

Capitalising Experiential Knowledge for Guiding Construction Procurement Selection

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ABSTRACT

Capitalising useful knowledge for construction procurement selection (CPS) decisions would provide a valuable asset to client organisations, as the successful/unsuccessful experience would help decision-makers avoid the occurrence of similar errors and ensure the most suitable procurement system is employed for a construction project. As a result, there is a need to examine the potential for developing a knowledge management model to capture and reuse experiential knowledge to guide CPS decisions. This paper begins by identifying a suitable approach for managing CPS knowledge. This is followed by a discussion of the knowledge required for CPS decision support. A prototype knowledge-management model is developed, using the case-based reasoning (CBR) approach, and a mechanism for the retrieval and reuse of knowledge for guiding CPS decisions is elucidated. The results indicate that CBR is a suitable tool for formulating the procurement selection parameters and selecting a suitable procurement system for a construction project. This is primarily because the CBR approach is flexible enough to allow closely matching historic cases to be retrieved as well as enabling the decision-maker to adapt the proposed solution based on the predominant characteristics of the client, project and external environment pertinent to the current project.

Keywords: case-based reasoning, construction procurement, knowledge management, procurement selection parameters.

INTRODUCTION

Industry is becoming more enthusiastic about the use of multifarious alternative construction procurement systems, and choosing an appropriate method of procurement to satisfy the unique client and project requirements is recognised as one of the most important activities involved today (Naoum, 1994; Sharif and Morledge, 1994; Rwelamila and Meyer, 1999). Over the last two decades, researchers have attempted to develop a reliable decision tool for construction procurement selection (CPS). These include the procurement path decision chart (NEDO, 1985); procurement rating (Franks, 1990); multiattribute (Bennett and Grice, 1990; Singh, 1990; Ambrose and Tucker, 1999); multivariate analysis (Chan et al., 2001); multicriteria/multiscreening (Alhazmi and McCaffer, 2000); analytical hierarchical process (Cheung et al., 2001); discriminant analysis (Skitmore and Marsden, 1988); decision support system (Kumaraswamy and Dissanayaka, 2001); and knowledge-based system (Brandon et al., 1988; Mohsini, 1993) models.

Although these research models could improve the transparency and objectiveness of CPS decisions, there are still problems to be resolved before they can become credible enough for practical usage. One major concern is to cater for the implicit interrelationships among the procurement selection parameters (PSPs) and their corresponded importance weightings instigated by diverse client's characteristics and needs, project features, and external environment (Ireland, 1985; Nahapiet and Nahapiet, 1985; Hamilton, 1987). Besides, as there are hardly any hard and fast

rules/guidelines, the suitability and likely outcomes of a particular procurement system are hard to envisage. Ward et al. (1991) and Masterman (1992) advocate CPS decisions being realistically founded on experiences of previous similar examples, coupled with intuitive evaluations of the distinctive requirements of the current situation.

However, it would be virtually impossible for decision-makers to acquire and/or recall all the experiential knowledge needed, as there is a diverse continuum of procurement options in practice (Kumaraswamy and Dissanayaka, 2001). Successful or unsuccessful experiences pertinent to each CPS decision should be systematically encapsulated and managed (cf: Storey and Barnett, 2000) to ensure useful knowledge being retrieved for strategic/tactical decision support (Silver, 2000). The concept of knowledge management has been introduced to construction project risk management (Tah and Carr, 2001) and selection of construction methods (Udaipurwala and Russell, 2002), and there is a need establish the extent to which knowledge management techniques can be effectively applied to CPS. This paper aims to develop a knowledge management model for capturing and reusing experiential knowledge to guide CPS decisions. A suitable approach for managing CPS knowledge is first identified. This is then followed by identifying the knowledge to be captured for CPS. Finally, the mechanism for the retrieval and reuse of knowledge is elucidated for guiding CPS decisions.

SELECTION OF KNOWLEDGE MANAGEMENT APPROACH

The principle role of a knowledge management system is to capture and disseminate relevant knowledge. However, to enhance performance and to increase the chance of project success (Ofek and Sarvary, 2001; Kamara et al., 2002; Mansell, 2002), it is desirable to create new (better) solutions based on the knowledge thus far accumulated (cf: O'Leary, 1998). This requires the incorporation of reasoning and justification mechanisms (Hsieh et al., 2002). More importantly, the distinctive characteristics of CPS should be considered when selecting an approach for managing knowledge. These include: (i) the existence of diverse characteristics, requirements and conditions unique to the project; and (ii) an implicit interrelationship of the PSPs that describe the distinctive characteristics of the client, project and external environment.

