, it is argued, can accrue to the performance of a construction team as a synergistic relationship develops between participants. Also there is an advantage in that the learning curve associated with developing a relationship between professionals can be short-circuited. This could therefore be taken to emphasise the importance of informal relationships as opposed to those dictated by formal contractual obligation.

In his research into communications, Hill (1995) also makes an interesting observation regarding the relative effectiveness of formality and informality in communications. A participant in the study mentioned that informal communication was what 'got the job done'. Hill noted the description was effectively borrowed from a formal understanding of the purpose of an organization. Ironically it appeared that the informal operation of communication fulfilled the explicit objectives of the formal system - which in turn indicated that the formal system set up was actually incapable of 'delivering the goods' for the organisation. Hill's concluding remarks with regards to a lack of understanding of and research into informal communication practices is in some way being addressed in this paper. However, previous work by Dulaimi and Dalziel (1994) uncovered some interesting behaviour in a comparison between the level of management synergy in design and build projects with those procured under traditional means. Their results showed communication was in general more informal and frequent in design and build projects, and that greater satisfaction with communication was reported in design and build projects.

THE CONTRIBUTION OF THE TAVISTOCK INSTITUTE PAST AND PRESENT

Communication and Decision Making

Seminal work undertaken by Higgin and Jessop (1965) for the Tavistock Institute of Human Relations is perhaps the most detailed investigation into communications in the building process. Their pilot study resulted in a further report being published by Tavistock Publications (*Interdependence & Uncertainty : A Study of the Building Process*, 1966). Although both reports can now be termed 'historic' research (given both thechange in modern project environments and extensive use of 'hybrid' procurement routes) they do present several points of interest significant to the research presented in this paper. Firstly, Higgin and Jessop comment that '[a] network of communications is rapidly built up and it is this network which manifests the relationships of the building team and so can be seen to constitute its structure' (1965, p89).

Also significant in the context of this paper is that they observed an evolving organisational structure over the life of the project, noting that '[w]hen communication flow is broken or blocked, different organisational groupings arise [compared to] when the communication flow is integrated… [there is no] static organization, it evolves as [needs] for different kinds of information [change]' (1966).

Their report also proposed a speculative mathematical model, known as AIDA (Analysis of Interconnected Decision Areas), as a means of making decision making roles and responsibilities more explicit. Preliminary evidence from the current study would not however suggest that such types of formal decision making techniques are being used. Consequently the research forming the basis of this paper focuses on determining project structures from the communication and decision making patterns which emerge out of the selected project 'critical incidents' (see Table 2).

Project Structures

The Tavistock Institute continues to contribute to understanding in the field of construction management research and specifically into project organisational structures. Current research concerns two projects commissioned by the Ministry of Defence in joint venture with the Department of Environment Transport and Regions (DETR), Amec and Laing. The pilot projects have been selected to test new procurement arrangements incorporating supply chain management principles. Holti (1997) explains the concept of the 'Building Down Barriers' project as a need to design project based inter-organisational work systems. Preliminary reports on these projects (Building, 1999) indicate the biggest implementation challenge has been changing entrenched role and responsibility behaviours of project team members. The idea of 'work cluster' arrangements with designers, sub-contractors and key suppliers working together on self-contained elements of the building has required 'cultural' changes in both behaviour and thinking. The objective of

the Tavistock institute in designing and testing project structures should assist the research described in this paper. Specific findings about communication and decision making behaviour will be of significant use.

RESEARCH METHODOLOGY

Having conducted an extensive literature review both within and without construction texts, it is interesting to chart the development of research within the field of communication and decision-making. Historically research conducted in communication and decision making (Leavitt, 1949; Bavelas, 1950) was laboratory based, largely as a result of such research being more simple than the field alternatives. Davis (1953) describes the problem that 'methods of studying communication outside [laboratories are] fraught with difficulties of [both] field research [and] social science'.

Terborg *et-al* (1976) identify several problems intrinsic in small group research:-

1) It has been conducted largely in laboratory settings
2) It has involved ad-hoc rather than naturally occuring groups
3) The group is examined at one point in time as opposed to longitudinal research.

This paper reports on research which takes these concerns into account in that it examines communication and decision-making that takes place 'in real time and real life' - what the Japanese refer to as *genba genbatsu* (Hartley, 1990). It is perhaps the criticisms of previous methodologies adopted by 'structural' researchers, which has resulted in both the selection of the methodology and the research methods (tools) adopted. Chia (1997) for example critiques work undertaken by Woodward (1965), Lawerence and Lorsch (1967), the Aston Group (Pugh 1968), and other positivist studies by Chandler (1981). Chia suggests that such initiatives had significant impact on the direction organizational theory has developed. Pym (1990) observed that criticism of 'the scientific method' is fast becoming a popular sport, acknowledging that his own schooling was within the 'positivist' tradition but being critical of the 'enormous authority it continues to exercise over social enquiry to this day'. Emotive language is used to emphasize further displeasure with scientific enquiry when he states that, 'textbook science and its prescribed research methods are essentially fraudulent, collusive and contribute to a debilitating game'. Clark (1990) warns that the Western approach to organization design has been strongly shaped by the optimism of the founding period of organization studies in the early 1960s. Although Clark makes no direct reference to the likes of the Aston Group studies he refers to this 'era' of research as one where stong assumptions developed that organizations could be designed and could be changed in planned directions desired by management.

Project Incidents: A means of structural analysis

The thesis of this paper is that communication and decision-making behaviour during the project can be used as a means of determining its organizational structure. Some means of capturing this behaviour was therefore necessary. The initial two of the total of twelve projects which were examined as part of this research provided an opportunity to pilot several methods. It was originally envisaged that a project communication diary could be completed by the main project team members as a means to establishing a communication trail. This technique had already been used successfully by Loosemore (1996) in examining crisis management in building projects. However it was apparent at a very early stage that co-operation of this kind would not be forthcoming and that alternative collection methods were required. It was also evident at this time that project personnel would provide information more readily if recounted verbally. It was therefore decided to visit the design team members on a regular basis during the project, with a guarantee of complete anonymity to any and all findings from the interviews. Interviewees were asked to recount project incidents that had occurred between visits, the majority of which, it turned out, had detrimental consequences to the project. It became apparent that the recalled incidents had recurring similarities of scope and context, and that these could be developed into generic typologies (Table 1).

The visits to conduct these semi-structured interviews developed over time as the researchers and the subjects began to generate an understanding of each other's expectations from the interview. were much akin to storytelling sessions, on many occasions the interviewers being told this was strictly 'off the record', this being after initial assurances that complete anonymitiy was guaranteed. Several of the interviewees seemed even to enter into the spirit of the research and before recalling their 'story' suggested in a gleeful voice 'you'll like this one'. On numerous occasions the interviewers received the impression that they were in fact being treated like consultant psychiatrists - providing an opportunity for 'getting off their chest'

problems and issues that normally would be internalised. Frequently, subjects who would stated that they were 'very busy' and had 'no time to spare' when a half hour meeting was scheduled, would end up talking for very much longer - often in excess of an hour and a half. Although this provided a significant and welcome resource for analysis, it did create difficulties of having sufficient time to devote to each interview.

Table 1. Generated typologies

Typology	Project Detrimental (frequency)	Project Enhancing (frequency)
Roles and Responsibilities	⊗⊗	⊗⊗⊗
Location of team members	⊗	⊗
Selection of team members	⊗	⊗
Continuity of team membership	⊗⊗	
Communication issues	⊗⊗⊗⊗⊗⊗⊗	
Design / detailing issues	⊗⊗⊗⊗⊗⊗⊗⊗⊗	⊗
Organisational politics	⊗	
Supplychain management	⊗⊗⊗	⊗⊗
Subpackage integration	⊗⊗	
Project location	⊗	⊗
Historical trade loyaties	⊗	
Macro-economic pressures	⊗⊗	
Planning control issues	⊗	
Client Internal Issues		

Table 1 shows the number of incidents recounted within each category for one project. It was decided to not present interviewees with typologies, since they may try to fit their 'stories' into an appropriate category rather than recounting them freely. The research team allocated incidents into typologies later, using rule based analysis of each project incident. It is important to mention that the initial intention to record and process full interview transcripts was discarded rapidly due to the excessive time required to complete them. The interviews were therefore recorded in 'semi-shorthand'. One aspect of these incidents related by almost all interviewees, was that the incidents were unintentional, and created periods of uncertainty in decision-making outcomes. Furthermore it was felt that these incidents were critical to project success, and mirroring Loosemore's research, constituted crises and developed a forced response of the system under observation.

Table 2. Decision making involvement questionnaire

	Implication of the problem	Decision to solve problem	Who did you communicate with?	Main 'actor' (s)	Degree of Involvement in decision	Degree of satisfaction in decision
Story 1: Bin store size & location	Can't open on time, bookings cancelled.				1. Heavily involved 2. Reasonably involved 3. Moderately involved 4. Minor involvement 5. Not involved	1. Extremely satisfied 2. Reasonably satisfied 3. Moderately satisfied 4. Moderately dissatisfied 5. Reasonably dissatisfied 6. Extremely dissatisfied
Story 2: Who is responsible for design	Integration of packages when detailing is a 'fuzzy area'.				1. Heavily involved 2. Reasonably involved 3. Moderately involved 4. Minor involvement 5. Not involved	1. Extremely satisfied 2. Reasonably satisfied 3. Moderately satisfied 4. Moderately dissatisfied 5. Reasonably dissatisfied 6. Extremely dissatisfied
Story 3: Multi-headed client	Difficult to get a decision consensus, minds change				1. Heavily involved 2. Reasonably involved 3. Moderately involved 4. Minor involvement 5. Not involved	1. Extremely satisfied 2. Reasonably satisfied 3. Moderately satisfied 4. Moderately dissatisfied 5. Reasonably dissatisfied 6. Extremely dissatisfied

The pilot projects provided evidence that it would not be possible to trace communication and decision-making behaviour for all incidents recorded. This not only being as a result of interfering with the work of the interviewees , but also the work load which would be imposed upon the research team. It was decided that the incident categories with the highest recorded incidents would be examined, and that two or three incidents which representing this category would be examined for communication and decision-making behaviour. Table 2 shows an example of the questionnaire that was used to enable this to take place.

Previous research conducted outwith the construction sector, but nonetheless, within an interorganizational project setting was seen to be of use as a correlation to the current research. The research undertaken by Bodensteiner (1970) and refered to in Wofford *et-al* (1977) provides several interesting points, These being

(1) The utilization of interpersonal communication channels is a function of project problems and the associated stress and uncertainty.
(2) Individuals distinctly prefer the richer face-to-face and telephone channels to formal, documented channels when faced with problems, stress, and uncertainty.

Quantifying Formality and Informality of Communications

The Tavistock pilot study provided the research described in this paper a framework for assessing formal and informal communications. Formal communications are categorized as 'those having some concrete form and provide a record, informal being those that do not automatically leave a record'. Interestingly Higgin and Jessop (1965) reference the use of 'trivia' (doodles on envelopes, sketches on menus, calculations on tablecloth!) as informal communication, and state that they were 'struck by the number of examples [in] which quite cruicial pieces of information essential to important decisions have been made in this way'.

