Construction Management & Economics

ISSN: 0144-6193 (Print) 1466-433X (Online) Journal homepage: https://www.tandfonline.com/loi/rcme20

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To cite this article: Derek H. T. Walker & Yue J. Shen (2002) Project understanding, planning, flexibility of management action and construction time performance: two Australian case studies, Construction Management & Economics, 20:1, 31-44, DOI: 10.1080/01446190110089691

To link to this article: https://doi.org/10.1080/01446190110089691

Published online: 22 Oct 2010.

Construction Management and Economics (2002) **20**, 31–44

Spon Press
Taylor & Francis Group

Project understanding, planning, flexibility of management action and construction time performance: two Australian case studies

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Received 11 December 2000; accepted 10 August 2000

Construction time performance (CTP) and flexibility in approaches to project time planning have been shown to be significantly associated. This raises interesting questions about how effective planning and control to facilitate flexibility in overcoming unexpected problems may be achieved. Case study data were used to explore links between planning and flexibility. This paper reports upon a recent study of two highly complex projects, a mental and forensic health hospital and a very large freeway/bridge/tunnel urban infrastructure project. The authors investigated planning flexibility using a framework of project team understanding and knowledge transfer to provide a model that contributes to our understanding of mechanisms and drivers that delivers flexible behaviour that may affect CTP. We conclude that both ability, supported by organizational and team competence, and commitment to explore construction method options in a flexible manner, i.e. responding to unanticipated problems, are necessary to facilitate good construction time performance.

Keywords: Construction time performance, construction planning, agility, flexibility, project complexity, case study

Introduction

The purpose of this paper is to facilitate better understanding of the mechanisms that help some organizations achieve better planning through adopting flexible approaches to overcoming unexpected problems.

The study of construction time performance (CTP) has moved significantly forward from the pioneering efforts of Bromilow, who sought to provide a model that could predict construction time based on construction cost (Bromilow and Henderson, 1976; Bromilow *et al.*, 1980). CTP is the rate of build expressed as the ratio of how long a project should have taken to construct (through a method of predicting time performance) compared with the actual time to construct. A CTP index can be constructed for comparing dissimilar projects (Walker, 1995). A study of 25 Australian building projects in the mid-1970s demonstrated that managerial factors played a significant part in determining CTP (Ireland, 1983). Numerous quantitative studies of construction projects in Australia, the UK and the USA have contributed to a better understanding of factors influencing CTP by indicating more clearly the nature of these managerial actions (Nahapiet and Nahapiet, 1985; Walker, 1994; Chan and Kumaraswamy, 1995; Chan, 1996, 1998; Walker and Sidwell, 1996; Vines, 1998). Effective planning and control of construction operations were common themes, as was effective communication within and between project teams. In a study using information from Hong Kong construction professionals, the top ranked factor was contractor-related (poor site management and supervision); this was followed by design team-related (particularly design complexity and mistakes and delays in design documentation) and labour related (skills gaps, motivation gaps and productivity gaps) factors (Chan and Kumaraswamy, 1997).

However, these studies have not involved close observation and multiple interviewing of key participants that provides rich sources of data from a case study approach (Yin, 1994). Case studies provide more

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Construction Management and Economics
ISSN 0144–6193 print/ISSN 1466-433X online © 2002 Taylor & Francis Ltd
http://www.tandf.co.uk/journals
DOI: 10.1080/01446190110089691

opportunities to test ideas and presumptions through observation, asking both structured and unstructured questions of multiple players as well as gathering documentary evidence (Yin, 1994). The case study approach was adopted and each of these data gathering techniques was used for the two case studies reported upon in this paper (Shen, 2000).

Studies undertaken in Hong Kong and Australia have demonstrated that CTP is significantly influenced by the managerial performance of construction management teams (Walker, 1994; Chan and Kumaraswamy, 1995, 1997; Chan, 1996; Vines, 1998). More specifically, it is has been demonstrated that it is critical for excellence in construction planning practice. Construction mangement teams need to achieve a high capacity to plan and execute work in a manner that allows them to identify problems before any detrimental impact becomes evident, and to overcome such difficulties if they arise (Walker, 1996a). Table 1 presents the result of a study of 45 Australian construction projects. These highlight factors relating to the willingness, capacity and ability of construction management teams to understand project constraints and respond accordingly. The values included in column 2 represent the trigger point where increases in an index measure of CTP for clusters of projects within the sample data achieved (at the 95% level of significance) higher CTP than values below that trigger point. For example, for factor 4, projects where 'analysis of construction methods' was rated 'very high' by respondents, the mean CTP index was 29% higher than for those with a rating of 'high' or lower than 'high' (Walker and Sidwell, 1996). Results from Table 1 provide quantified findings that studies cited earlier describe in more general terms. Key implications for high CTP to be expected can be drawn from Table 1 results:

- that the client/client representative must have a strong focus on achieving a short project construction time;
- that the working relationship needs to be acceptable (slightly below average or better); and
- that the construction management team's response to planning and control needs to be excellent.

These results provide support for the need for agility and flexibility of response that has been a hallmark of 'lean construction'. Leanness relates to reducing non-value-adding processes and activities in the supply and production chain. It implies striving to use less of everything in a way that squeezes out waste and non-value activities or processes (Womack and Jones, 2000). The basic idea of lean production in construction is to keep things as simple as possible. It encompasses concepts such incremental improvement (Imai, 1986) but explains this as part of a strategy for just-in-time resource delivery that achieves excellence in communication and co-ordination (Melles, 1997). 'Agility' refers to the responsiveness of manufacturers and suppliers to customer demands and to the production process. 'Drivers' can be summarized as a need to be agile, a strategic intent to be agile, having a strategy to be agile and having agility capabilities, i.e. responsiveness, competence, flexibility and speed, (Zhang and Sharifi, 2000). 'Responsiveness' includes an ability to identify when change is required and to respond to these changes (either reactively or proactively) to recover from them (Ballard and Howell, 1997; Zhang and Sharifi, 2000). Koskela has indicated an interesting connection between a view of construction production as transformational (input, process, output), flow (movement of materials, resources etc., exemplified by the just-in-time approach) and value (as represented in the concepts of a value chain) (Porter, 1990, 2001; Koskela, 2000). The concepts of supply chain management and value chain management focus on improvement of the planning and co-ordination of production resources (O'Brien, 1997; Koskela, 2000) as well as on the people interface, to achieve better responsiveness, more intelligent utilization of value in terms of knowledge (Nonaka and Takeuchi, 1995), and commitment (Womack and Jones, 2000).