The notion of framing "a contextualised piece of knowledge representing an experience" in a case (Kolodner, 1993, p.13) has rendered the CBR approach an attractive option for managing CPS knowledge, as recalling incident (i.e. constraint @ solution @ outcome) by case and reusing/adapting the solution of a similar case to suit the current situation is a frequently applied approach to solving practical problems (Aamodt, 1990; Barletta, 1991). Furthermore, by storing and retrieving cases in a mega-knowledge format (Aamodt and Plaza, 1994), CBR approaches should have a high potential for modelling the procurement selection decisions under a complex dynamic environment.

KNOWLEDGE TO BE CAPTURED

To identify a process of CPS and knowledge required for supporting CPS decisions, semi-structured interviews were conducted with five experts with experience in this domain. The experts interviewed included managers of major client (including four governmental and one private) organisations in Australia. The results of the interviews indicated that the CPS process involved: (i) the formulation of PSP's; and (ii) the selection of an appropriate procurement system, and the knowledge required is different for each of these two stages.

Knowledge Pertinent to PSPs Formulation Stage

Since the aim of this stage is to establish a set of PSPs that would



Figure 1: Knowledge pertinent to PSPs formulation stage

Client's characteristics & needs	Project's features	External environment
Experience Experience level of the client and his or her organisation in the construction domain, i.e. primary experienced, secondary experienced	Project scale Size of the project measured by its estimated value	Market competition Level of competition in the market with regards to this project
Type Nature of the client's organisation in reference to this particular project; i.e. government bodies, investors, developers, occupiers, etc.	Building type Type of the proposed building in this particular project, i.e. commercial, residential, industrial, etc.	Environmental impact The impact of natural environment on the project procurement process, i.e. inclement weather, natural disasters, etc.
In-house capability Client's capability to use their own resources in this particular project and client's wishes to be directly involved in this particular project.	Construction type Type of the construction method in this project, i.e. new construction, refurbishment, combination of both	Cultural impact The impact of cultural differences on the project procurement process
Time limitation Does the client require any restrictions on time in this particular project?	Site conditions Relative assessment of conditions of various site factors having impact on the project procurement such as site access and egress, foundations, etc.	Political impact The impact of political activities on the project procurement process
Financial limitation Does the client have any restrictions on finance in this particular project?	Site location Geographical location of site	Resource availability <ul style="list-style-type: none"> i) Availability of contractors and subcontractors who have enough expertise to fulfil the requirements of project specifications ii) Availability of technology to carry out a certain construction techniques required by the project specifications iii) Availability of materials as required in the project specifications

Table 1: Factors influencing the formulation of PSPs

adequately represent the characteristics and requirements of the client, project and external environment (cf: Ambrose and Tucker, 1999), the knowledge required should be composed of both the problem and solution parts (Figure 1). The problem part should encapsulate the knowledge regarding: (i) the features of all existing projects for which various procurement systems were employed; (ii) the characteristics and needs of the clients; and (iii) the properties of the external environment that encountered by clients. Luu et al. (2003) summarised the factors that could influence the choice of the PSPs (Table 1). The solution part focuses on the knowledge pertinent to the PSPs, their weightings adopted in previous CPS evaluations, and reasons/justifications for previous solutions.

Knowledge Pertinent to Procurement Selection Stage

During the procurement selection stage, the set of PSPs formulated during the preceding stage need to be used to establish the relevance and appropriateness of each procurement system. In addition to comparing the benefits and weaknesses of each procurement system against the predominant characteristics and requirements of the client, project and environment, decision-makers have to recall the outcomes of previous similar examples. Therefore, the knowledge related to this stage should consist of three major components – problem, solution and outcome

(Figure 2). The problem part should represent the knowledge of the PSPs used in the previous CPS processes - these PSPs being related to time certainty, cost certainty, speed, flexibility, responsibility, complexity, price competition, risk allocation and quality as illustrated in Table 2 (see Sidwell, 1984; NEDO, 1985; Nahapiet and Nahapiet, 1985; Skitmore and Marsden, 1988; Walker, 1989; Hughes, 1989; Masterman, 1992; Masterman and Gameson; 1994; Love et al., 1998; Rowlinson and McDermott, 1999; Ambrose and Tucker, 1999; Alhazmi and McCaffer, 2000; Chen, 2000; Kumaraswamy and Dissanayaka, 2001).