Although the research described in this paper avoids using 'traditional' organisational structure descriptors, the use of communications formality previously helped the efforts of other researchers such as the 'Aston Group.' Pugh *et-al*'s (1968) research of fifty-two organisations used six structural dimensions. These dimensions being specialization, standardization, formalization, centralization, configuration and traditionalism. There are, however, major differences between the Aston Group research and the study detailed in this paper. These include a concentration on 'corporate' rather than 'project' organisations, concern for 'inter-organisational' analysis and the environmental condition differences given time lapse. There is also concern for the degree to which communication is constrained by rules, procedures and instructions and the locus of authority make decisions. Table 2 and Table 3 both address these issues.

Table 3. Formality Ratio

Project Name:		1	2	3	4	5	6	7	Cumm Total
Client	1								
Architect	2	0/0		30/70	30/70	40/60	100/0	100/0	300/ 200
Proj Manager	3	0/0	0/100		75/25	50/50	0/100	0/100	125/ 375
Contractor	4	100/0	10/90	40/60		20/80	10/90	10/90	190/ 410
QS	5	100/0	0/0	100/0	50/50		0/0	0/0	250/ 50
Structural Engr	6	0/0	20/80	0/0	80/20	0/100		0/0	100/ 200
M&E Engineer	7								
Cumm totals		200/ 0	30/ 270	170/ 120	235/ 165	110/ 190	110/ 190	110/ 190	

PRELIMINARY RESULTS AND CONCLUSIONS

At the time of writing this paper the research is 75% complete and therefore only 'tentative conclusions' can be reported. Only two out of the twelve projects are complete and neither of these have reached the stage where the communication and decision making paths of selected 'incidents' have been completely traced. There are, however, a number of conclusions that can be drawn at this preliminary stage of the data recovery and analysis process:-

1) Thus far the 'footprint' of project incidents generated by analysis of interviews, with a frequency of those incidents, has been found to be extremely useful (Table 1) to the research. Comparing the 'footprint' of incident typologies between projects is a simple way in which the researcher can get a 'feel' for the nature of the project - especially the main areas in which things are going wrong.

2) The incidents shown (Table 2) demonstrate the 'project problems' provide a vehicle for trackingpaths of communication and resultant decision making around incidents. It has become clear that frequently no decision was in fact made. These are not formal 'decisions not to make decisions'; rather it emphasizes the time dimension to project problems in so far that problems become prioritized and what was important yesterday to some team members, is not important today.

3) The formality ratios (Table 3) have provided the researchers with a valuable comparative tool for looking at the types of communication taking place. The formality ratio also allows a reasonable comparison between projects on the various typologies. For example, as more results come in it may be possible to discover a connection between the degree of formality in communications and problems co-ordinating and managing the supplychain etc.

4) Results to date suggest the use of communication and decision making as an tool to define organisational structure is robust enough to describe inter-organisational project structures. However it has been seen that, as with those projects being studied, the research has to evolve in order to deal with new realities. Such adaptation would not normally be deemed satisfactory by many positivistic (i.e. 'scientific') researchers, since it somewhat changes the 'goal posts' for the research. That is to say although the tools used to collect data are constant, the analysis and synthesis undertaken with this data has undergone change so as to match its benefit to both academe and industry.

5) The research has highlighted difficulties encountered in conducting longitudinal case studies, especially in that the research team could not be present on the sites daily. A reliance was therefore placed on 'retrospective perspectives' from interviewees. The 'limitations' of the situation allowed richly contextural data to be collected, which would not have been possible via a postal survey. The research team had to be highly involved (i.e. 'get dirty') in order to collect and analyse data, building up a relationships with the actors. This it may be argued discredits the research, in that the actors fulfilled researcher expectation, i.e. a self fulfilling prophecy. However the authors suggest that this research constitutes 'real life' in the construction industry, reporting on real perceptions important to real people and therefore is important research. Furthermore, communication and decision making behaviour enacted during project lifespan determines not only the success, but results in continued patterns of behaviour which impact on future projects, independent of the procurement route and form of contract.

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A PROCESS APPROACH TO PROJECT RISK MANAGEMENT

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ABSTRACT

This paper is based on research into project managers' influence upon the project and team structure, and their ability to manage risks. The individual risk philosophies of the team members are considered in light of the effect they may have upon risk management. This paper briefly reviews project management, risk and risk perception and their interrelated effects upon the construction process. It is suggested that just as risk philosophies of individuals affect the decisions made in their lives away form their professional careers, so their perceptions and experiences of risk can affect their professional decisions. The approaches utilised for the research to explore this theory are also discussed within this paper.

Keywords: Process; Project Management; Risk Perception; Risk Philosophy

INTRODUCTION

This research is being undertaken as part of the Process Protocol II project (Cooper et al, 1998), for which the author is responsible for the mapping of the project and risk management activity zones.

There are three related topics covered within this paper: risk propensity, defined as a person's desire to either avoid or to take risks; risk preference, the perceived level of risk and uncertainty a person is willing to accept in a given situation; and risk perception, the subjective view of the perceived risk associated with a hazard (Adams, 1995). These areas have been largely overlooked by construction management research, which has instead concentrated on the harder issues of risk management, such as risk quantification using statistical analysis and the methods adopted to do this (Edwards & Bowen, 1999).

The terms risk and uncertainty have become interchangeable, and one can often be found in the description of the other. Within this paper risk and uncertainty will be defined and used accordingly as separate issues of the same complex phenomena, that of hazard management, as proposed by Beck (1986).

A persons risk propensity plays a fundamental role in decision making and risk management procedures, (McGowen, 1999), and as such requires investigation to discover the extent of the influence of individual propensities, especially considering the nature of the construction project and project management.

To date the research into the area of risk propensity, preference, and perception has been established from an extensive literature review in the areas mentioned. The literature review has also incorporated areas concerning the construct of risk, and the author supports the position that risk is a social construct, (Thompson 1980, Douglas 1985,

Douglas & Wildavsky 1982). The research will be furthered by way of case studies to establish the behaviour of project managers at work and the ways in which they affect the project team.

The intention of this research is to establish the importance of the roles of risk propensity, perception and preference, which can be referred to as a persons risk philosophy, and the implications this can have on the behaviour and decision making of project managers in the work place. These three concepts, or risk philosophy, can be described and highlighted using the metaphor of the 'risk prism', shown in figure 1, and described later in this paper.

It is expected that the results of the research will be incorporated into the Process Protocol II framework,enabling more efficient risk management procedures to be implemented, taking into account the three areas of risk behaviour and their impact upon the risk management process. It is hoped that a method for assessing the risk attitudes of individuals can be utilised to establish a comprehensive risk profile of employees. This combined with a record of the employees experience and management style could be utilised to enable project teams to be brought together to better suit the nature of individual projects and clients.

PROJECTS AND PROJECT MANAGEMENT

Turner (1993) provides an encapsulating definition of a project as; *"..an endeavour in which human material and financial resources are organised in a novel way.."*

Projects are distinct from operations due to their unique nature. Operations are repetitive, projects are one off endeavours. As with any new venture there is uncertainty. Assumptions are made, as a matter of necessity, by construction management in situations where there is insufficient data or information to continue with a task (Edwards & Bowen 1999).

The risk and uncertainty associated with a venture are managed by the implementation of a risk management process; the objective of which is to reduce risk (Adams, 1995). The project, the unique undertaking, is utilised to afford the client a means by which to achieve a competitive edge within the market in which he operates and is fraught with uncertainty as no aspect of the project environment will be the same as any previously undertaken. Projects have an undeniably inimitable nature which require specialist skills in managing their processes.

The development of Project Management can be traced from it origins in 1930's America, where it was first initiated by the *".. US Air Corps' and Exxon's project engineering co-ordination"* (Morris, 1994). As a discipline Project Management is a relatively recent introduction to the construction industry, having only existed in its' present form for approximately twenty to thirty years (CIOB 1996).

WHAT IS PROJECT MANAGEMENT?

The basis upon which Project Management is founded is the separation of the design, management and executory functions. (CIOB, 1996). The Construction Industry Council (CIC, 1996**)** defines Project Management as "*.. the overall planning and co-ordination of a project from inception to completion..*"

People are the primary ingredient of any project team. The management and motivation of these teams is one of the requirements of the Project Manager (Cleland 1998, Turner 1993)**.** Execution of the clients decisions and the maintenance of effective communication between the parties to the project are seen as primary responsibilities of the project manager by the CIC (1996).

Shikrazi et al (1996) consider the design of the project organisation as one of the more critical tasks expected of senior construction management. Each project, as a unique undertaking, operates temporarily within a unique, dynamic environment, not before encountered by the participants to the project. To this end the structure and theory of the temporary project multi-organisation (Cherns & Bryant (1984), must reflect the need to adapt and to satisfy the demands of the project within this unique environment (Root, 2000).

To bring any project to a conclusion requires that the project manager first negotiate the complexity of the project; the cause of which is the uncertainty, inimitability and demands of the project and the project environment, as discussed in the following section.

PROJECT COMPLEXITY

The elements comprising project complexity can be considered in two dimensions, those of organisational complexity and those of technological complexity. (Williams, 1999; Baccarini 1996).

Jones (1993) describes technological complexity within project management as a threefold element; the interdependency of the tasks, the lack of certainty upon which the tasks are based and the variety of the tasks. The interrelationships of tasks has been discussed by Williams (1999) as three differing types of task interdependencies; pooled, sequential and reciprocal. The reciprocal interdependency is the most complicated of the three, and defined as that situation where each elements output becomes an input to another element.
It is when dealing with the reciprocal interdependencies that the project manager may encounter the "wicked problem" where there is no true or false answer, only good or bad, (Rittel & Webber, 1973). The concept of the wicked problem arises with open systems where *"The planner who works with open systems is caught up with the ambiguity of the causal webs."*(ibid). The solution to the immediate problem will have ramifications for those operations linked with that solution via the project organisation.

This is becoming increasingly the case where project complexity escalates and it is not possible to adequately define the ramifications of some decisions because of the reciprocal relationships of some of the project elements (Williams, 1999).

"…because the work is unique, it involves a level of risk. Because, it can cost more to eliminate this risk than the potential damage it might cause, it is more effective to manage it than eliminate it. Project management, therefore, becomes the management of risk" (Turner, 1993).

To enable the project manager to manage risk effectively, he must have a strong understanding of the nature of risk, the stakeholders and the construction management team's perceptions of risk.

DEFINITION OF RISK

Any definition of risk is likely to carry an element of subjectivity, depending upon the nature of the risk and to what it is applied. As such there is no all encompassing definition of risk. Chicken & Posner (1998) acknowledge this, and instead provide their interpretation of what a risk constituents:

Risk = Hazard x Exposure

They define hazard as *".. the way in which a thing or situation can cause harm,"* (ibid) and exposure as *".. the extent to which the likely recipient of the harm can be influenced by the hazard"* (ibid). Harm is taken to imply injury, damage, loss of performance and finances, whilst exposure imbues the notions of frequency and probability. It can be argued that hazard is not the *".. way in which .."* rather it is the *'thing'* its self.

The Royal Society (1983) view risk as the probability *"..that a particular adverse event occurs during a stated period of time, or results from a particular challenge."* The Royal Society also state that *"as a probability in the sense of statistical theory risk obeys all the formal laws of combining probabilities"*. The problem with statistical theory is that it is only ever a guess, or an approximation of what is to occur. There is no certainty involved with any statistical probability; hence the use of the term 'probability'; which is defined in Collins Concise English dictionary as; *" (3.) a measure of the degree of confidence one may have in the occurrence of an event"*.