Table 1 contains evidence establishing that construction management teams that are excellent at planning often are associated with good CTP through the use of lean and agile production approaches. Shen's (2000) study was able to shed some light on this question by exploring characteristics that these organizations share.

Factors that influence agility and flexibility in planning and control

Being flexible or agile is dependent upon organization and people drivers and inhibitors. Agility drivers are those influences that encourage organizations and individuals to be agile (the competitive environment), the strategic intent to become agile, and the strategy adopted (reactive or proactive). Capabilities demonstrating agility include the practices, methods and tools directed towards being agile. These are enhanced and facilitated by information for decision-making, and include information on organization, technology, people and innovation (Zhang and Sharifi, 2000). The ability to reflect upon theory (a plan) and practice (actions and consequences as they unfold) has been highlighted as a critical capacity for professional competence. Examples of this reflective capacity have been adapted from corrective responses to conditions of error (Schön, 1983). Although these do not relate

Table 1 Construction management team planning, control and administration skills

Factors affecting CTP	Significantly higher CTP when	Increase in mean CTP
Construction management team's skills in planning, control and administration in		
1 General management performance	High, or Very high	20%
2 Management systems	Very high	23%
3 Forecasting planning data	Very high	31%
4 Analysing construction methods	Very high	29%
5 Analysing resource movement	Very high	33%
6 Monitoring and updating plans	Very high	26%
7 Response to problems/opportunities	High, or Very high	33%
8 Co-ordination of resources	Very high	26%
9 Level of construction management team communication management	Very high	39%
10 Client's representative/construction management team working relationship	Slightly high or higher	28%
Client's objectives		
11 Client's time minimization objective	High or Very high	27%

Source: Walker and Sidwell (1996).

specifically to construction planning, they do support some findings presented in Table 1. They are illustrated in Table 2, and indicate how excellent planning practice may impact upon action (control through flexibility of action and responsiveness to actual events).

The above description highlights the need for an open environment where knowledge is shared, tested and scrutinized. Tacit knowledge held in the minds of hands-on construction team planners is made explicit through planning documentation. The process of knowledge creation and effective use has been shown to flow from tacit (subjective, experiential practical knowledge that is not codified) to explicit (rational, codified, theory) in a spiralling manner. Tacit knowledge becomes externalized through developing models and plans. This can involve a considerable amount of social interaction and discussion, where tacit knowledge is exposed to challenge and scrutiny and combined with other forms of explicit knowledge that reside in corporate data files, corporate memory (experience from previous projects), supply-chain members who may contribute to the planning process and perhaps knowledge from the client and/or design team. Planning is an evolving process. Knowledge creation is a vital area of competence for effective and innovative organizations (Nonaka and Takeuchi, 1995). Drivers and inhibitors of agility influence a construction team's capacity to exercise flexibility. Competence, responsiveness, flexibility and speed of delivery are manifestations of agility capability (Zhang and Sharifi, 2000).

Figure 1 presents the proposition that the degree of ability of construction management teams to exercise flexibility options during construction to obviate unexpected problems is influenced by two key factors, the ability to be flexible and the commitment to do so. Team and individual ability to be flexible is influenced by the degree of understanding of project complexity and flexibility to adopt options to overcome unexpected problems. The degree of understanding of the project, its complexity and the existence of options for

Table 2 Overcoming the primary inhibitory loop of planning conditions of error

Planning conditions of error	Table 1 factor	Corrective responses to aid flexibility
Vagueness	3, 4, 5	Specify clearly: workflows, resource movements, methods, expected duration, logic relationships between tasks, phases, etc.
Ambiguity	3, 4, 5	Clarify assumptions and expectations of planned progress.
Untestability	6, 7	Make testable: allow challenges, encourage improved ideas and approaches.
Scattered information	1, 2, 8	Concert, consolidate and make accessible all required information.
Information withheld	8, 9, 10	Reveal, ensure that a rich source of background strategies and planning data is available during the operational phase.
Undiscussability	6, 7, 9, 10	Do not hide poor progress variances planned from actual. Be transparent to allow remedial and planning review of original assumptions. Document and fully assess and analyse risks.
Uncertainty	5, 7	Inquire: undertake simulations, what-if analysis and scenario planning to explore options.
Inconsistency incompatibility	11	Resolve: be clear about the objectives and that they do not clash.

