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Capturing and Reusing Unstructured Experiential Knowledge for Construction Procurement Selection

Duc Thanh Luu
School of Architecture and Built Environment, University of Newcastle, University Drive, Callaghan, NSW 2308, Australia.

S. Thomas Ng
Department of Civil Engineering, University of Hong Kong, Pokfulam Road, Hong Kong

Swee Eng Chen
School of Architecture and Built Environment, University of Newcastle, University Drive, Callaghan, NSW 2308, Australia. .

Abstract
The process of selecting an appropriate procurement system for a construction project is influenced by a diversity of factors including the specific requirements of client and project and the dynamic features of environment. Procurement selection can, therefore, be regarded as an unstructured domain with inherent difficulties in capturing, representing or generalising the knowledge simply by a set of decision rules. Instead, decision-makers usually rely on intuition and past experience (through success or failure of previous similar cases) for making procurement selection decisions. While the use of valid experiential knowledge has been advocated by many researchers and practitioners as a key aspect for project success, capturing and representing such knowledge in a logical manner is never an easy task. Building upon the notion of recalling and adapting mega experiential knowledge, the case-based reasoning (CBR) approach might have a high potential in capturing, retrieving and reusing valuable procurement selection decisions for future projects. This paper discusses how experiential knowledge on procurement selection is captured and structured in a CBR format. A framework for reusing and adapting the previous cases for formulating the procurement selection criteria and selecting an appropriate procurement system for a new project will then be proposed. Notably, a case-based procurement selection system which has incorporated the linguistic retrieval mechanism would be a first step in structuring this crucial but dynamic process.

Keywords
Procurement selection, case-based reasoning, fuzzy similarity

1. Introduction

The multifaceted nature of the construction environment breeds complexity, especially in the field of procurement selection. Construction procurement selection (CPS) can be regarded as an unstructured problem domain since the information required for procurement selection, i.e. the problem definition, identification of alternative procurement methods and assessment of potential procurement solution, are unstructured in nature (Gorry and Scott-Morton, 1971). A major problem of unstructured problem domains is the absence of an explicit model for problem solving due to the lack of a logical sequence of activities required (Klein and Tixier, 1971). This, when adding to the presence of a diverse continuum of procurement selection data, i.e., procurement options, client's characteristics, project requirements and external environments (Kuramaswamy and Dissanayaka, 1998) has made the task of ascertaining the suitability of various alternative procurement approaches for construction projects extremely difficult. As a result, CPS decisions are often made on the basis of experiences of previous similar examples, coupled with intuitive evaluations of the distinctive requirements of the current situation (Ward *et al*, 1991; Masterman, 1992).

Although the inherent subjectivity of experience-based procurement selection approaches has consistently been accused as the main reason for unjustified procurement decisions in the construction industry (Masterman, 1992), Cleaves (1987) insists that expert's judgement does not necessarily lead to poor decisions but could provide a useful means to create shortcuts for complex tasks (Raftery and Ng, 1993), and foster innovation and success (Tiwana, 2002) if being logically and systematically encapsulated, managed and retrieved for strategic/tactical decision support (Storey and Barnett, 2000). Furthermore, as the trend of organisational downsizing and reengineering are becoming increasingly popular, companies are rigorously in search for effective knowledge management methods for capturing and disseminating valuable experiential procurement selection knowledge in order reduce costs and enhance learning and performance (Tiwana, 2002). As a result, there is a need to 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. A framework for capturing and reusing the previous cases for formulating the procurement selection criteria; and how the model could help select an appropriate procurement system for a new project is then described.

2. Knowledge Management Approach for managing CPS knowledge

The pivotal role of a knowledge management system is to capture and disseminate relevant knowledge (Davidson and Voss, 2002). However, in order to enhance the performance and to increase the chance of project success, O'Leary (1998) realises the need for creating new and better solutions based on the knowledge accumulated and this requires the help of suitable 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 a diverse continuum of characteristics and requirements of the client, project and external environment and (ii) implicit interrelationships of procurement selection criteria (PSC) that describe these characteristics and requirements (Luu *et al,* 2003a).