Smith (1999) defines risk as a decision expressed by a range or possible outcomes with attached probabilities. When there are a range of possible outcomes but no assumed probabilities, there is only uncertainty (ibid).
Hertz & Thomas (1984) have suggested that *".. risk means uncertainty and the results of uncertainty… risk refers to a lack of predictability about problem structure, outcomes or consequences in a decision or planning situation."* The problem with risk management is that it concerns events that have yet to transpire, which are in turn dependent upon events which may not be knowable at the time of prediction, that are also dependent upon events, and so the cause effect chain continues. To truly predict a hazard an

encompassing holistic view is required of the situation, which will never be totally achievable, even in laboratory conditions.

A NEW DEFINITION OF RISK

The Royal Society define 'hazard' as a situation which could lead to harm. It is the realisation that a situation may induce 'harm' that inspires the recognition of risk in association with the hazard. It can be postulated that risk is the philosophy concerned with the understanding of the nature of harm associated with the hazard.

Risk can be considered as a *"systematic way of dealing with hazards"* (Beck, 1986). If it is assumed that there is uncertainty associated with any prediction of a hazard occurring, then there is only uncertainty because there is only ever a *prediction* of the likely occurrence.

Therefore for a risk to exist there must be a *hazard*. The perception of hazards is entirely subjective. What one person finds hazardous, his neighbour may not. It is the way in which we feel threatened by circumstance and in turn the opinion we develop by association with the threat or hazard.

This perception of hazard is centred around previous experience, cultural values and to some extent the aspect of specialist training in an area or field of expertise to which the hazard relates.

RISK PERCEPTION

Adams (1995**)** contends that *"Everyone is a true risk 'expert'.."* , our expertise is based upon our everyday experiences and the ability to learn from those experiences. The difference between the scientific perception and the non scientific perception is that the scientist will quantify the risk, relying on scientific analytical paradigms to prescribe the method of interpretation, and the lay person will rely on experience and intuition.

Both the scientific community and the laity will arrive at their own notion of objectivity regarding the risk. Again there are similarities in how they will arrive at their decisions. They will both, via dialogue and comparison with peers, agree between themselves; which amounts to inter-subjectivity; or their own group consensus of what is objective reality. It is argued that this happens with great regularity in construction projects.

The lay public are not interested in, nor can they identify with, probabilistic quantification's of risk. Beck (1986) realises that *".. what becomes clear in risk discussions are the fissures and gaps between scientific and social rationality in dealing with the hazardous potential.."*. The chances of not winning the lottery are renowned to be remarkably high, probabilistically speaking; however millions of people each week still gamble on becoming a millionaire.

In addition to this there is also the aspect of the cultural influence upon decision making. "*When faced with estimating probability and credibility, they come already primed with culturally learned assumptions and weightings."* (Douglas, 1992). Depending upon the social setting in which norms and related experiences have been established, the notions of risk will differ widely from those of others; our experiences help to construct 'filters' through which we view the world (ibid).

It has not yet been established to what extent risk perception affects construction projects. However, risk perception on its own arguably forms only one half of the risk behavioural cycle. Taken in conjunction with risk propensity, that is a persons willingness to either take or avoid risks a more detailed potential impact of an individual may become apparent. If a person is risk averse, i.e. they do not like exposure to risks then they may not be suitable to a project requiring innovative construction or contractual methods. However a project of such a nature overpopulated with risk takers, may not be all that successful having taken one risk too many.

It is now possible to assume that the professionals whom we trust with the tasks of risk management are affected by risks and view risks in the same manner as a lay person, the non 'expert'.

They are prone to the same influences that shape a persons risk philosophy as the next man, and just as personal perception guides our daily lives so can it guide our actions whilst at work. The risk management software available is still only as effective as the person utilising the data. The perceptions of the individual inputting the information into the computer will naturally bias that information, not only in its raw state, i.e. what is to be included as an uncertainty, but how the manipulated data, i.e. the risk, is to be acted upon.

Therefore, we can assume that risk is a cultural construct (Thompson, 1980), and that the language used to communicate risks has an effect upon an individuals risk perception. It may therefore be possible to develop an 'organisational buffer' to mediate in the interpretation of the hazard by the individual, before the hazard is translated into a risk and acted upon.

Figure 1 shows how the risk philosophy of an individual, shown operating as a 'risk prism', can refract the persons view of a hazard which implicates its self in the persons behaviour as either an under or over estimation of the actual exposure to the hazard. This subjective estimation, as a result of the individuals risk prism, may not comply with the organisations view of the hazard.
Therefore it should be plausible to construct an organisational buffer of culture and language etc, which can be 'applied' via education and exemplary behaviour, to the person to alter the 'refraction indices' in favour of the organisational view of the hazard.

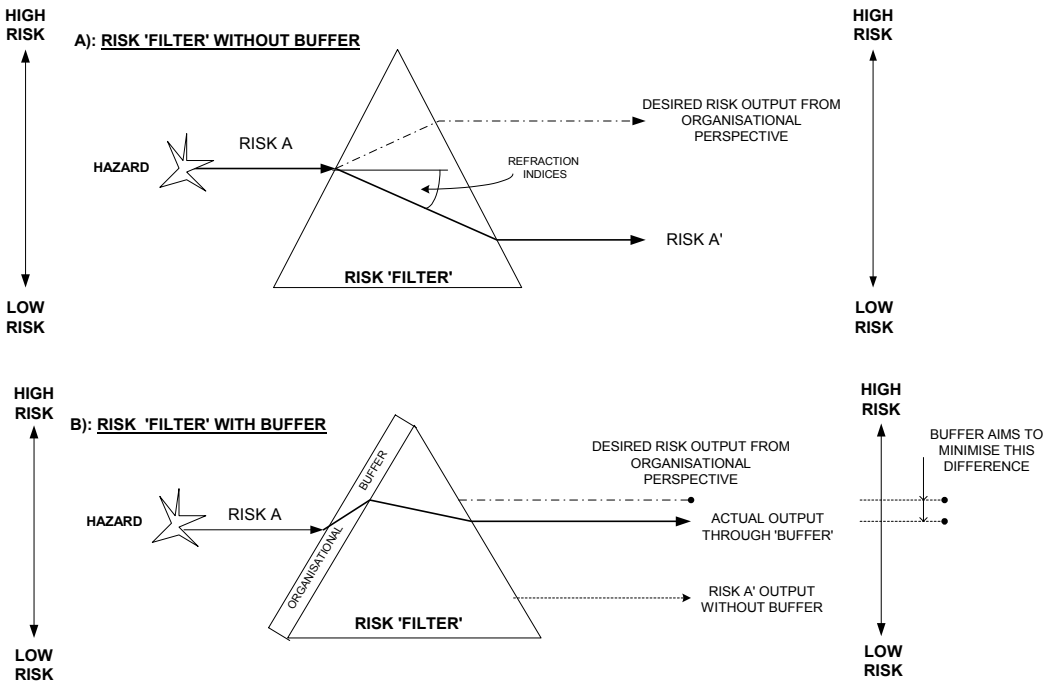

Figure 1. Risk Filter

METHODOLOGY

A literature survey has been conducted into the areas of project and risk management to establish background knowledge of these disciplines. This not only provided the most immediately accessible font of information, but also allowed under researched areas of project and risk management to be highlighted. It was from the literature review that the need for further research concerning the 'softer' areas of risk management was identified; (areas of perception, propensity and preference and the role they may play within construction projects). The literature reviews also highlights areas of best and better practice concerning these disciplines which may be incorporated within the Process Protocol II process mapping.

Research was also undertaken to establish the lead industry and professional bodies concerned with the disciplines of project and risk management. These bodies have been contacted and the developments they are making within their own discipline are monitored for inclusion within the process maps.

Preliminary interviews were arranged to corroborate some of the information garnered from the literature review and to allow further reasoning of any theories and possible advances within the risk and project management disciplines.

Subsequently, nine full interviews were arranged with project managers and senior management within the construction industry to establish actual project and risk

management processes as applied in practice. Information regarding the Process Protocol were sent to the interviewee in preparation for the interview.

A semi-structured interview format was adopted, allowing greater depth of questioning where required, whilst also allowing flexibility in regards of the direction of interviewing and areas covered. Tape recordings and written notes were made by the interviewer of the entire interview.

Interviews were then transcribed; the information was collated; commonalties identified amongst definitions and practices established. (Provisional maps of the processes were then drawn, as shown in figure 2).

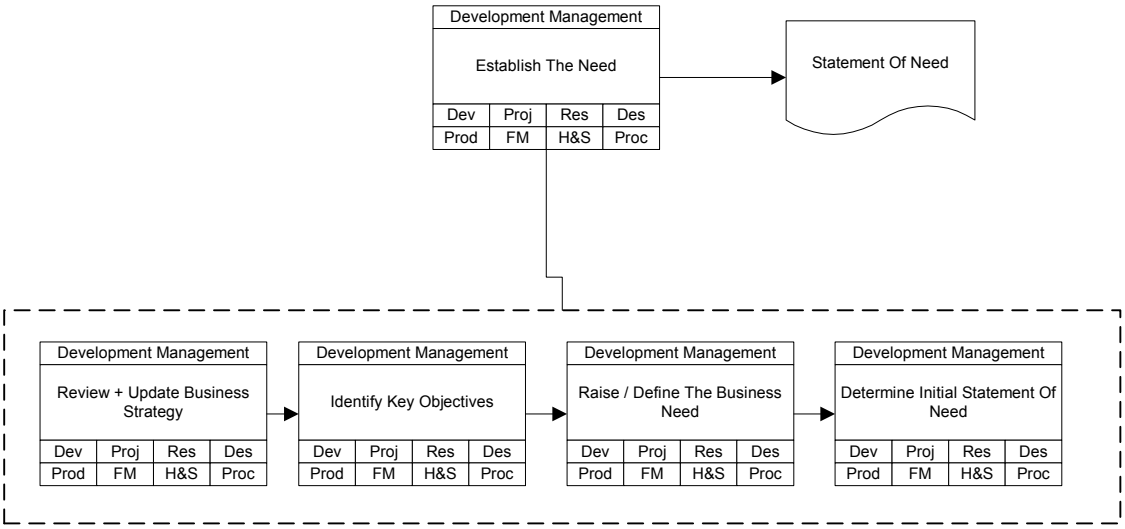

Figure 2. Process Map

The mapping techniques evolved over nine months through discussion and workshops involving senior members of the academic staff and researchers at both Loughborough and Salford universities, taking note of experience from Loughborough universities' mapping on the ADEPT project. The mapping software tool VISIO professional was identified as the most suited for the task.
A generic mapping lexicon and methodology were also established, enabling comparative mapping to be undertaken at both universities.

Academic staff then critiqued the maps, which were revised taking account of the comments and feedback. Workshops were arranged to allow industrial partners to comment on the maps and processes. Again the feedback was incorporated within the maps and a second workshop arranged to allow for any 'fine-tuning'.

The industrialists were provided with copies of the maps prior to the workshops to allow them the opportunity to make notes and prepare. At the workshop the industrialists were divided into two groups, each containing academics, with a nominated 'chair' for each who would order the ensuing open discussion and debate.