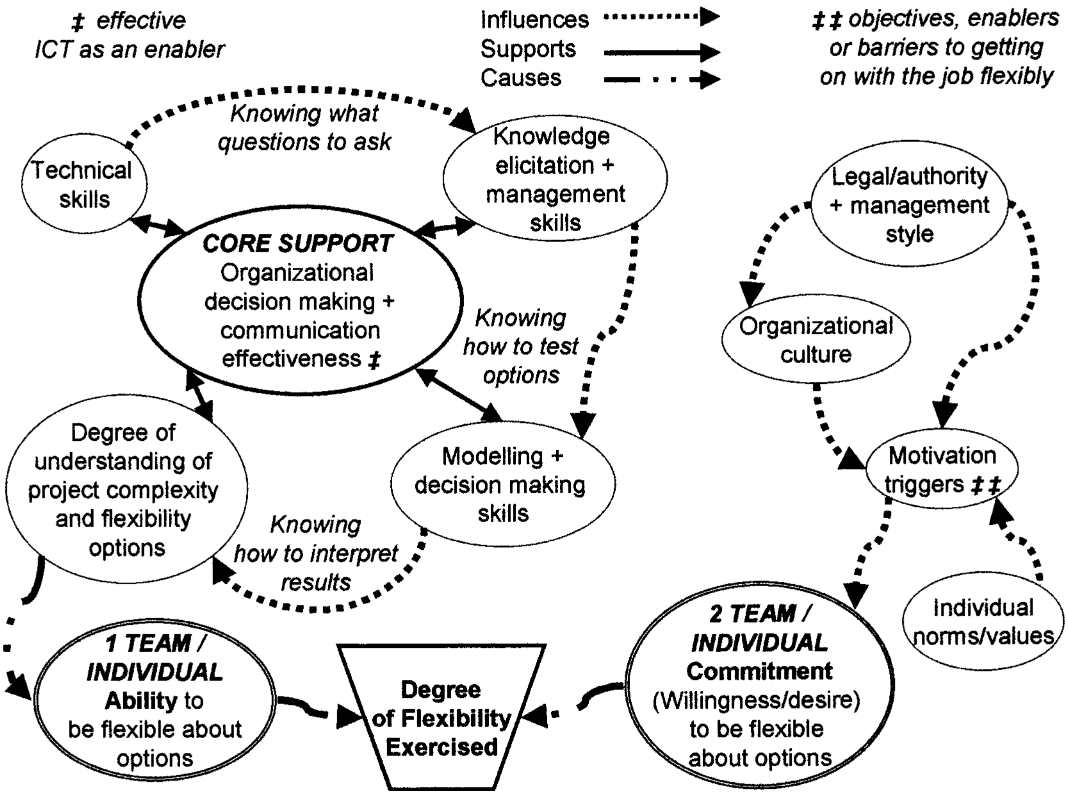

Figure 1 Exercising flexibility options model

flexibility is a primary agility driver. This is influenced by an infrastructure of core support provided by the project organization and the construction management team. This support allows decision-making and communication effectiveness, and can be enabled through effective use of information and communication technologies (ICT).

Understanding is derived from core support infrastructure, influenced by: (i) knowing what questions to ask when planning requires technical skills and knowledge elicitation skills, (ii) knowing how to test options for undertaking construction operations (which requires both knowledge about the available options and an ability to model options and to make decisions), and (iii) knowing how to interpret planning and simulation test results (which is based upon modelling and decision-making skills). An effective core support infrastructure provides effective ICT that facilitates both an understanding of the range of options available and their likely impacts. This underpins a flexible approach to planning and the ability to rapidly modify existing plans to take advantage of changed circumstances or to capitalize on opportunities that may arise for improving CTP.

However, flexibility and agility require both an ability and commitment to be flexible/agile. The extent to which each of these drivers influences the degree of flexibility exercised is unclear at present, but it is proposed that without a capability for both flexibility and commitment, flexibility will be unlikely to occur.

Commitment (motivational triggers) to being flexible is influenced primarily by individual/team enabling goals and by objectives to 'get the job done', and this may be affected by the organizational culture that may enable or inhibit an environment that allows the clear establishment of goals and objectives and provides recognition and rewards for achieving such goals. These can reflect objectives established by the construction contractor and/or client or client representative, and effectively can be internalized through development of what Senge, Schön and others refer to as 'shared mental models'. These are commonly accepted visions of outcomes, processes and objectives or 'preferred futures' (Argyris and Schön, 1978; Schön, 1983; Senge, 1992; Nonaka and Takeuchi, 1995; Senge *et al.*, 1999). These mental models can also influence the organizational culture of teams, and act as drivers or inhibitors for flexible action. For example, a culture that is timid or punishes experimentation and learning from mistakes inhibits the motivation for increased flexibility if it requires risk taking (Argyris and Schön, 1978; Senge *et al.*, 1999). Motivation needs to be intrinsic, i.e. appealing to personal needs for overcoming challenges. These are stronger drivers in the long term than more immediate or transitory rewards such as bonus systems, etc. (McGreggor, 1960). Organizational culture must support flexibility by valuing and encouraging opinion diversity. It is necessary also to create an organizational culture that encourages risk taking, provided that lessons are learned from mistakes and near misses as well as from success. This needs to be supported by a management style that encourages empowerment, team interaction and provision of appropriate reward systems.

Empowerment and encouraging diversity of views to explore and arrive at shared mental models have been promoted widely as being important for knowledge workers (Bolman and Deal, 1991; Senge, 1992; Katzenbach and Smith, 1993; Hamel and Prahalad, 1994; Field and Ford, 1995; Ragins, 1995; Argyris and Schön, 1996; Hersey *et al.*, 1996; Pedler *et al.*, 1996; Cope and Kalantzis, 1997; Barlow *et al.*, 1998; Limerick *et al.*, 1998; Goleman, 2000; Hamel, 2000; Walker *et al.*, 2000). The result of factor 11 in Table 1, as presented in Table 2, indicates e.g. that a client with clear non-conflicting objectives can also contribute to a focused direction in planning projects, leading to a positive influence in CTP. With these elements in place there is likely to be an enhanced attitude towards exercising flexible options.

Figure 1 established a theoretical link between flexibility, planning and scheduling skills, communication, and factors driving commitment to 'get on with the job'. Different parties in the construction management team may exercise and demonstrate their planning skills in different ways. The result remains manifested in systematically planning the project and documenting such plans so that assumptions of construction methods and construction time scheduling objectives can be understood clearly by those undertaking the work. Thus, they can modify plans as necessary because of their understanding of the underlying assumptions. Commitment to flexible planning is manifested in construction time performance objectives being established clearly and in maintaining their integrity through monitoring and control while being flexible enough to tactically re-plan where necessary to deal with unexpected problems.

Two case study projects were studied and analysed from the perspective of how the construction planning process was used to develop an understanding of project complexity and to exercise flexibility options. Two of three projects studied as part of a research programme (Shen, 2000) were chosen. These projects were large in scope and complex in terms of organization and the external environment. The third project was small and relatively simple in scope and complexity, and it was decided to exclude this project from the analysis presented in this paper.