Figure 2: Knowledge pertinent to procurement selection stage

PSPs	Description
Speed ^{a,d,e,f}	Speedy procurement process, e.g. a desire to have the project completed as soon as possible.
Cost certainty ^{b,c,d,e,f}	Price and the stipulated time and knowledge of how much the client has to pay at each period during the construction phase. A reduction in unanticipated extra cost over-run
Time certainty ^{b,c,d,e,f}	Degree of certainty that the project will be completed on the date, which is agreed by client and contractor when signing the contract. A reduction in unanticipated extra time over-run.
Flexibility ^{a,b,d,e,f}	Ability to accommodate design changes during both design and construction periods
Responsibility ^{a,b,c,d,e,f}	An involvement in, and a need to be kept informed about, the project throughout its life
Complexity ^{a,d,e,f}	Client may specify innovative design/ high technology building and require particular subcontractor, or constructability analysis
Quality level ^{a,d,e,f}	Contractor's reputation, aesthetics and confidence in design. A building which reflects the clients activities and image
Risk allocation/avoidance ^{a,d,e,f}	A wish to identify risks and uncertainties during the procuring process
Price competition ^{a,c,d,e,f}	Covering such issues as value for money, maintenance, costs and competitive tendering.

Note: ^a Bennett and Flanagan (1983); ^b Hewitt (1985); ^c Masterman and Duff (1994); ^d NEDO (1985); ^e Skitmore and Marsden (1988); ^f Singh (1990)

Table 2: Common PSPs

The knowledge in the solution part should, however, contain the procurement system used, and its sub-managerial systems, such as the tendering method and contractual arrangement, etc. As for the outcome knowledge, feedback detailing the successfulness of the procurement system adopted in a particular project would be beneficial. According to Kumaraswamy and Dissanayaka (2001), the successfulness of a construction project can be measured in terms of the reduction in capital and lifecycle costs, greater cost and time certainty, shorter procurement duration, better quality, more effective and efficient decision-making and communication, and minimisation of disputes. It would be useful if both successful and unsuccessful construction projects are recorded in the knowledge-base, as the failure examples can alert decision-makers to the potential problems that may occur should a particular procurement system be used under certain constraints (cf: Scacra and Miyashita, 1994).

RETRIEVING AND REUSING KNOWLEDGE FOR DECISION SUPPORT

The basic procedure of retrieving and reusing CPS knowledge through the CBR engine is illustrated in Figure 3. In essence, the underlying mechanism of CBR is to retrieve "similar" historic cases and knowledge based on the characteristics of the new scenario. As with any other real-world domains, it is difficult to have a historic construction project that fully resembles the current case. Therefore, not only is it necessary to establish whether the new and retrieved cases are similar enough to provide decision-makers with the relevant and reliable knowledge, but it is also desirable to have a high level of flexibility when the cases/knowledge are retrieved and reused. Therefore, during both the PSPs formulation and procurement selection stages, cases are retrieved according to a similarity matching concept known as nearest neighbour retrieval. Once the new solution is adopted, the knowledge is stored automatically for future use in the case repository.