At the mid point of the workshops group members were interchanged to allow ideas and issues to be exchanged between groups, and to prevent discussions from becoming 'stale'. At the conclusion, the two groups were brought together and the ideas, suggestions and comments from both were summarised in a presentation.

All participants had individual process maps upon which they could make adjustments etc. throughout the workshop. These were collected, rationalised and combined with notes taken by the academics. The mapping and processes were then revised and re issued for further validation at the second workshop.

The maps from all activity zones will be validated in the same manner, before being combined to form the completed Process Protocol II map.

Risk Methodology

Harriss (1998) postulates that all our observations are interpreted using information and experience, and therefore the interpretations are subject to influence from theories. These are our; *".. preconceived notions and our background beliefs,"*. He states that there has to be some generalization of circumstance, some theory, that will enable us to understand the world. That is how people learn. By generalization and by galvanizing these generalizations into 'life skills.' (ibid)

Therefore the methodology adopted to investigate risk perception will differ from that of project management, in so much that risk and the perception of risk is a social construct. It is something that must be observed within the workplace and can not be objectively measured, mapped or implemented as a matter of organisational policy. Therefore a multi-paradigmatic approach has been chosen as the best way forward for this research.

Preliminary interviews have been undertaken with two project managers, one senior planner, one chief engineer and two risk consultants, one of whom is the chair of the APM SIG concerned with risk management and co-editor of the PRAM guide. These interviews allowed the researcher the opportunity to further investigate the need for the research, consolidate the preliminary findings of the literature review and to plan for the case studies which will comprise the next stage of the research.

The case studies will test the theories realised from the literature review and the preliminary interviews. Case studies allow phenomena to be observed and recorded within a true to life environment and context.

It is hoped that once a suitable project has been found and permission is obtained to conduct the case studies, the activity and behaviour of construction management personnel can be recorded and observed. These observations will then assist in either establishing or refuting the validity of the hypothesis that risk perceptions have an effect on the decision making behaviour of construction management.

Only one project need be identified for the case study, as it is the construction management personnel who will be the individual actors observed; their interactions with each other and the project environment and how they establish decision making criteria and arrive at courses of action to be taken.

Prior to the case studies, a risk and management style profile will be compiled, utilising a method similar to that method preferred by Greenwood (1999).

This will allow the comparison of the measured, expected behaviour of the manager, as established by the profiling, to be compared with observations in the field. Cross analysis of the effects of inter personnel communication can be ascertained by observation and corroborated with the profiles to establish the impact of leadership style on risk perceptions and decision making.

These results can then be generalised to assist in the establishment of a risk perception theory relating to leadership style and decision making within construction management.

CONCLUSIONS

This research is striving to assess the existence and impact of the '*risk philosophies'* of construction management personnel on the construction process. This area of risk management has in the past been under researched within construction management. There is a genuine need for the construction industry and for the project management profession to realise the potential impact of the individual risk propensities of management personnel if risk management methodologies are to have any future and be taken seriously (Hillson, 1999).

The contribution of the research will be the explicit consideration of risk philosophy as an adjunct to existing risk and project management processes. This will include a process, and a proposed recognised method, by which risk attitudes can be assessed.

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STOCHASTIC MODELLING OF CONCRETE OPERATIONS

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The concrete delivery and pumping process is a stochastic system. If analysed deterministically there is the danger that the negative effects of the random distribution of events are not taken into account, leading to poor estimates of production and cost. By representing the system as a random process the construction engineer can firstly achieve improved estimates of the overall productivity and thus schedule deliveries better, and secondly, determine the effect of non-anticipated events such as excessive delivery or pour times. Research will be centred on studies of actual construction projects, which will be used to study cyclic processes in general, and concreting placing operations in particular. In addition, data will be gathered from concreting operations, which will be used as a basis for the modelling of concreting operations. These models will be developed and analysed using a number of techniques, notably discrete-event simulation, with the intention of producing software for the practical analysis of site operations. The ultimate aim of the investigation is to minimise the cost and maximise the productivity of concreting operations.

Concreting, Modelling, Queuing Systems, Stochastic Systems

INTRODUCTION

For thousands of years, concrete has been used as a construction material. However, as processes within the construction industry have been systematically modernised and allocated rigid procedures, this has not been the case with concrete placing. The process of concrete batching, transport and finally placement is subject to interruption, irregularity and fluctuation for which there can be very little control. Due to their random nature it is possible to treat concrete placement operations as a stochastic system. This random nature suggests that in many cases there is a variable nature to the rate at which material is delivered, which may result in an underutilisation of plant and labour or an additional cost for storage of raw materials. By representing the processes as queuing

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systems, they can be analysed by a multitude of techniques that are available to the systems analyst, for example queuing theory, regression analysis and simulation. Indisputably it will be advantageous for the industry as a whole to encourage workers to apply management techniques to construction to increase its productivity and effectiveness.

This paper reports on the findings of a pilot study undertaken by the University of Edinburgh in collaboration with Tarmac Civil Engineering (now Carillion plc.). Real construction data were obtained from large concrete pours on a major UK motorway viaduct project, and this provides the basis for the case study in this paper. This paper will look, briefly, at queuing systems in general as well as discussing the proposed research methodology.

OBJECTIVES

The main objective of this work is:

i. To investigate and provide a better understanding of cyclic construction processes with particular reference to concreting operations
ii. To study live construction projects to gain data of cyclic processes
iii. To examine methods to assist in the planning and estimation of cyclic construction processes
iv. To examine systems which enable construction engineering organisations to better manage cyclic construction processes, in terms of the efficiency and effectiveness of resources
v. To provide systems which ultimately minimise the costs, in financial, material and human effort contexts, and maximise the productivity of concrete placing operations.

METHODOLOGY

There are two main aspects to the project; firstly, it is important to find suitable live construction sites for further study. These sites should initially allow observation of concrete operations to provide a full understanding of the procedures and activities that make them up. The factors that influence their output and the differences between contractors, geographical areas, time of year and weather. Concreting operations will also be observed on a work-study basis in order to extract raw data that can be later used as model input. Secondly, it is anticipated that it will be possible to develop numerical models of the concreting process and analyse these in a variety of ways. Discrete-event simulation has, to date, already been implemented on earthmoving processes as well as concreting processes by Smith (1998,1999). It is hoped that this technique may be used again using both commercially available software and new applications developed for this

purpose by the author; other methods will also be investigated, for example queuing theory, regression analysis and the petri-net theory.

The analysed models will be used in two ways: firstly, to undertake parametric experiments on the concreting process, and secondly to provide a tool for the estimation, planning and management of concreting operations.

The research project should follow a pre-determined plan if it is to run both effectively and efficiently. However research is a dynamic process, therefore there must be a certain amount of flexibility – implying, although not requiring, that a contingency approach would be helpful.

The research project is expected to follow the following route.

1. Literature Survey

An essential early stage of virtually all research is to search for and to examine potential relevant theory and literature. Theory and literature are the result of previous research projects.

For this particular project the literature survey has almost been completed, however, it is fair to say that it may never be entirely finished. The survey took advantage of the multitude of powerful search engines available on the World Wide Web and these yielded many favourable results. The majority of research found relating to concrete operations took place outside of the UK so from a very early stage it was noted that there was definite research potential within the UK.

2. Model Development

As with all modelling exercises, whether physical or numerical, the main aim is to represent the concreting system in a way that can be investigated practically, economically, and safely. In the concreting cycle presented here we will treat it as a single server queuing system (see Fig. 1). No account has to date been made of the batching process as it can be considered a system in its own right and may be considered in future work..

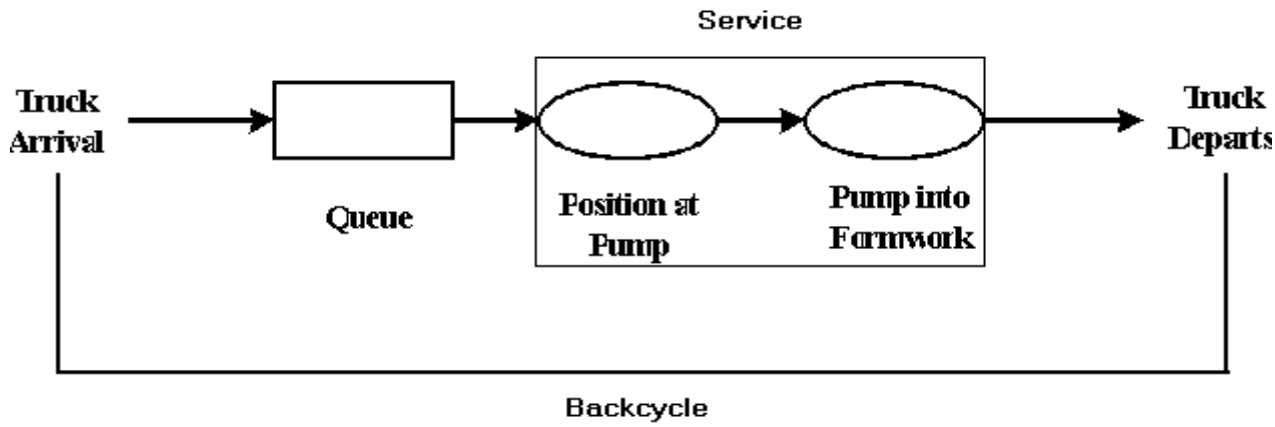

Figure 1 Schematic diagram of a general Concrete Placing Cycle.

A queuing system consists of both customers and servers, Carmichael (1987). For each server, customers will queue until they are served and then leave. In the case of the Concrete Placing Cycle (CPC) as concrete truckmixers arrive they will join the 'service' (if there are no other truckmixers in the queue to be served) or join the back of the queue of waiting truckmixers. Service requires the truckmixer manoeuvring into position then discharging the concrete into the hopper of the pump, which then pumps the concrete into the required formwork. This operation is common to many of the thousands of construction sites throughout the world. When the truckmixer has been served it will then join the backcycle until they rejoin the system – again queuing if the server is busy. In an ideal system the rate at which trucks arrive, position and have their concrete pumped would be constant. Therefore, it would be possible to determine the time between arrivals (the interarrival time) of the trucks in order that no queuing, and thus underutilization, of trucks occurred.

There are other alternative systems available to the construction industry, for example placing concrete using a crane and bucket or by using a wheelbarrow. The later is very labour intensive and dated, however, the crane and bucket method has previously been researched, Tommelein (1997).

A real system is stochastic and the events that occur within the system (e.g. the interarrival times, pump start times) take place at irregular intervals. This point has been mentioned previously but it is one that is fundamental to the Concrete Placing Cycle. Queuing of trucks can be expected, as it is unlikely that the interarrival time will be both regular and at such a rate that trucks arrive just when the previous one departs. If trucks arrive late, there will be a lengthening of the process, with plant and labour becoming inactive. The rates at which trucks are used are also dependent on the speed at which they are positioned and the concrete is pumped.

As can be seen, the output of the system is dependent on the variability of the system events. What must also be considered are the factors that influence this variability. In the

majority of concrete pours it is possible to determine a number of factors that affect the effectiveness and efficiency of the Concrete Placing Cycle, such as site location, location of the supplier and the age of trucks. Establishing all of these factors may well improve the efficiency of concrete operations and so reduce wastage.