The case studies

The first case study project is a 135-bed secure hospital facility in Australia. Most of the facility was newly constructed, and a small part was a refurbishment of former hospital wards. The existing hospital had specialized in the treatment of tropical diseases, infectious diseases and AIDS. The site was subject to medical waste products having been dumped on-site over an extended period in unknown locations. This represented a hidden health hazard that caused complications to project progress when the waste products were discovered during the construction phase. The project used a fixed lump sum tender procurement strategy. The construction cost was A$22 million and the construction time 240 working days. Approximately 50 subcontractors (representing about a dozen different trades) and 10 major suppliers were engaged on the project. Construction work on the hospital project involved pre-cast, structural steel and timber framing structural technologies. The project required extensive refurbishment of old buildings and installation of sophisticated security services, and presented both technical and managerial complexity. The hospital project's client procurement system (Masterman, 1992) is illustrated in Figure 2. A project director/manager was appointed as the client's representative and to also provide constructability advice. The general contractor was responsible for on-site construction work following a traditional fixed cost/time design then tender procurement approach. The culture and management authority influence was traditional, with limited scope for contractor authority to drive design clarification issues or to strongly influence the priorities of the client representative's objectives.

The second case study project is part of one of Australia's largest urban road infrastructure developments. The entire project included 22 kilometres of multi-lane expressway joined by two new tunnels and

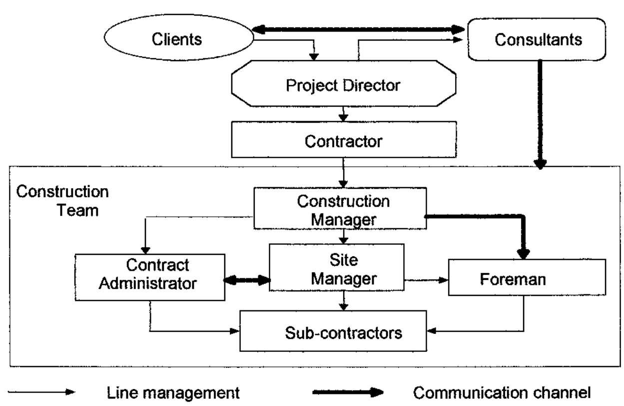

Figure 2 Hospital project case study organization chart (source: Shen, 2000)

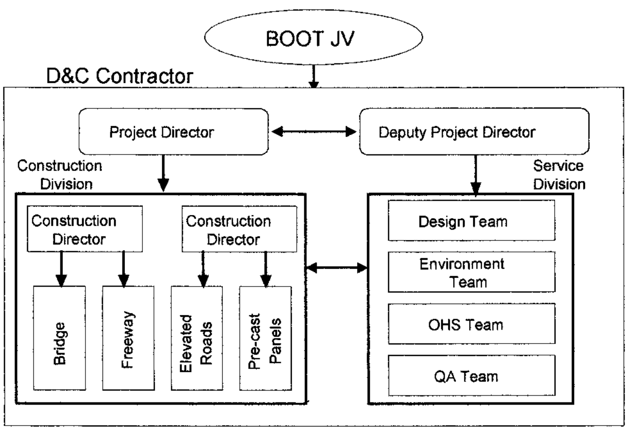

Figure 3 Freeway project case study organization chart (source: Shen, 2000)

a major bridge. The case study focuses on the western section of the project development, which was delivered using a 'build, own, operate, transfer' (BOOT) approach. The western link (freeway) project was subcontracted using a design and construct (D&C) approach. The cost of the western section was A$140 million and the contract period was 37 months. Figure 3 indicates that a construction-orientation approach guided the principal project management ethos adopted by the D&C contractor on the project.

Both a construction division and a service division were established for the project. The construction division was divided into four business units. Four senior project managers, which according to Masterman's (1992) categories are the equivalent term to construction manager, were appointed to be responsible for each unit. The service division included: the design team, the environment team, the occupational health and safety (OHS) team and the quality assurance (QA) team. These teams were service groups spanning each business unit. The design team was only one of the service groups, and it was not the dominant group in the project management team. The interesting aspect of this project was that planning was undertaken holistically with occupational health and safety (OHS) and environmental management (EM) being integrated with quality management (QM). This system was also influenced by buildability/constructability exercises, where the design and construction teams collaborated to simplify the design wherever practicable. Thus, the culture and management authority provided a high level of opportunity for the construction management team to drive design issues and time objectives for the project. This appeared to enhance the construction management team's intrinsic motivation.

Table 3 summarizes the two case studies in terms of the project characteristics that illustrate the degree of complexity for each project. Complexity is seen to have a number of dimensions. The size, scope or scale of a project presents complexity in the shear magnitude of effort required. The number of entities and elements needed to be co-ordinated also presents complexity, as does the nature of these interactions (Baccarani, 1996).

Effectively, both projects used ICT to support their decision-making and communication. The study identified how contractors responded to the challenges and constraints presented during the course of construction and, more specifically, how they initially planned their projects, how they dealt with complexity during construction and what was their level of flexibility in responding to challenges.

Ten senior construction and client representative staff were interviewed, using a structured questionnaire to seek relevant details with which they had been intimately associated over a period of 4 months for the hospital project. The lead field researcher visited the site to observe meetings, to discuss issues informally with project staff and to observe the day-to-day action unfolding on site. Eleven senior staff on the freeway project were similarly interviewed, with follow-up interviews of an open ended nature to allow numerous issues important to interviewees to emerge. These were undertaken over a 4-month period with site visits, informal discussion with numerous site staff and observation of meetings and construction activity. Follow up clarification and verification of data gathered were conducted with several key staff, generally using telephone and fax. The questions and issues reported upon in Tables 3–7 reflect the structured interview questions directed to key construction management staff, and verification was sought through cross-checking with other site management staff interviewed. File notes were recorded, and samples of planning and control documentation gathered and maintained for reference at the data analysis stage of the research project.

Respondents from both projects felt that their team contribution was 'effective' (on a scale of 1 = 'not effective' to 5 = 'very effective') in their ability to make and modify plans for planning, monitoring and control plus their ability to transfer planning information between teams. The hospital project respondents felt that the construction management team was 'effective' in its ability to make decisions and changes and quickly implement them, and the freeway respondent rated this ability as 'very effective'. On this basis, the hospital project could be rated as 'successful' in terms of planning flexibility effectiveness, and the freeway project planning flexibility could be rated as 'highly successful'. We shall now discuss the evidence gathered and make our own assessment based upon survey information provided, the project time records and observations made and recorded during the projects.