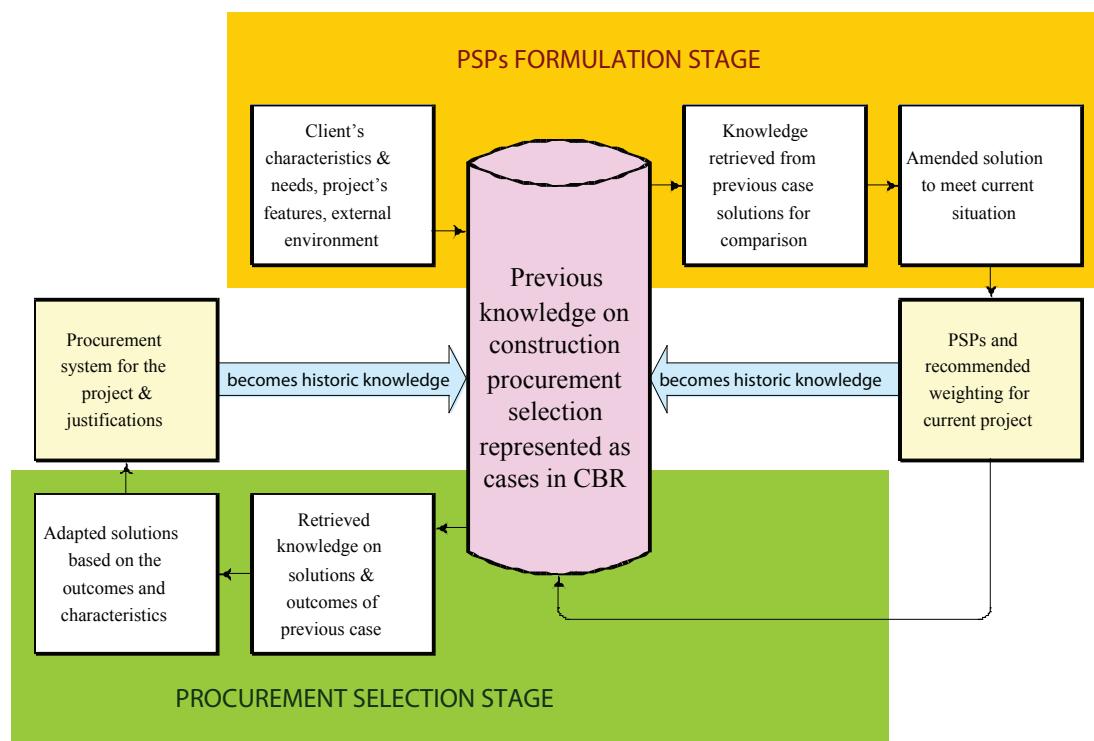


Figure 3: Basic mechanism of retrieving and reusing the stored knowledge

PSPs Formulation Stage

An interface, as shown in Figure 4, is designed to capture the characteristics and requirements of the client, project and environment pertinent to a new project. To minimise data inputting time and errors, a list of possible values is provided through a pull down menu against each input item. For instance, the decision-maker can classify his/her organisation as a "primary inexperienced" or "secondary experienced" client (Figure 5). The system also accepts blank entries when the decision-maker is unsure of the most appropriate answer to describe certain client/project characteristics.

The predominant characteristics of all stored cases can be compared with the data entered by the decision-maker, and

the similarity of each attribute computed based on the following formula:

$$\text{Similarity Score} = \frac{\text{Attribute Score}}{\text{Maximum Presented Score}} \times 100$$

Where: Attribute score = the sum of matching scores between attribute values of the stored and presented cases.

Maximum presented score = attribute score when the stored case is exactly identical to the presented case.

Client Characteristics		Project Characteristics		External Environment	
Client Experience	Primary Experienced	Project Scale	\$3 to \$20 millions	Market Competition	Medium
Client Type	Investors	Building Type	Commercial	Environment Impact	Yes
In-house Capability	No	Construction Type	New Construction	Cultural Impact	No
Time Limit	Yes	Site Conditions	Favourable	Political Impact	No
Financial Limit	Yes	Site Location	Busy Urban	Resource Availability	No

Figure 4: Interface for extracting the characteristics of client, project and environment

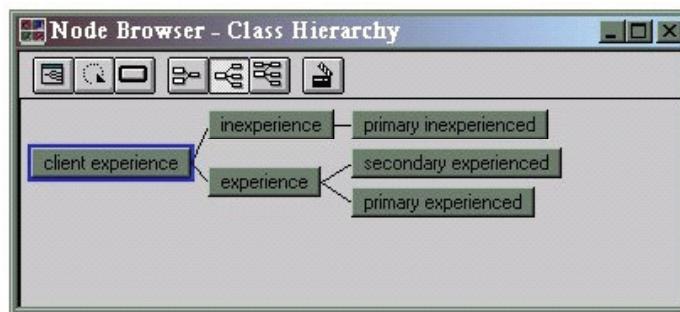


Figure 5: Possible values for the attribute of "client experience"

Once the individual scores are generated for all attributes, a final similarity score for each case (Figure 6) can be derived for cases to be rank-ordered. The five cases with the highest similarity scores are then presented through the user interface for consideration. As shown in Figure 6, preliminary information about the most similar historic case, i.e. the case features and client's satisfaction, are highlighted. Depending upon the project performance, the decision-maker can decide whether to further examine the particulars of the

most similar case or to browse the preliminary information for the next most similar case. Further details on the PSPs used (Figure 7) can be obtained by pressing the "view details" button. If the knowledge of the most similar case is applicable to the current project, the "accept recommendation and move to the next module" button (Figure 7) can be checked and a screen as shown in Figure 8 presented to initiate the procurement selection stage.