3. Data Collection

It is fundamental that for models to be a good representation of real life projects they must be based on real data. In this pilot study data were gathered from a major civil engineering project in the North-West of England. The data gathered was spread over a two-year period, however the vast majority of data was collected during the summer months. The project involved the construction of a motorway viaduct and widening and involved pours ranging, for the whole project, from $2m^3$ to $1200m^3$ of concrete. A sample of larger concrete pours provided the following data:

i. Truck arrival time,
ii. Pump start time,
iii. Pump complete time,
iv. Batching plant used,
v. Truck quantity, and
vi. Concrete slump.

The overall volume of the sampled operations ranged from $33m^3$ to $470m^3$ with an average of $180m^3$. The average number of truckloads was 31 and the average delivery volume was $6.15m^3$ for the 63 pours sampled.

Table 1 shows a typical example of a data sheet that provided the basis for the investigation. The data collected were summarised on a Microsoft Excel spreadsheet and the times of interest extracted.

Table 1 A typical example of a data sheet used on site to record relevant times.

Pour Date									
Location									
				Interarrival Time	**Truck Wait Time**	**Truck Position Time**	**Load Pump Time**	**Pump Time**	**Operation Inactive Time**
Batch	**Arrive**	**Start**	**Complete**						

As mentioned previously, the pilot study only considered data from 63 pours. It is intended that further sites will be selected to enable a wider range of data to be sampled.

Due to the wide variety of construction sites, data will be gathered from very different site locations, for example the comparisons between rural and inner-city sites.

4. Data Analysis

Analysis may be carried out with respect to data available, the objectives and any hypothesis, so that the most robust and rigorous analytic methods will be used, thereby maximising confidence in the results (Fellows et al, 1999). It is important to consider, evaluate and plan analysis methods from the very beginning.

Analysis can begin by examining the raw data, gathered from construction sites, for patterns and relationships. It was hypothesised at the start of the literature survey that the most relevant times from the concreting system were the interarrival, position and pump times. These can now be subjected to statistical analysis and it is normal to analyse queuing systems in a non-deterministic way using methods that will be discussed below.

i. Queuing Theory. An operations research technique used in many applications. Its application to construction has been extensively researched by Carmichael (e.g. 1986, 1987) who applied the theory to earthmoving and mining operations.

ii. Simulation. Simulation involves the use a model to represent the essential characteristics of a reality, either a system or a process. So, whilst a model may be a static representation, such as an architectural model, a simulation involves some element of dynamism, if only because it models a process rather than an object (Fellows et al, 1999). This makes simulation ideal for concreting operations. By synthesising input data based on the probability distributions of actual operations, each step of an operation can be recreated. A computer can recreate each step very quickly thus allowing the simulation of lengthy, real operations.

iii. Petri Net Theory. Petri nets are used as a tool for the study of systems. Petri net theory allows a system to be modelled by a Petri net, a mathematical representation of the system. Analysis of the Petri net can then, hopefully, reveal important information about the structure and dynamic behaviour of the modelled system. This information can then be used to evaluate the modelled system and suggest improvements or changes.

iv. Neural Networks. Artificial neural networks are computational devices. Most researchers and developers at this time simulate their neural networks using software simulation. A neural network is a highly interconnected network of many simple processors each of which maintains only one piece of dynamic information and is capable of only a few simple computations. No previous work has been found exploiting the uses of neural networks in concrete operations so further research is being carried out in this area.

v. Regression Analysis. This is a statistical tool that provides equations for outputs derived from real operation data. These equations can then be used to deterministically analyse further operations. Regression analysis provides the chance to analyse the variables in pairs – one dependent and one independent. Fellows et al, state that regression analysis establish only any relationship between the realised values of the variables which occur; they do not establish causality. This may have to be taken into account at a later date.

5. Further Data Collection

After the initial data has been gathered and analysed it will be necessary to collect further data. This will involve going to different sites in order to get a wider range of data for sampling and to put right any errors which are felt may be in question from the first data collection. The process of going back on to site multiple times allows for any new ideas and thoughts to be explored.

6. Model Verification

After the model or models have been researched and put in place it is important to refine them to ensure that they are being used to their full capacity. Verification of a model involves determining whether the structure of the model is correct; this is achieved by testing the model, by examining the outputs resulting from the model under a given set of inputs. The model is verified if the outputs are appropriate, i.e. they approximate to ideas of what a good model would generate.

7. Validation

The next stage of any modelling process is validation. At this point any model that was not verified must be discarded or under go further amendments. The validation of a model is fundamental to the achievement of ones initial aims and objectives. If the model is not an accurate representation of the system being studied then any conclusions gained from the model cannot be relied upon. When carrying out the validation stage it will be useful to test several sets of input data and known outputs over a range of conditions – including extremes. When more than one model is being used and has passed verification then it will be necessary to chose the most appropriate model

8. Dissemination

When the final model has been chosen it is going to be important to disseminate the results and findings appropriately. This is an integral part of any research project. It is

hoped that the results of the project will show that there are definite signs of ways to minimise the cost and maximise the productivity of concreting operations.

BENEFICIARIES

Potential impact of the work

The results of this work will have the potential to:

i. Assist in the planning and estimation of concrete placing operations. Construction contractors normally have a very short period of time in which to do this when tendering and thus increased accuracy and speed would be welcome.
ii. Assist in the management of concrete placing operations. Operations on a construction site may often be conducted in a reactive way, responding to events as they happen. By increasing the understanding of planned operations, site personnel may be better placed to manage them pro-actively.
iii. Increase efficiencies, reduce wastage and increase cost effectiveness of concrete placing operations. Smith (1998) has already indicated that cost reduction of concreting operations is a possibility through a stochastic as opposed to a deterministic approach.
iv. Provide a base of experimentation and results for other internationally

Beneficiaries of the research project

The beneficiaries of this work are primarily expected to be construction organisations, from the increased competitiveness through the minimisation of cost and maximisation of productivity. Particular beneficiaries within the construction industry will be:

i. Contractors, who will benefit from improved planning and increased productivity; and
ii. Materials suppliers, who will benefit from reduced costs through increased utilisation of equipment.

It is expected that the academic community of workers in process modelling will also benefit.

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CASE STUDIES IN CONSTRUCTION PROCESS IMPROVEMENT

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Keywords
Capability Maturity Model (CMM), process improvement, SPICE.

ABSTRACT

Construction industry reports by Latham [1994] and more recently Sir John Egan [1998], have highlighted the need for the construction industry to increase productivity, improve quality and reduce defects. In particular, the Egan report urged the industry to focus on construction processes as route to these improvements. However, the industry has not had a recognised framework or methodology to base a process improvement initiative on.

SPICE is a current research project that is developing an evolutionary step-wise process improvement framework for the construction industry. The research has drawn specifically on the Capability Maturity Model (CMM) which has been used successfully in the IT sector by clients for supplier assessment and by suppliers for process improvement.

This paper begins by introducing the SPICE concepts and research to-date which has investigated the validity of the framework and the suitability of the assessment.

The paper then goes on to describe four case studies that have been conducted as part of the research.

INTRODUCTION

In recent times, the construction industry has been under ever increasing pressure to deliver a service of consistent quality and increase its productivity. However, the targets set back in 1994 by Sir Michael Latham in his industry report 'Constructing the Team' [Latham 1994], have yet to be fully realised. The subsequent report in July 1998 by Sir John Egan [Egan 1998] emphasised the call for productivity improvements and in particular, urged the industry to focus on the construction process. Hammer and Champy [1993] support this view by suggesting that it is no longer enough for organisations to do traditional tasks better, but rather recommend that the old "individual-based task-oriented" management concept be discarded completely and replaced with a "team-based process-oriented" management concept. However, the industry has lacked a recognised methodology or framework to improve its processes. Until now, organisations that have attempted various improvement initiatives without guide-lines have found that the efforts are often isolated and benefits cannot be repeated or co-ordinated. The industry has been unable to systematically assess construction process, prioritise process improvements, and direct resources appropriately. Moreover, the absence of a standard process model has meant that it has not been possible for companies to benchmark and measure their performance with time or relative to other organisations.

SPICE

Structured Process Improvement for Construction Enterprises (SPICE), is research project that is currently nearing the conclusion of its two year research programme. The project is developing a construction industry process improvement framework. Evidence from other sectors [Imai 1986, Paulk 1993] has shown that continuous process improvement is based on many small, evolutionary steps, rather than revolutionary measures. With this in mind, the SPICE framework is based on a model containing a series of evolutionary steps. The philosophies of Joseph Juran [1988] and W. Edwards Deming [1986] advocate that real process improvement must follow a sequence of steps, starting with making the process visible, then repeatable, and then measurable. This approach to process improvement has been widely used in the other industries and the research draws on the extensive experience of the IT sector. Specifically, the research focuses on the use of the Capability Maturity Model (CMM) [Paulk1993, Saidian 1995]. The US Department of Defense commissioned Carnegie Mellon University to develop this framework to provide them with a means of assessing their software suppliers. However, not only was it a successful benchmarking tool, suppliers implementing the framework found that it delivered significant business benefits. For example, Hughes Aircraft (USA) reported a 5:1 ROI, and Raytheon (USA) achieved a 7.7:1 ROI and 2:1 productivity gains [Saiedian 1995]. Industry analysis by J. Herbsleb [Herbsleb 1994] showed that companies implementing CMM achieved an average of 35% productivity improvements and an average of 39% post delivery defect reduction. The SPICE research sets out to investigate whether the model can be successfully utilised in the construction industry with a view to ultimately delivering similar results. If so, then significant progress would be made in answering Sir Michael Latham's call for a 30% reduction in costs and zero defects on a construction project.

The SPICE project aims to tailor the original CMM framework into a construction specific maturity model. Studies by Lillrank [1995] show that the transfer of innovation across countries (and industries) cannot take place in their original

packaging. The core idea of an innovation must be abstracted and then recreated in a form which fits local conditions.
The SPICE framework comprises two elements. The model itself, and the assessment mechanism by which an organisation is assessed against the model.