Being an artificial intelligence technology that "*solves new problems by adapting solutions that were used to solve old problems"* (Riesbeck and Schank, 1989), case based reasoning (CBR) is an attractive option for managing CPS knowledge as recalling incident by case and reusing or modifying the solution of a similar case to suit the current situation is a frequently applied paradigm for practical problem solving (Aamodt, 1990), especially in domains that are unstructured, not fully understood or open-ended (Gorry and Scott-Morton, 1971). Moreover, by storing and retrieving cases in a mega-knowledge format (Aamodt and Plaza, 1994), CBR approaches are highly potent for modelling CPS decisions under a complex dynamic environment.

3. Mechanism for Capturing and Reusing CPS Knowledge

Semi-structured interviews were conducted with five experts of four governmental and one major private organisation in Australia to elicit the process of CPS and knowledge required for supporting CPS decisions. The results indicated that the CPS process consists of two consecutive stages, (i) the formulation of PSC and (ii) the selection of an appropriate procurement system, both of which resemble the CBR mechanism. Accordingly, a model for retrieving and reusing CPS knowledge in the form of CBR is proposed as shown in Figure 1.

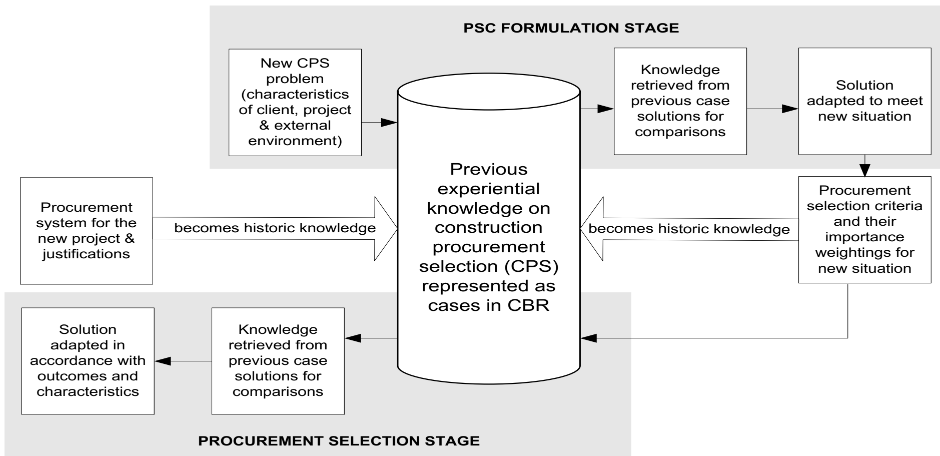

Figure 1: Mechanism of retrieving and reusing the stored knowledge

3.1 PSC Formulation Stage

In CBR, previous experiences are captured in the form of cases which generally consist of three main components, namely problem, solution and outcome (Kolodner, 1993). Since the aim of this stage is to establish a set of PSC that would adequately represent the characteristics and requirements of the client, project and external environment, the knowledge to be captured for the problem part of the PSC formulation case, therefore, encapsulates such factors as (i) the features of all existing projects for which various procurement systems were employed; (ii) the characteristics and objectives of the clients; and (iii) the properties of the external environment that encountered by clients (Luu *et al*, 2003b). A detailed list of case attributes that represent the problem part of the PSC formulation case can be found in Luu *et al* (2003c). On the other hand, the solution part of the PSC formulation case focuses on the knowledge pertinent to the PSC and their importance weightings adopted in previous CPS evaluations. Luu (2000) reports a list of nine commonly used PSC including time and cost certainty, speed, flexibility, responsibility, complexity, price competition, risk allocation and quality. In addition, the reasons as to why the previous solutions were made are included as a knowledge component.