Table 3 Project complexity measures

Project complexity	Hospital	Freeway
Contract sum	Lump sum: A$ 22 million	Design and construct: A$ 140 million
Contract period	8 months	37 months
Number of subcontractors	50	200
Number of suppliers	10	20 ~ 30
Nature of construction work	Pre-cast concrete, structural steel; timber framing; refurbishment.	Civil engineering work for widening and upgrading existing freeway.
Management culture and authority influence	Client's representative driven: Dominant client representative and design team influence/culture	Construction management team driven: Dominant construction management team influence/culture

Source: Shen (2000)

Case study results and discussion

Figure 1 illustrated factors influencing flexibility including the importance of understanding the complexity characteristics of the projects and the organizational and personal skills required of teams to be able to exercise flexible options. These included undertaking risk analysis as part of a planning methodology that identifies potential problems, working out ways of overcoming these and meeting challenges, and then communicating those plans so that they may be monitored and adjusted flexibly as part of project time control actions undertaken. The plans should have included the overall construction schedule, which is informed by method statements in terms of the project as a whole (the global method statement or GMS), the management of resources including the management team, the consideration of construction methods, material movement strategies, site establishment and layout, and detailed method statements for identifying individual tasks or groups of tasks. These plans should also have linked with detailed plans for managing OHS, EM and QM systems.

Figure 1 referred to the ability of construction teams to exercise project flexibility in terms of several drivers, including project understanding, organizational and personal skills in construction planning and control, and organizational and personal skills in effectively communicating information and knowledge creation. The effectiveness of applying these drivers can be tested through evidence supplied regarding the way plans were developed initially and how they were used during the construction process.

Table 4 illustrates global method statement issues that were considered at the time of initial project planning. These provide an indication of the depth of thought applied to addressing risk planning to cope with complexity in terms of the technology used and organizational structure required to manage and co-ordinate the many suppliers and subcontractors engaged on the project.

The theory discussed earlier suggests that pre-project planning is important and that the GMS is a vital set of documents and resources that informs the planning process of knowledge creation to facilitate understanding. Evidence presented in Table 4 suggests that the value of GMS knowledge is less important than would be expected. The GMS production also appears to be influenced by the procurement approach. The hospital project was tendered on a traditional basis, and so the GMS formed a crucial part of the tender documents because it was both necessary and also needed to be prepared quickly (see Q2 results in Table 5), to develop the expected time plan and to be used to estimate the on-site management infrastructure costs, i.e. the preliminaries (Harris and McCaffer, 1995; Walker, 1996b). The freeway project was procured on a D&C basis: time planning evolved more incrementally as the design development proceeded with other issues, such as the OHS, EM and QM procedures influencing the design solutions and construction planning. The freeway project also involved constructability and value analysis exercises that informed the detailed level planning more fully than a GMS might. Thus while the freeway project appeared not to place great importance on the GMS, detailed discussions with construction team members confirmed that these issues were considered at the detailed planning level for groups of activities treated as subprojects. The value of this knowledge was acknowledged and captured at the subproject planning rather than project (holistic) planning stage. This places a different complexion on results reported in Table 4. Also, because the freeway project was designed and constructed in an integrated fashion, a lot of consideration was given to resource flow and resource management issues (core part of GMS deliberations), despite Table 4 indicating low planning levels.

Table 4 Issues included in the global method statement. The construction manager provided responses on the hospital project (***bold italic*** numbers*) and the senior project manager on the freeway project (**bold** numbers in parentheses) with the scale: 1 = 'not at all', 2 = 'slight', 3 = 'average', 4 = 'considerable', and 5 = 'high' for the level of detail of the global method statement with respect to the tabulated issues

	Issues included in the GMS	Level of detail				
1.	Overall construction schedule logic (OCS)	1	**(2)**	3	4	***5****
2.	Organization	1	2	**(3)**	***4****	5
3.	Construction methods	**(1)**	2	3	***4****	5
4.	Site layout (site establishment/access)	**(1)**	2	3	***4****	5
5.	Materials handling/delivery	**(1)**	2	***3****	4	5
6.	Resource allocation/labour management	**(1)**	***2****	3	4	5
7.	Information management (IM)	1	**(2)**	***3****	4	5
8.	Occupational health and safety (OHS)	1	2	***(3)****	4	5
9.	Quality management (QM)	1	2	***(3)****	4	5
10.	Environment management (EM)	1	2	***(3)****	4	5

Source: Shen (2000)

Table 5 presents data on the way the GMS was developed. Table 4 indicated that site layout, construction methods, material handling and resource allocation were not considered for the freeway project when developing the GMS at the initial stages of planning. This was because very little information was known at that stage of design development. Table 5, question 1, indicates that the freeway project design development was less than 25% complete when developing the GMS, whereas the hospital project was at a 76–100% complete stage. Larger scope projects with greater availability of management resources provide potential for substantial diversity of opinion, knowledge and experience. Questions 3 to 6 indicate that three senior managers were available to share perspectives and knowledge in developing the GMS for the freeway project, whereas on the hospital project only the construction manager developed the plan. Nonaka and Takeuchi (1995, p. 81) argue that diversity of opinion and experience is critical to knowledge creation, which lies at the core of construction planning. Having just one perspective, despite the quality of qualification and skill of that individual, limits the testability of plans and potentially other important features such as clarity and level of inquiry, as outlined in Table 2. While the extent of the client's knowledge of the project and its technical aspects (question 4) for the hospital project seemed to be rated very high, a crucial issue of medical waste products having been dumped on site in an unknown location did not come to light until a critical incident unfolded that resulted in time delays, industrial relations and other problems that had a negative impact upon the project's construction time performance.