The SPICE Process Improvement Framework

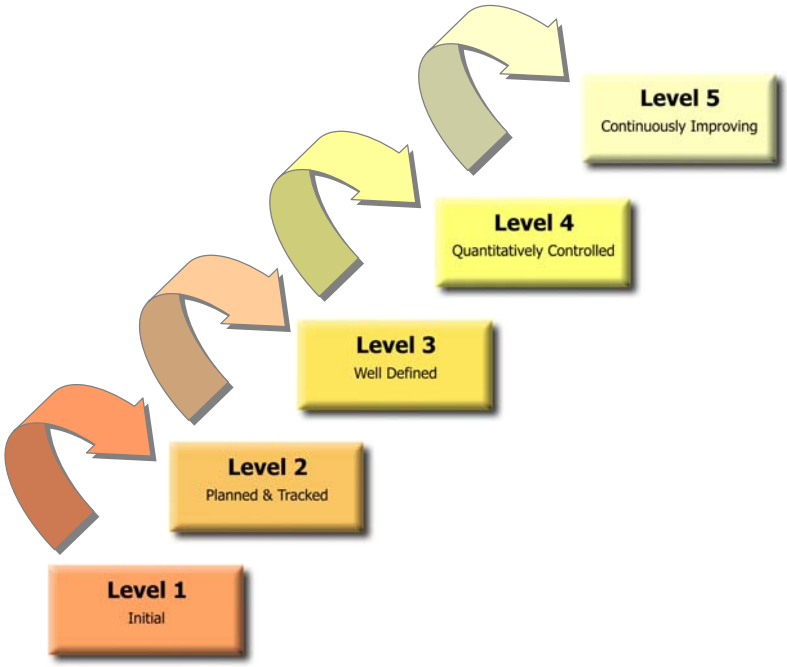

Figure (i)- The SPICE Process Improvement |Model

The SPICE model is based on five evolutionary steps of process maturity [Sarshar 1998]. The framework organises these steps into levels or 'plateaus' that lay successive foundations for the next level. Each level comprises a set of key processes that, when satisfied, stabilise an important part of the construction process. The levels define a scale by which the maturity and capability of a construction organisations processes can be measured. By establishing their position on the scale, priority areas for process improvement efforts can be identified.
The model states that little value is added to the organisation by addressing issues at a higher level if all the key processes at the current level have not be satisfied.
In general terms, the levels can be characterised and distinguished as:
Level 1, Initial- The processes are characterised as ad hoc, and occasionally even chaotic. Few processes are defined, and success depends on isolated effort.
Level 2, Repeatable- Basic project management processes are established and repeatable. The necessary process discipline is in place to repeat successes on previous projects.
Level 3, Defined- The processes for all activities are documented, standardised, and integrated into the organisation. All projects use an approved, tailored version of the organisation's standard process.
Level 4, Managed- Detailed measures of the processes and product quality are collected. Both the processes and products are quantitatively understood and controlled.
Level 5, Optimising- Continuous process improvement is enabled by using feedback from the processes to pilot innovative ideas and technologies.

To date, the research has focused on the lower levels of the model and specifically on Level 2. The Key Process Areas for Level 2 are listed below, together with a brief description.

- **Brief/Scope of Work Management** - Establishes a common understanding of the project requirements between the client and the project team.
- **Project Planning** - Establishes realistic plans and programmes of work for all activities during the project.
- **Project Tracking and Monitoring** - Ensures that there is an awareness of actual project performance so that management can take corrective actions when the project's performance deviates significantly from the plans.
- **Sub-contract Management** - Involves selecting a suitable subcontractor, establishing commitments, and tracking and reviewing their performance and results.
- **Project Change Management** - Tracks revisions to the project by assessing and controlling the impact of any changes and informing all relevant members of the project team.
- **Health & Safety Management -** Ensures compliance with all current health and safety legislation in relation to design, construction and facilities management. Health and safety risks are identified, assessed, and action is taken to eliminate or minimise the probability of occurrence.
- **Risk Management -** Identifies, assesses, monitors and mitigates risks.
- **Project Team Co-ordination -** Draws on the experience of other organisations within the project team in order to effectively meet project requirements.

The SPICE Assessment Mechanism

The SPICE assessment procedure assesses each of an organisations key processes against five 'Process Enablers' defined by the framework. The Process Enablers provide guidelines and focus on results that *can be expected to be achieved* from a key process. This is a forward-looking approach that indicates process capability *before* a process takes place. They provide detail of features that a key process must posses in order to yield successful results. Ensuring that all the process enablers are in place, improves the performance and predictability of the key processes. The Process Enablers are common across all the key processes and each enabling feature must be satisfied for a process to be considered mature. These Process Enablers are itemised below.

- **Commitment -** This criterion ensures that the organisation takes action to ensure that the process is established and will endure. It typically involves establishing organisation policies. Some processes require organisational sponsors or leaders. Commitment to perform ensures that leadership positions are created and filled and the relevant organisational policy statements exist.
- **Ability -** This describes the preconditions that must exist to implement the process competently. It normally involves adequate resourcing, appropriate organisational structure, and training.
- **Verification -** This verifies that the activities are performed in compliance with the process that has been established. It emphasises the need for independent verification by management and quality assurance.
- **Evaluation -** This describes the basic internal process evaluation and reviews that are necessary. These internal evaluations are used to control and improve the processes. During the early stages of maturity, this translates into efforts by the team to improve their existing processes.

- **Activities -** This describes the activities, roles and procedures necessary to implement processes. It typically involves establishing plans and procedures, performing the work, tracking it, and taking corrective action as necessary.

The Assessment Procedure

Initially, a questionnaire is issued to a cross section of staff from all disciplines and corporate levels within the assessment group. The responses to this questionnaire are used to identify patterns and recurring themes and give the assessors indications of the organisations process strengths and weaknesses. They also provide direction for the assessors to base a programme of interviews. A smaller sub-set of staff is chosen from the original questionnaire sample and these are interviewed individually or in functional groups. A minor document review is then also performed to find collaborative evidence to support any findings from the questionnaires or interviews. The data from all three sources is then analysed by the assessors to establish the perceived maturity of each key process area. The assessors support their findings using a 'tracability matrix', whereby each finding can be substantiated by evidence from multiple sources. The findings are then documented in a final report and the results can be condensed and displayed on a matrix as in Figure (iii). These findings are then presented at workshop with the assessment participants to discuss recommendations and an improvement plan. It is then the responsibility of the organisation to take the proposals forward. The SPICE assessment procedure is shown below in Figure (ii).

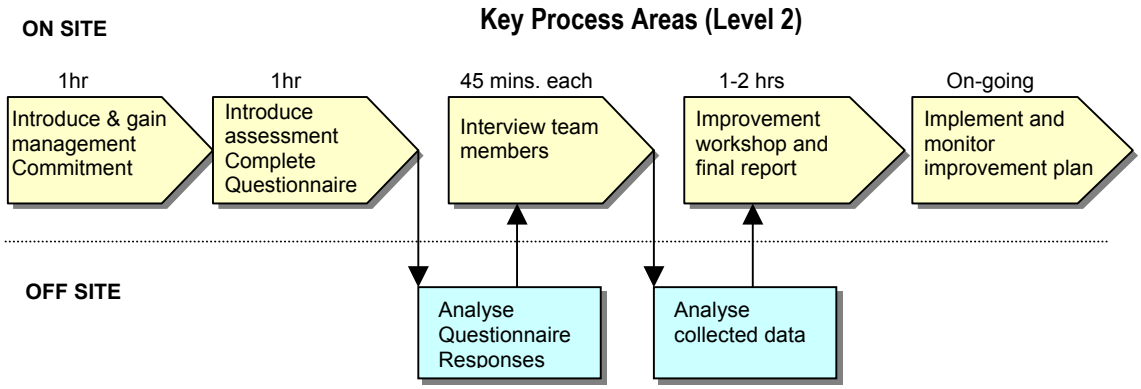

Figure (ii) - The Spice Assessment Procedure

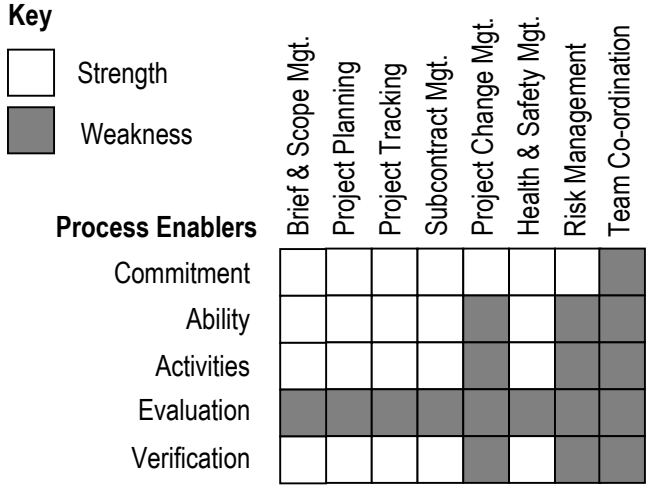

Figure (iii) - Example of an assessment results matrix

REARCH METHODOLOGY

The research approach employed can be classified as a ‘testing-out research’ due to its nature. This approach operates by finding the limits of previously proposed generalisations (in this case from the software sector) and, subsequently, specifying, modifying or clarifying their content [Starke 1995]. 'Testing-out' research has to be carried out in ‘real world’ conditions where the kind of control present in a laboratory is not feasible and not even ethically justifiable. Thus, a case study research strategy, with multiple case study design, was adopted.

A review of existing process improvement literature was performed with specific reference to the original CMM. Significant research has been documented for other industries such as manufacturing and IT. However, with notable exceptions [Kagioglou et al, 1998], the authors found very little documented evidence of construction process research.

A steering group of 7-8 practitioners and academics lead the research by developing the theoretical propositions which the core research team would investigate. At this point, it is generally acknowledged that there are large gaps between industrial perspectives and requirements, as opposed to the academic outlook [Brandon 1999, Gill 1986]. The SPICE project directly addresses this balance by conducting the research in close collaboration with several industrial partners and with support from the DETR.

Research findings are continuously verified by dissemination and exchange of ideas with industry representatives. These findings culminate in a bi-annual presentation to a 'panel of experts' workshop where 30-40 senior academics and industrialists provide discussion, feedback and future direction. The theoretical proposals are further refined and validated by industry questionnaires and during four industry case studies. Figure (iv). shows the project's iterative approach and output.

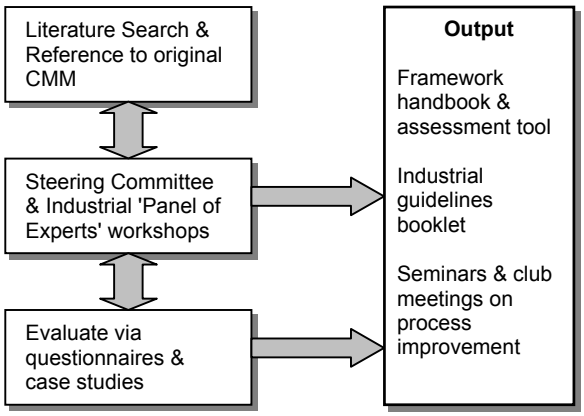

Figure (iv) Research Methodology

Questionnaire and Pilot Study

During the early stages of the research an industry questionnaire and a pilot assessment were performed. Their main purpose was to establish the relevancy and appropriateness of the subject area in the construction industry and to refine and develop the framework before entering into a 'live' case study environment. The limited nature of the studies prevented any detailed analysis at this stage but provided useful indications of industry perceptions of the topic area.

The questionnaire was a tailored version of the original CMM questionnaire [Paulk 1993] with minor modifications. 'Software' was replaced with 'Construction' and changes were made to the questions and process definitions in order to make the terminology relevant to the construction industry. An assumption was made at this stage that the majority of the selected organisations would have little experience of process maturity and hence, these organisations were likely to reside at the lower levels of the SPICE maturity framework. As such, the questionnaire was constructed to include questions for levels 2 and 3 only.

The questionnaire was then sent to 80 industry recipients. The target audience was from a broad disciplinary cross-section of the industry and from a mixture of large organisations and small to medium enterprises. It also included representatives from clients and suppliers in order to capture both an internal and external perspective.

32 individuals responded to the questionnaire, a response rate of 40%. The responses to the questions and comments showed that the subject area was understood and appropriate. However, it was apparent that further modification to the terminology would be required in order to make the framework construction specific. The responses also confirmed the relevancy of the level 2 and 3 key process areas (KPA) specified by the model. When asked to rate the perceived importance of each key process area on a scale of 1-5, each KPA rated 4 or 5.