In essence, the underlying mechanism of CBR is to retrieve "similar" historic cases and knowledge based on the characteristics of the new situation. 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 it is 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, the PSC formulation cases are retrieved according to a similarity matching concept known as nearest neighbour retrieval. Using this retrieval method, the degree of appropriateness in problem solving of the experiential knowledge (stored cases) to the current problem (presented case) is measured by the similarity between themselves. This similarity is computed based on the following formula:

$$\text{Case Similarity} = \frac{\text{Sum of matching scores between attribute values of stored \& presented cases}}{\text{Sum of matching scores between attribute values when stored \& presented case are identical}}$$

Since the intrinsic characteristics and requirements of the retrieved and presented cases may differ slightly, the solution of retrieved case may not be ready or good enough for solving the current problem, and therefore modifications to the retrieved solutions would be inevitable. An adaptation technique called *critic-based adaptation* (Brown and Lewis, 1993) is used to guide the decision-makers to go through the solution of each retrieved case sequentially and modify it in accordance with the predominant situation. Once the modified solution has been adopted for the current problem, the knowledge is stored automatically for future use in the case repository.

3.2 Procurement Selection Stage

Since the relevancy and appropriateness of each procurement system to the current project situation can be assessed on the basis of the PSC formulated during the preceding stage, the problem part of the procurement selection case represents the knowledge of the PSC used the previous CPS processes. The knowledge in the solution part, however, contains the details of the procurement system used and its sub-managerial systems such as the tendering method, contractual arrangements, etc. As for the outcome knowledge, feedback detailing the degree of success of the procurement systems adopted in the past project would be beneficial. 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 (Sycara and Miyashita, 1994).

Unlike the preceding stage, Ng *et al* (2002) found that most of the case attributes that represent the problem part of the procurement selection case, i.e. the PSC are in fact linguistic or fuzzy in nature. These attributes possess domain values that have implied logical relationships among themselves. A sample attribute of this kind is the "speed of project", which has the values of *high*, *medium* or *low*. For this type of data, it is essential to have the actual relationships between the values of its definition domain properly dealt with so that the accuracy of the case retrieval process can be achieved. As a result, a special kind of similarity retrieval mechanism called *fuzzy similarity retrieval* (Luu *et al*, 2003a) is adopted, whereby a similarity score between two cases is computed in accordance with the following formula:

$$\text{Similarity}\,(P, S) = \Sigma\, f\,(P_i, S_i)\, w_i \times 100$$

where: P, S = presented and stored cases
n = number of attributes in each case
i = an individual attribute from 1 to n
w = importance weightings of attribute i
f = similarity function for attribute i in cases T and S

Two types of similarity functions (f) are available within the *fuzzy similarity retrieval* mechanism, one designated for symbolic attributes and the other specific to linguistic ones. The similarity function for normal symbolic attributes is similar to that of a usual nearest neighbour retrieval. The similarity function for fuzzy linguistic attributes is derived from the *area ratio approach* (Liao *et al,* 1998). A stored case with the highest similarity score based on the above formula is deemed to be the most appropriate source of problem solving knowledge for the current situation.

However, a combination of different adaptation strategies including the *critic-based adaptation* (Brown and Lewis, 1993) and *parameterized adaptation* (Kolodner, 1993) is also implemented for modifying the solutions of the retrieved procurement selection cases in accordance with the current problem situations if necessary. Unlike the critic-based adaptation which relies solely on the knowledge of the decision-makers in carrying out the case adaptation activities, the parameterised adaptation is powered with adaptation rules which determine the extent to which adaptation is required for the retrieved case. In procurement selection, these rules can be compiled on the basis of the advantages and disadvantages of currently available procurement systems. Like the previous stage, once the retrieved solution has been adapted and reused, the knowledge is stored automatically for future use in the case repository.

A computer prototype named CaPS has been developed to substantiate the above mechanism (Luu *et al*, 2003a; 2003c). The success of validation and verification tests on CaPS confirms its usefulness in managing CPS knowledge (Luu *et al,* 2003d).

4. Conclusion

This paper has established that CBR is a suitable approach for capturing and reusing CPS knowledge since not only can it retrieve close matching cases but it can also allow users to adapt the solution of the retrieved case to suit the predominant characteristics of the current project. A model for capturing and reusing experiential CPS knowledge in the form of CBR is proposed, which comprises of two consecutive stages, (i) PSC formulation and (ii) procurement selection. The success of validation and verification tests on a computer prototype built on the basis of this model confirms its usefulness in managing CPS knowledge.

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