Table 6, questions 1 and 2, effectively illustrate how the global method statement was developed and used during the construction process. Tables 5 and 6 provide insights into how planning was developed and how effectively the GMS was used to inform plans. The responses to Table 6, questions 3 and 4, indicate that clearly the value of the GMS is perceived as low for the freeway project compared with the hospital project. This can be explained by the degree of design development at the time of developing the GMS. A number of question responses remain similar to both case studies. Both had well qualified staff preparing time plans, and in both cases the client's representative had a low involvement with the GMS. The design teams had a high involvement at various planning stages; however, in both cases this input did not generate significant ideas relating to time planning. The stage of design development also seems to have influenced the usefulness of the GMS. The GMS information for the hospital project was relatively current compared with the freeway project, so that the response to the perceived practicality of the GMS is lower in the freeway project than in the hospital project. However, the value is not perceived as high for both projects (see questions 2, 3 and 4). This stresses the dynamic nature of planning complex construction projects and its impact upon project understanding.

Table 7 indicates the way in which plans were monitored. In each case accuracy of plans was reported as very high. This suggests a good communication support structure for facilitating sharing knowledge between those responsible for detailed planning and those carrying out the work. Questions were also asked about the richness of presentation forms of planning information to project team members. Both projects used milestone data, two-dimensional sketches, drawings and photographs, models and checklists to inform knowledge users of the plan and progress throughout the project. The freeway project also used other methods of communicating monitoring data, including resource reconciliation data (labour plant and materials) and graphical data indicating logical links

Table 5 GMS development. The construction manager provided responses on the hospital project and the senior project manager on the freeway project.

Items of comparison	Questions asked and responses (**bold italic** display responses)	Hospital project	Freeway project
Q1 State of completion of design before construction work commenced	Extent of the design has been completed at the stage of developing GMS : 1 = 0~25%; 2 = 26~50%; 3 = 51~75%; 4 = 76~100%	***4***	***1***
Q2 Lead time for developing GMS	• Lead time for developing the GMS	2~3 weeks	10 months
	• Lead time for the pre-construction stage:	***6 weeks***	***7 months***
Q3 Construction-knowledge and experience of persons who are responsible for developing GMS	• Person who is responsible for developing GMS: 1. Project manager 2. Construction manager 3. In-house planner 4. External consultants 5. Project engineer 6. Contract administrator 7. Others: (state in notes)	***2***	***1, 3, 5***
	• Years of relevant experience the main person has: 1. 0~2 years 3. 5~8 years 2. 2~5 years 4. > 8 years	***4***	***4***
	• His/her highest education 1. High school 2. Associate diploma 3. Graduate 4. Postgraduate	***4***	***3***
Q4 Involvement of site managers	• Involvement of site manager in developing GMS:	***Yes*** / 1 site manager	***Yes*** / 3 site managers
Q5 The client's knowledge about the project and its technical aspects (to facilitate ideas)	• Extent of client's knowledge about the project: 1 = none; 2 = low; 3 = average; 4 = high; 5 = very high.	***5***	***3***
	• Extent of clients' involvement with the GMS: 1 = none; 2 = low; 3 = average; 4 = high; 5 = very high.	***2***	***2***
Q6 Involvement of design team and other consultants	• Extent of the involvement of the design team in the various planning areas and stages. 1 = none; 2 = low; 3 = average; 4 = high; 5 = very high.	***4***	***4***
	• Extent of the design team contributing their ideas to the construction planning. 1 = none; 2 = low; 3 = average; 4 = high; 5 = very high.	***3***	***2***

Source: Shen (2000)

between activities (network analysis charts). Also, a computer simulation model was used at a critical stage for optimizing cycle times and resource usage on repetitive activities (the software package Ithink was used briefly for planning one section of the project, involving external consultants). The hospital project relied upon traditional reporting forms, and so there were less rich forms of knowledge representation provided to team members. Despite these differences, a variety of knowledge representation was used on both projects to inform construction, design and client representative team members of progress in relation to planned construction, to allow the identification of potential problem areas requiring a flexible response to overcome difficulties.

Representatives from both projects stated that although the technology presented little complexity, the environment was rated as causing regular time delays on the freeway project but rarely on the hospital project. However, the impact of one incident of contaminated waste products being discovered during the hospital project had a major environmental impact and

Table 6 Effectiveness of GMS use

Items of comparison	Questions and responses (***bold italic*** display responses)	Hospital	Freeway
Q1 Accuracy of assumptions made in the GMS	• How has the nature of actual construction assumptions differed from the GMS assumptions? 1 = 'very low'; 2 = 'low'; 3 = 'average'; 4 = 'high'; 5 = 'very high'	***4***	***4***
Q2 Practicality of the GMS	• Rate the level of integration/coherence of the parts of the GMS as a useful working brief. 1 = 'very low'; 2 = 'low'; 3 = 'average'; 4 = 'high'; 5 = 'very high'	***3***	***2***
	• Rate the extent of GMS matching the skills and resources available in market. 1 = 'none'; 2 = 'low'; 3 = 'adequate'; 4 = 'extensive'; 5 = 'total'	***3***	***3***
	• Rate the extent of commitment of the project teams to the ideas and plans prepared in the GMS. 1 = 'none; 2 = 'low'; 3 = 'adequate'; 4 = 'extensive'; 5 = 'total'	***4***	***3***
Q3 Use of the GMS in the construction process	• Indicate the extent of the use of GMS in the production process. 1 = 0~20%; 2 = 20~40%; 3 = 40~60%; 4 = 60~80%; 5 = 80~100%	***3***	***1***
Q4 Importance of GMS in the construction process	• Indicate the importance of use of GMS for decision-making and time control in the production process. 1 = 'not important'; 2 = 'slightly important'; 3 = 'moderately important'; 4 = 'important'; 5 = 'very important'	***4***	***2***

Source: Shen (2000)

delayed the construction time. Further, when respondents were asked to rank the occurrence of factors that caused delays, the hospital project ranked client-initiated variations first, mistakes in design documentation second, and environmental factors third. For the freeway project, however, the environmental factors were ranked first, delays in design information second, and long waiting time for approval of drawings third. The freeway project had to contend with a number of environmental issues, including the preservation of a rare frog species, noise control and special vigilance regarding waste liquid products such as wash-out from concrete and other waste products. The freeway project construction management team adapted proactively to this EM challenge, and turned a negative position into a proactive positive one by becoming ISO14000 accredited.