The pilot assessment took the form of a much reduced CMM assessment.

The findings of the initial studies are as follows:

- Construction participants generally understood the issues addressed in the CMM questionnaire.
- The assessors (from the IT industry) could relate to, and interpret the pattern of the responses (in a construction company). The responses reflected some organisational characteristics, which are also encountered in software development organisations.

- Organisation culture and communications issues in construction are similar to those encountered in software development organisations.
- Process capability characteristics are broadly similar to that in the software industry.
- Systematic quality management, change management and other project control mechanisms would have similar benefits in the construction industry, to those anticipated in the software industry.

Some of the differences between the construction and software development industries, which were noted by the IT management consultants were that:

- In construction, professional qualifications, customs and working practices are better established.
- In construction industry standards and data are more readily available.

Case Studies

The research team has undertaken four case studies in 'live' construction environments as detailed below.

Case Study	Organisation	Contract	Scope of Assessment	No. of Staff
One	Large Contractor	Large PFI	Single Project Team	12
Two	Large Contractor	Medium sized Design & Build	Single Project Team	15
Three	Small Architect (<50)	-	Whole Organisation	4
Four	Partnered Delivery Team	Design & Build Partnership	a) Management Team (inc. Design) b) Project Team c) Specialist Contractor (x2)	32

Table 1. - Case Study Profiles

In each case, the organisational unit was assessed against level 2 of the SPICE framework.
The objectives were to further refine and develop the framework by:

- Identifying any process issues not already addressed by the framework;
- Testing the suitability of the assessment mechanism in a construction environment
- Testing the effectiveness of the assessment mechanism by determining if any of the recommendations derived are meaningful;
- Capturing experiences of the project team that would benefit development of the framework

Case Study 1
Case study one was a £6 million design and build fit-out project late in its construction phase. 12 members of the project team were involved in the assessment across disciplines and from senior management to site operatives. The assessment found that the project management processes such as project planning, project tracking and monitoring and sub-contract management were in place and generally well managed. However, virtually no evaluation of project processes was despite staff being able to identify inefficient processes, and in some cases, suggest improvements. Many of the design control procedures were weak or not in place. "Commercial Risk Management" and "Project Team Co-ordination" were not adequately implemented. The assessment also identified cultural issues not specific to the model. The team as a whole had an open culture, but project goals were not communicated throughout the team. Good work and project successes were not recognised or rewarded and this often demotivated staff.

Case Study 2
Case study two was a £55 million Private Finance Initiative design and build project at mid-construction phase. 15 members of the project team were involved in the assessment across disciplines and from senior management to site operatives. The assessment found that general project management processes were well managed. Not only were the processes well planned and documented at the commencement of the project, there was also evidence that they were practised and validated during the project. The major weakness identified was similar to case study one, the processes were not periodically reviewed, evaluated and improved during the project. Some managers were of the opinion that the time and resource constraints of a live project prevent improvement activities. Senior management dismissed this view. A workshop was held to develop improvement proposals. However, since the majority of the Key Processes defined by Level 2 were satisfied, the recommendations of the assessors was for the organisation to focus on Level 3 issues of the model.

Case Study 3
The previous two case studies were conducted in a large organisation. This case study provided the opportunity to test the assessment tool on a small to medium sized organisation of less than 50 staff. This reduced size also allowed the whole organisation to be assessed and not a single project as before. This case study was performed in a small firm of architects and also allowed the framework to be implemented for the first time in the design function as opposed to the construction operation as before. Four members of the practice were involved in the assessment, including project architects, technicians and a director.

It was found that it was still feasible to perform an assessment with limited participants in an organisation of this size. Although there were fewer staff, each performed more than one function and therefore from their evidence it was still possible to develop a meaningful process maturity profile. The assessment also confirmed the key process areas as relevant for construction design activities.
A document accurately detailing company procedures, roles and responsibilities existed. However, this document had neither been implemented nor communicated to the staff. As a result, it was found that many of the key processes were improvised and thus were inconsistent through the office. This reduced management visibility into individual projects and made the monitoring of projects more difficult.

Case Study 4
Case study four was performed in a partnered supply chain environment. This took the form of four separate assessments analysing a project management team, a site based project team and two specialist contractors. 34 participants in total were involved in the assessment selected as a broad cross section as in previous studies. The assessment found a comprehensive documented construction process document in place. It clearly defined procedures and identified roles and responsibilities within the team. A high 'process awareness' existed within the organisation. However, since the original process was introduced, the team had innovated and improved their working methods and the documented process no longer reflected the current mode of working. As a result, although the majority of the management processes were clearly understood and performed, the ability to validate and evaluate these processes was poor. Thus the potential for continuous improvement was also weak. The team also had a strong existing focus on technical processes and their continuous improvement. Productivity gains had already been achieved through this initiative but anecdotal evidence suggested that over time, improvement opportunities were becoming increasingly difficult to find. During attempts to identify potential technical process improvements, staff increasingly found that inefficient technical processes were inextricably linked to weak management processes. It was felt that future productivity improvements could be found in tighter control of the management processes. The case study confirmed that the management processes referred to closely mirrored those key process areas of the SPICE model.

REVIEW OF THE SPICE FRAMEWORK

The case studies highlighted the following issues that the research team has incorporated into the framework.
1) The terminology used in the framework requires more refinement to make it familiar to construction professionals. This is being addressed as on-going activity in collaboration with industrial partners.
2) Many problems associated with any phase of a construction project are often inherited from a previous phase. ie. Pre-construction to construction or construction to commissioning and maintenance. To gain an entirely accurate project/organisation profile, it is necessary to assess at *all* stages of the project life-cycle.
3) "Health & Safety Management" was identified as a key process. This is not contained in the original CMM as it is of minor importance to the software industry. However, it was highlighted as of major importance to the construction sector and it has been included in the model.
4) The "Risk Management" key process is often confused with health and safety risk assessments. The definition has been clarified.

5) During construction phase, "Brief /Scope of Work Management" loses much of its meaning as the brief has already been defined and established during a previous phase. Similarly, "Project Change Control" takes on increased importance at this phase since modifications to the brief occurring subsequent to it being established are processed as changes.

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DEVELOPMENT OF CONSTRUCTION BEST PRACTICE EXPERT SYSTEM

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Abstract

The performance level of construction industry in the UK is generally considered to be low. The reasons for this situation are twofold, firstly due to the temporary organisational structure of construction team and secondly the inefficient construction process. Previous research in this area has focused on developing a generic model to represent the construction process.

It is necessary to develop a process model, which clearly identifies the roles and responsibilities of the major parties on the building team and identifies the key issues within the project cycle. The method for presenting this model is by using an expert system.

The primary aim of this paper is to discuss the development of the CONstruction Best Practice System (CONBPS). The theoretical framework of CONBPS and the development and evaluation of the system will be described. The future research will also be discussed. Finally, the advantage of this model will be identified.

Keywords

Best practice, construction process, modelling,

1. INTRODUCTION

Construction projects have been criticised for under-achievement for many decades (Carpenter, 1981; Egan, 1998). The reasons for this situation are generally two-fold: the inefficient construction process and temporary multi-organisation (Karbu and Lahdenpera, 1999; Low, 1998; Tucker and Ambrose, 1998).

Modelling the construction process has been a popular topic this decade. Earlier research on this topic focused on modelling the construction process. The representative researches include Karbu and Lahdenpera (1999), Sanvido and Norton (1994) and Walker (1985). Later, researches concerned not only modelling the process, but also considered the participants as well. These researches include Austin et. al. (1999) and Kagioglou et. al. (1998). The new trend is an introduction of computing skills into the modelling of the construction process. However, this approach seem as too complicated for the non-computer literate. Moreover, previous research developed models which can be applied to any construction procurement process. However, this approach may bee seen as too generic to some extent.

2. AIM OF RESEARCH

The primary aim of this research is to develop a construction best practice expert system for successful building projects. This system focuses on projects which use the traditional procurement strategy, as it is the most popular procurement strategy but at the same time subject to most criticism (RICS, 1994 and 1996; Tucker and Ambrose, 1998). This model will clearly identify the roles and responsibilities of the major parties in the building team and identifies the key issues, i.e. time, cost, quality and safety, within the project cycle, which can prove critical to project process. Because of the limitation of time, this project will focus on the early stage of the construction cycle, i.e. from inception to scheme design stage.

The aim of this paper is to discuss the development of the CONstruction Best Practice System (CONBPS). This paper is divided into five sections: theoretical framework of CONBPS; its development process; its evaluation process; conclusion and a discussion of its future research.

3. THEORETICAL FRAMEWORK OF CONBPS

The skeleton framework of the best practice model is based on the standard cycle of work in a building project identified in the Royal Institute of British Architect (RIBA) Architect's Job Book (1995) and known as 'the RIBA Plan of Work'. It also includes the information from various documents, like publications from the National Joint Consultative Committee for Building (NJCC, 1989), the Royal Institution of Chartered Surveyors (RICS, 1983), the Chartered Institute of Building (CIOB, 1996), Her Majesty's Treasury (HM Treasury, 1993, 1994, 1996 and 1998) and the Health and Safety Commission and Executive (HSC, 1995a, 1995b and HSE 1994) etc., so as to reflect modern management issues. The review of the development and a description of the model have already been discussed in Poon et. al. (1999a).

Figure 1 shows the framework for identifying best practice in the RIBA Plan of Work Stage A "Inception" stage. Because of limitation of paragraphs, the first few activities have been shown.

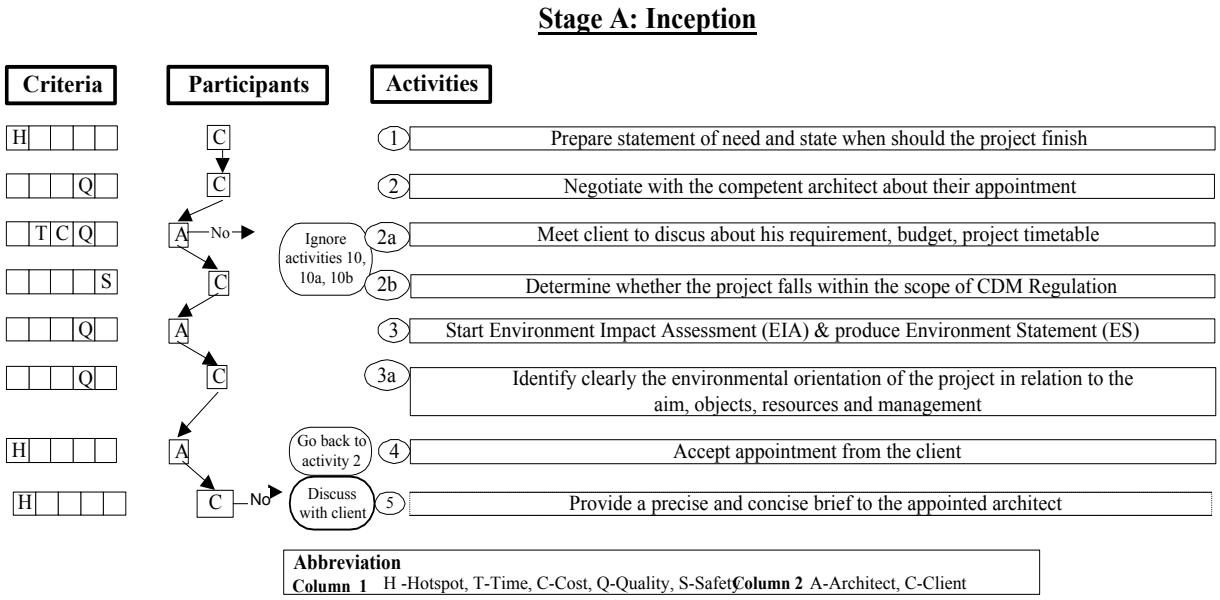

Figure 1 Framework for RIBA Plan of Work Stage A 'Inception' stage (Part)

The diagram is divided into three columns. The first column states the *criteria*. The criteria in this model include time, cost, quality and safety. Apart from these criteria, certain 'hotspots' are also identified within each stage of the project cycle. The 'hotspots' are the 'critical activities', to which each participant should pay special attention in order to ensure satisfactory performance before proceeding to the next stage. The 'hotspots' were identified following an extensive literature search and feedback from practitioners.