Matching Results		Recommendation on Procurement Selection Criteria	
Score: 053 - Case: ROUSE-HILL-SCHOOL	Project Name: BUNNING-WAREHOUSE		
Score: 053 - Case: THE-SAND-CASTLE	Client Rating on Project Performance: GOOD		
Score: 060 - Case: TAREE-TAFE	Time Certainty: NO		
Score: 067 - Case: BUNGARA-POLICE-STATION	Cost Certainty: NO		
Score: 073 - Case: BUNNING-WAREHOUSE	Speed : MEDIUM		
	Flexibility : HIGH		
	Responsibility: MEDIUM		
New Problem	Complexity : HIGH		
Search Case	Price Competition: LOW		
View Details	Risk Allocation : LOW		
Next Module	Quality : PRESTIGE		

Figure 6: Cases retrieved during PSPs formulation stage

Project: BUNNING-WAREHOUSE					
Client Experience	Secondary Inexp	Project Scale	\$500,000 to \$3	Market Condition	High
Client Type	Occupiers	Building Type	Commercial	Environment Impact	Yes
Inhouse Capability	No	Const. Type	New Constructio	Cultural Impact	No
Time Limit	Yes	Site Condition	Normal	Political Impact	No
Financial Limit	Yes	Site Location	Suhurban	Resource Availability	Yes
Speed	MEDIUM	Flexibility	HIGH	Price Competition	LOW
Time Certainty	NO	Responsibility	MEDIUM	Risk Allocation	LOW
Cost Certainty	NO	Complexity	HIGH	Quality	PRESTIG
What would you like to do now? <input type="radio"/> Go Back and View Another Case's Details <input type="radio"/> Accept Recommendation and Move to Next Module <input type="radio"/> Move to Next Module and Modify Recommendation					
OK					

Figure 7: Solution adopted in the previous case during PSPs formulation stage



Figure 8: Interface for altering the PSPs and weightings at procurement selection stage

Procurement Selection Stage

The knowledge extracted through the preceding stage provides an initial but valuable guideline to the decision-maker for establishing which PSPs should be used for the procurement selection stage. Nevertheless, the decision-maker might still wish to modify the PSPs to reflect the inherent discrepancies between the new and old cases; and this can be achieved by making the necessary adjustments to any of the items as illustrated in Figure 8. Like the preceding stage, the nearest neighbour retrieval approach is used to compute the similarity score for each case based upon the input features. The decision-maker can also

request the system to display the details of the most similar case for further evaluation. As depicted in Figure 9, knowledge regarding the procurement system, tendering method, contract type, and client's overall rating is disseminated through the user interface. Those not familiar with the proposed procurement option can simply click on the "system details" button to view the features, advantages and disadvantages of the recommended procurement system. When users are convinced that the solution and possible outcomes are suitable for the current project, they can adopt the previous solution for the new project.

Speed	HIGH	Flexibility	LOW	Price Competition	MEDIUM
Time Certainty	YES	Complexity	MEDIUM	Risk Allocation	HIGH
Cost Certainty	YES	Responsibility	HIGH	Quality	BASIC
Procurement System		COMPETITIVE DESIGN AND BUILD			System Details...
Tendering Method	SELECTIVE TENDERING				
Contract Type	C21				
Client Overall Rating	GOOD				

Figure 9: Solution and outcome of the retrieved cases at procurement selection stage

However, since the intrinsic characteristics and requirements of the new and retrieved cases may still differ slightly, modifications to the historic solutions would be inevitable. As a result, a technique known as critic-based adaptation (Brown and Lewis, 1993) is built-in to allow users to go through the retrieved solutions sequentially and modify the solution corresponding to a particular step to suit the predominant situation. The "adaptation strategy" section in Figure 10 outlines all the details used in arriving at the recommended solution, and these include the details of the new and historic cases. Driven by pre-determined rules/formulae, and based on the extent of difference between

the new and retrieved cases, the model will prompt the user to consider modifying certain PSP(s), such as "speed" as in the case illustrated in Figure 10 (refer to the "Yes/No" status in the "to be adapted" column). By clicking the "actions to improve" button, the user is presented with different alternatives to modify the solution and the revised recommendation is made to the decision-maker for final consideration. This not only allows for 'what-if' scenarios, but also provides a more relevant and reliable solution to improve the chance of project success.