This suggests that management orientation, possibly resulting from the D&C procurement approach, facilitated the interaction of the construction team with the

Table 7 Monitoring plans

Type of plan (1)		Time frame (2)	Revision interval (3)	Accuracy of time planning(4)
Long term	Hospital project	1 year	Monthly	<75%
	Freeway project	>1 year	Monthly	90% ~ 75%
Medium term	Hospital project	3~1 month	Weekly	90% ~ 75%
	Freeway project	3 months	Monthly	90% ~ 75%
Short term	Hospital project	Fortnight	Weekly	90% ~ 75%
	Freeway project	1 month	Weekly	> 95%
Progress reporting	Hospital project	1 month	Monthly	N/A
	Freeway project	1 week	Weekly	N/A

Source: Shen (2000)

design team as partners in a problem solving exercise. This appears to have had a significant influence upon the flexibility of action and empowerment of the freeway project team. The hospital construction management team, however, was tightly constrained by the traditional procurement arrangements that seemed to isolate them from a joint problem-solving approach with the design team. The hospital project organizational and personal communication of knowledge appeared to be 'average to slightly high' (tending towards 'high' through good planning skills but undermined by lack of access to the client's representative and the design team decision-makers). For the freeway project, the level of personal communication of knowledge was observed to be 'high'.

Analysis

Yin (1994) argued that in case study research the researcher's own observations and conclusions based upon detailed in-depth fieldwork and investigation of archival data can provide rich and meaningful evidence. The principal field researcher developed a system of mapping the construction management team's flexibility on the projects to illustrate the levels of flexibility and to help explain the consequences of the observed levels. These are illustrated in Figures 4 and 5. They are subjective measures based upon survey responses received, which are tempered by observations made by the field researcher over the project duration and based upon the project time performance assessment.

The hospital project

On a scale of 1 = 'very low' to 5 = 'very high', CTP on the hospital project was rated as 2 (or 'low'), because the overall construction work was several months delayed. Low ranking with many aspects in Figure 4 reflects that many reasons contributed to this significant time delay in construction progress.

Interviewees on the hospital project reported that the client's representative and/or the project director did not appear to stress a high time minimization objective for the construction work. This attitude, together with the client's representative's slow decision-making over some major issues associated with construction work and a considerable quantity of client related and design team related variations, significantly contributed to the low level of CTP in a fundamental way. These factors neither supported nor encouraged the construction team adopting and exercising flexibility options in their planning and construction approaches, and also the factors were not within the construction team's control. However, there were opportunities where the construction team could have exercised better control over some factors that caused construction time delays: e.g. proactively responding to the discovery of the medical waste with a thorough consideration of risks and a well development risk management plan at the pre-construction stage; and better communicating and co-ordinating with the client's representative and other consultant teams to achieve quick solutions about the client's variances and design changes through a flexible management performance. The construction team's planning ability, communication ability and decision-

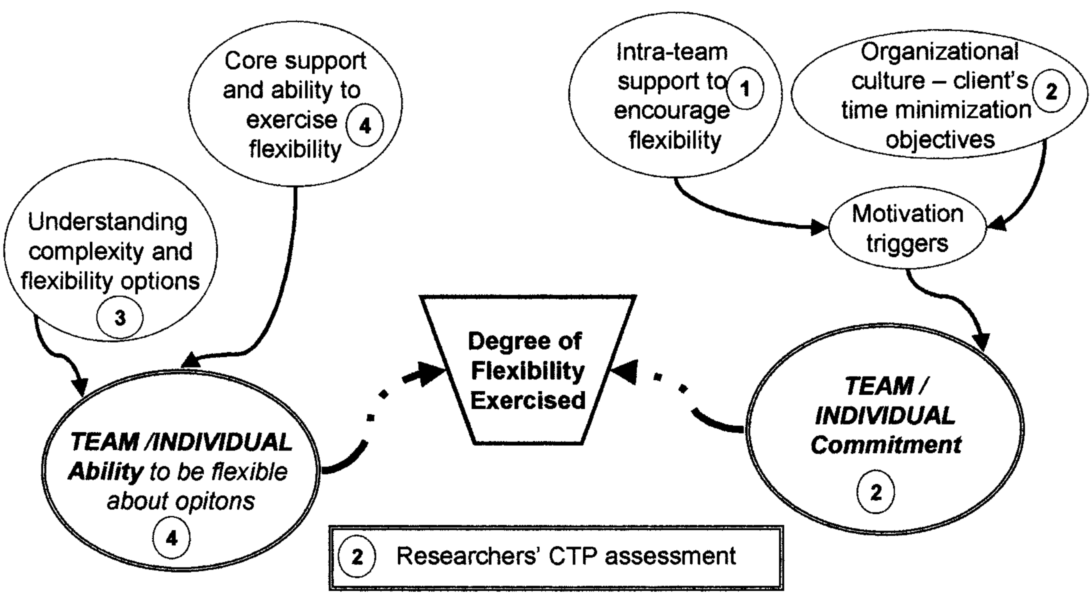

Figure 4 Researchers' interpretation of the hospital project flexibility and the CTP (1 = 'very low' to 5 = 'very high')

making ability were all rated as 'effective'. However, they failed to provide for dealing with a high risk: the hidden health hazard located on the construction site. The discovery of medical waste products caused many progress and construction management complications, including OHS issues and industry relation problems. This negatively impacted on the construction team's commitment to construction planning and exercising flexibility in the construction process, which was rated to be 'low'. It is interesting that although the ability to exercise flexibility was present, low commitment to exercise flexibility reduced their capacity to act.

From a knowledge management perspective, there appeared to be a blockage in the system preventing open and transparent sharing of perspectives. Tacit knowledge was not effectively socialized and combined between teams to improve decision-making, and this has been nominated as an important barrier to achieving good CTP (Nonaka and Takeuchi, 1995).