The second column identifies the *participants* in the construction process. The participants, at the pre-contract stage, include the architect, quantity surveyor, client and the planning supervisor.

The arrows show the sequence of work. If the activities reach the 'hotspot' and there is no agreement at that point, the participants should go back and re-start the procedure again. In some activities, only one party needs to participate.

The third column shows the *activities* of the construction process, the numbers indicate the sequence of work. The information in this column is abstracted from various sources of literature that has been listed out in the previous section.

Figure 1 is the input information for the development of the CONBPS model.

4. DEVELOPMENT OF CONBPS

4.1 Development tool of CONBPS

The expert system shell is the tool used for developing CONBPS. It is the package designed to support the development of a knowledge-base system. These shells comprise a predefined inference engine that knows how to use the knowledge base to reach conclusions.

The expert system shell that was used for developing CONBPS is XpertRule. XpertRule is a software tool for graphical development and maintenance of application in general and knowledge based applications in particular.

4.2 Knowledge acquisition of CONBPS

Knowledge acquisition involves eliciting, analysing and interpreting the knowledge that a human expert uses to solve a particular problem.

The process of knowledge acquisition of CONBPS embraces four stages:

- Literature reviewing: Reviewing of text books, journals and reports etc.
- Survey experts: Sending out questionnaires to experts
- Prototyping: Offering the developed prototype model for criticism
- Interview: Semi-structured interview with experts for abstracting experts' knowledge and experience

The knowledge acquisition process of CONBPS has been discussed in Poon et al. (2000a) and the research findings of the second stage knowledge acquisition 'survey experts' is reported in Poon et. al. (2000c).

4.3 Knowledge representation of CONBPS

The 'decision tree' was chosen as the knowledge representation method in this project. A decision tree is a hierarchically arranged semantic network and is closely related to a decision table. It is composed of nodes representing goals and links that represent decisions or outcomes (Awad, 1996).

The system is divided into sixteen modules. The first twelve modules represent each construction stage while the other four modules represent the success criteria for the construction project, i.e. time, cost, quality and safety. The reason for dividing the modules in this way is to assist the user. The user can choose the modules depending on which construction stage they are currently in and use and which criteria they wish to emphasise.

The details of the development of CONBPS have been discussed in Poon et. al. (1999b).

4.4 Operation of CONBPS

The basic operation of CONBPS is shown in figure 2. It is a totally interactive procedure where the users communicate with the system through a user interface. The first five levels (from the knowledge acquisition process to the CONBPS knowledge base) described the process of developing the knowledge base. It has been discussed in the previous sections.

The lower part of figure 2 shows the operation of CONBPS. CONBPS will state the construction activity and ask whether the user has been finished. If the user wants more information, then it will link to the explanatory facilities and provide additional information. If the users do not ask for more information, it will continue to the next activity. If the 'hotspot' activity has been reached and the user has not satisfied all the criteria within that activity, the system will loop back and re-start the mini-cycle again.

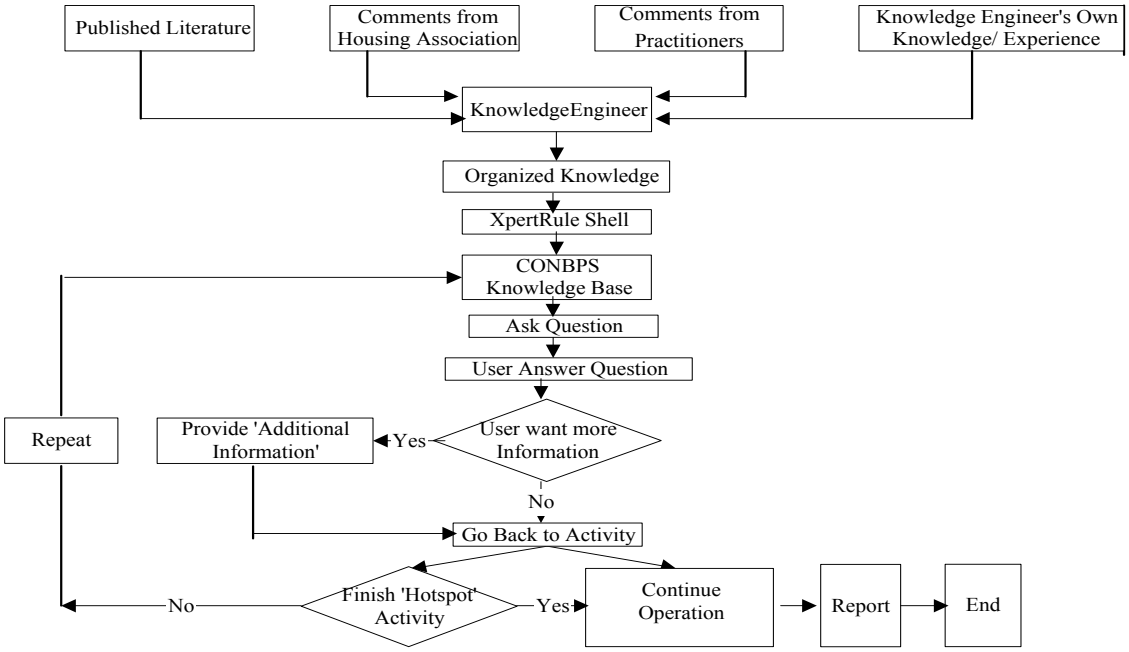

Figure 2 Operation of CONBPS

Figure 3 shows an example of the screen for each activity. A key question is asked at each stage and the user should respond either 'yes' or 'no'. If they choose 'yes', then the system will continue to the next activity. If they choose 'no', then the statement 'ensure the previous activity has been finished before proceeding to the next activity' will appear in the screen. It aims to ensure the user has finished all activities. If the user has not finished a certain 'hotspot' construction activity, they should go back as indicated and re-run the procedure again.

Additionally, there is also the explanatory facility which has been built into the system. Other than 'yes' or 'no', the user can choose the icon 'information'. This icon provides an explanation of the terminology and additional information about the project.

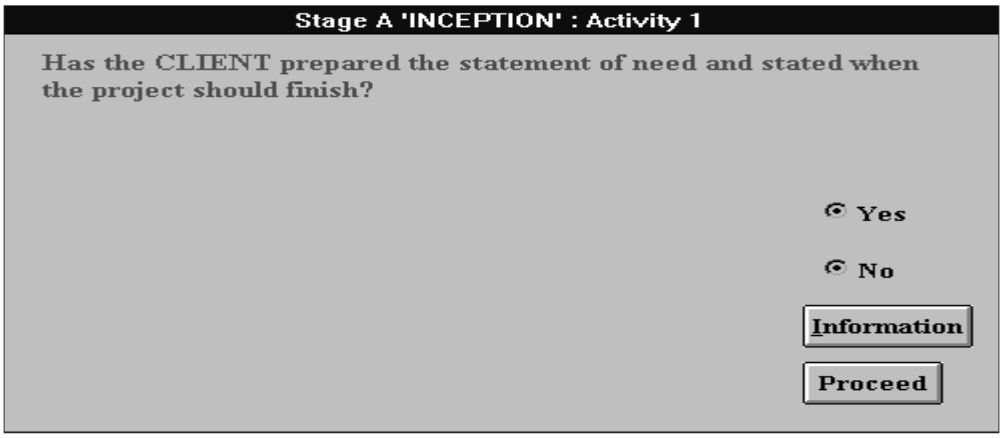

Figure 3 Activity 1 of Stage A 'Inception A'

The structure of CONBPS has been discussed in Poon et. al. (2000b)

5. EVALUATION OF CONBPS

The evaluation process of CONBPS includes verification and validation. The method used to carry out the verification of this project is by the submission of the prototype rules to the construction participants for criticism and evaluation. Their comments and suggestions will be incorporated into the system wherever this is possible. The aim of this practice is to ensure that the system does not contain technical errors, the description of activity is clear and its sequence is correct.

As with the verification process, the validation process consists of two stages. The first stage focuses mainly on performance issues specific to the specification of the system. The second stage is by running the test case. The aim of verification is to ensure the practicability of the system.

6. CONCLUSION

The CONstruction Best Practice System (CONBPS) is a new approach for modelling the construction process. The advantages of this system are twofold: the design of the system and the presentation of the system. The well-known RIBA Plan of Work (1995) has been chosen as the framework, users should therefore be familiar with the general format. The expert system was chosen as the presentation method. It can provide the 'question and answer' function and also provides additional information. Therefore, it can help inexperienced participants to become familiar with the construction process. It can also assist the project manager in planning the project cycle before execution.

The system has certain functions that benefit both the project manager and participants. The system has identified the key criteria for each activity, so the user will know what is the impact on time, cost, quality or safety if they don't finish that particular activity. Besides, the system will loop back to the previous activity if the user did not finish the activity. For the 'hotspot' activity, it will even 'loop back' to the beginnings of the particular cycle and re-start the process again. It can be used to improve the efficiency of the design and construction process.

In summary, the benefits of CONBPS include:

1. 'Focus' and the 'detail' - It focuses on a particular procurement strategy, it lists the construction activities in detail and identifies the relevant parties. Additionally, it also provides information on the activities.
2. Practicability – It uses the well-known RIBA Plan of work as the framework, so the operations are easier to follow. The design of the interface is user-friendly.

7. FURTHER RESEARCH

CONBPS is still under development. The preliminary system has been developed. Currently, it is in the final stage of knowledge acquisition process. The interviewee includes the various participants of construction process, i.e. architect, quantity surveyor, planning supervisor and client. The clients include private client, public client and quasi-client, such as Housing Associations. As the first four stages, i.e. from Inception to Scheme Design have been completed for demonstration, therefore no contractor has currently been targeted for interview.

After finishing the interview stage, the practitioners' comments will be included in the system so as to refine the system to become more practical and usable.

The future development of CONBPS is to incorporate a hierarchical mathematical model into the system. The preliminary design of the model should have four levels: the top level is the overall success of the construction; the second level is the success within individual construction stages (i.e. from inception to feedback); the third level is the success under the individual criteria of time, cost, quality and safety; the fourth level is the success factors for construction project.

The results of the analysis will be drawn from the report and placed at the front of each construction stage. The aim of this exercise is to alert the user's about the factors which influence project success. The method chosen for analysis is the analytic

hierarchy process (AHP). This method has been chosen to enable the user to rank the important criteria by the use of a weighting system.

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