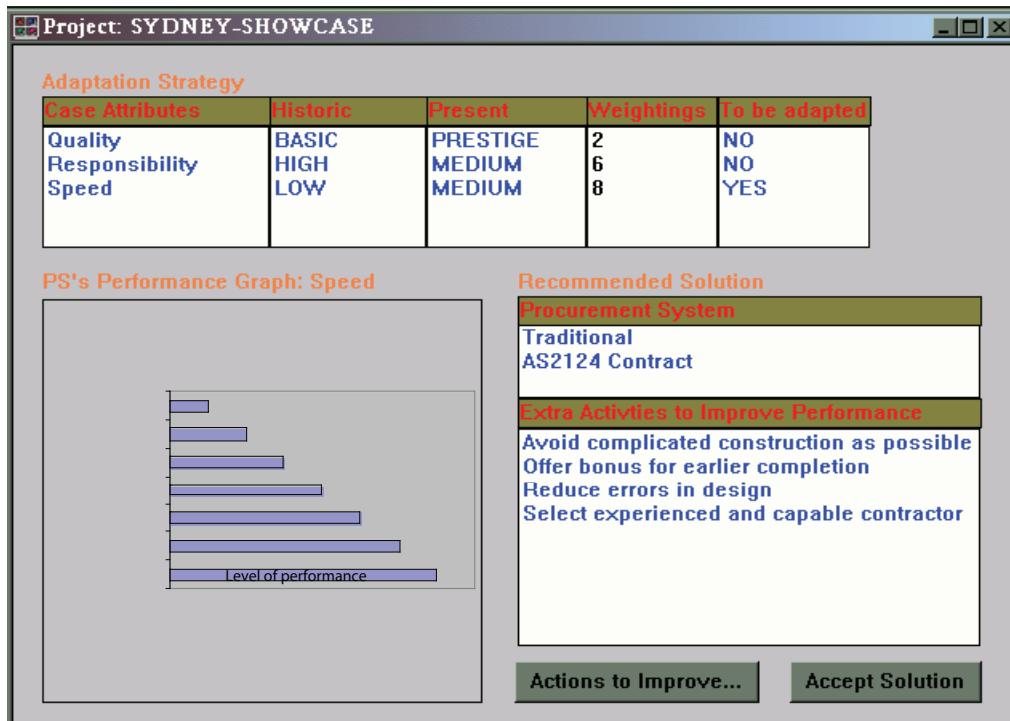


Figure 10: Critic-based adaptation at procurement selection stage

CONCLUSIONS

This paper has examined some methods for capturing and reusing CPS knowledge. As the characteristics and requirements of the client, project and external environment differ from one project to another, and therefore give a diverse continuum of procurement options, the approach to managing the knowledge must be very flexible. CBR is considered a suitable approach for storing CPS knowledge, as not only can it retrieve close matching cases based on the nearest neighbour retrieval mechanism, but it can also allow users to adapt the solution of the retrieved case to suit the predominant characteristics of the current project.

Knowledge to be captured will be specific to the two main CPS stages. During the PSPs formulation stage, the knowledge related to the client's characteristics and needs, project features, and external environment (the problem part) as well as the PSPs and weightings (the solution part) will be encapsulated. Knowledge pertinent to the procurement selection stage includes the features of the PSPs and weightings (the problem part). Furthermore, the procurement option, tendering method, and contractual arrangement (the solution part) together with the client's satisfaction (the outcome part) should also be considered. Clients and consultants should consider developing and maintaining a knowledge repository for CPS to capture useful knowledge such as factors governing the selection of procurement method, the reasons for selecting a procurement approach, as well as the project outcomes caused by the procurement method selected. Such knowledge would serve as a reference to clients and consultants when selecting a procurement method for a project of similar characteristics and requirements.

A prototype knowledge management model for CPS was developed in accordance with the CBR concept, and the functionality of the model has been elucidated in this paper. The prototype shows that PSPs and weightings can be formulated by referring to the solution of similar historic cases, and that this

knowledge can then be used for retrieving a project with similar characteristics to the current one. By examining the procurement option adopted by the most similar project (and its outcome), decision-makers would have an idea as to which procurement system to opt for (and its potential outcome). The provision of an adaptation strategy also allows for 'what-if' scenarios, which would be very useful to decision-makers in an increasingly uncertain construction environment.

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