The freeway project

The freeway project was completed on time. The impact of the construction team's flexibility in preparing and executing the freeway project plans can be seen as 'high' in every aspect, as shown in Figure 5. The strong focus of the client's representative upon time minimization, on strong inter-team support and on encouraging flexibility provided a solid foundation for the commitment to exercise flexibility. This, coupled with the strong ability of the team through their construction management planning and communication procedures, provided a high capacity to act upon flexibility options. The degree of exercising flexibility options was 'high', and this assisted the good CTP. From a knowledge management perspective, there appeared to be a facilitating system that supported open and transparent sharing of perspectives. Tacit knowledge was effectively socialized and combined between teams to improve decision-making, and this was nominated as an important driver in achieving a good CTP. This project was also was observed to have high autonomy for taking action and for challenging and justifying ideas, and these are important in knowledge creation (Nonaka and Takeuchi, 1995) and reflective learning (Argyris and Schön, 1978).

Conclusions

The lesson learned from the hospital case study provides evidence to support the proposition illustrated in Figure 1 that the ability of construction management teams to exercise flexibility options during construction, to obviate unexpected problems, is *insufficient by itself* without the desire to do so. On both projects there was a demonstrated ability to understand the project complexity and to prepare flexible plans to overcome unforeseen problems. The freeway project results support the proposition because both ability and commitment drivers appeared to be present, and the resultant CTP was good. On the hospital project, however, the construction management team had skills and agility drivers but there appeared to be a lack of commitment towards a good CTP. Thus both case

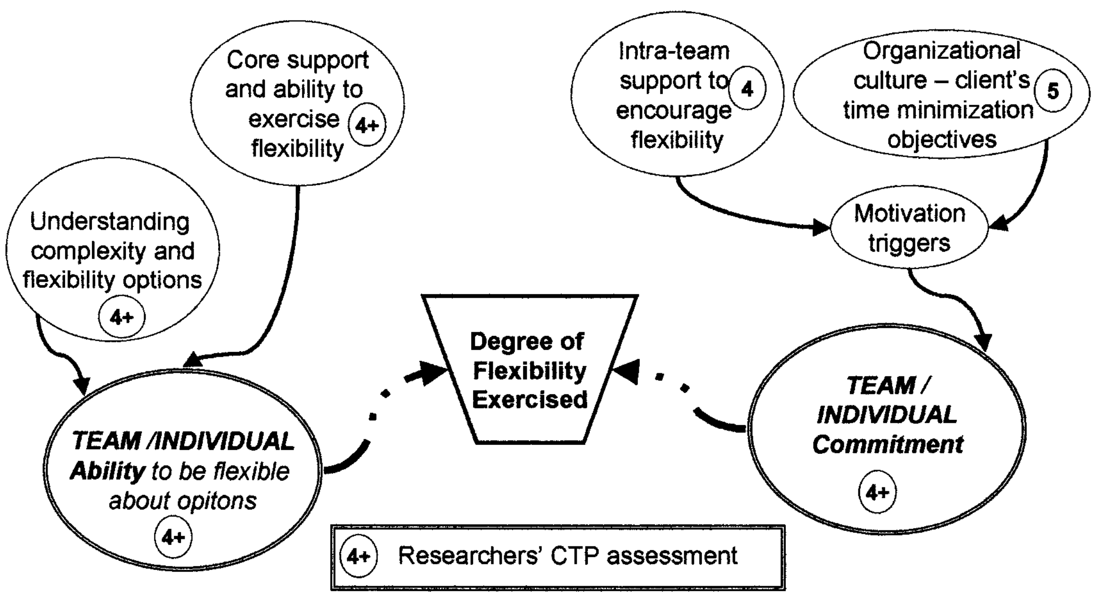

Figure 5 Researchers' interpretation of the freeway project flexibility and the CTP (1 = 'very low' to 5 = 'very high')

studies indicate support for the proposition illustrated in Figure 1. Although this evidence cannot be readily generalized, the case studies provide rich data to explain how the roles of both ability and commitment may impact upon the CTP, and this expands our understanding of the processes at work (the full evidence presented is limited by the scope of a paper rather than that of a full research dissertation).

A construction team having the strong ability to exercise flexibility in planning, decision-making and communication will not necessary lead to a high level of construction time performance. There also needs to be a desire to act flexibly and a supporting structural capacity. With all these elements in place, it appears that better CTP levels are more likely.

This paper started by drawing upon previous studies that indicated that a construction management team's superior planning and communication abilities have a significant correlation with a better CTP. A model (Figure 1) was presented that might better explain how the ability to exercise flexibility is created. The model was then examined using two case study projects. Data were presented that showed the manner in which planning was undertaken and plans communicated. Data on the effectiveness of the techniques used were presented and analysed.

While it is recognized that there was an important CTP issue in the hospital project relating to medical waste products being discovered, we suggest that the risk analysis stage was not as rigorously undertaken as would be expected, because of vital information being held back from the construction management team. However, the client's representative's design changes and the slow documentation communication by the design team also were indicated as major factors affecting the CTP, and this undermined the desire to exercise flexibility through crucial information being withheld when most critically needed. When analysing these two projects from an organizational learning and knowledge management perspective, it becomes evident that freedom to explore options, open communication of knowledge, and shared mental models and objectives are pivotal, because they enhance trust and commitment through process transparency. These organizational cultural characteristics underpin a supportive structure that enhances flexibility of action. This supportive environment for motivating a desire and a commitment to be flexible is an important factor that has been absent from much of the literature relating to construction time performance cited earlier in this paper. The implication of this work is that (organizational) cultural aspects must be adequately addressed, as much as current efforts placed in construction management teams honing their planning and control skills.

Case study findings cannot be generalized to support a hypothesis, though a case study can provide evidence to reject one. However, case studies can provide valuable and rich contextual evidence. The conclusions presented in this paper contribute valuable CTP insights by linking both an ability and a desire/commitment to adopt principles of flexibility/agility. This study has provided substantial insights into how projects are planned and managed through the construction process, and into the importance of exercising flexibility options to CTP. Clearly, flexibility/agility in construction management teams is of critical importance to CTP. Further case studies need to be investigated to explore and better understand how a culture of organizational learning and knowledge management may support commitment to enhance flexibility in dealing with construction problems that trigger changes to planned action.

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