A KNOWLEDGE-BASED SYSTEM FOR CONSTRUCTION SUBCONTRACTOR APPRAISAL

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ABSTRACT

While a significant proportion of work in a construction project is carried out by subcontractors, keeping track on their performance becomes an important management task to ensure their work is completed satisfactorily and to avoid inferior subcontractors from being appointed in future. Yet, the industry lacks a systematic mechanism to appraise the performance of subcontractors. Despite some clients and contracting organizations have produced their own internal guideline, it is not unusual for their staff to interpret the required quality standard qualitatively and this could lead to disparity and unfairness. To improve the rigor of subcontractor performance appraisal and to facilitate comparison, a more structured approach should be adopted for appraising subcontractors. Knowledge-based systems appear to be a promising approach to formalize the subcontractor appraisal decisions. In this paper, the decision structure governing construction subcontractor appraisal is first highlighted. It is then followed by an introduction to the prototypical knowledge-based system developed for subcontractor performance appraisal. Finally, the ways to apply the results of the knowledge-based subcontractor appraisal model to decision making concludes the paper.

Keywords: construction subcontractor, performance appraisal, knowledge-based systems, decision structure

1. INTRODUCTION

The concept of subcontracting has been applied in the construction industry for years, as it has proven to be an invaluable mechanism to improve the overall efficiency (Richter and Mitchell, 1982) and cope with a fluctuating construction volume (Usdiken and Sözen, 1985). Nonetheless, subcontracting has been used by some contractors as a means to cut corners and pass their risks onto the subcontractors (Hinze and Tracey, 1994). With a relatively simple organization setting and low capital, certain subcontractors may not have the sufficient capability bear an excessive amount of risks and hence carry out their job satisfactorily (Kumaraswamy and Matthews, 2000).

While it is necessary to scrutinize the contractor closely, clients should not lose sight on those subcontractors who are actually performing the work on site. Concerns over the performance of subcontractors have led to various measures which aim to elevate the rigor of subcontracting. Relevant industry initiatives include voluntary / compulsory subcontractor registration (PCICB, 2002a); mandatory disclosure of participating subcontractor (California Subletting and Subcontracting Fair Practices Act); maximum percentage of subcontracting (e.g. US Army Corps of Engineers and some Departments of Transportation in the US); partnering or other forms of relational contracting approaches between the main contractor and subcontractor (Australian Contractors Association, 1999; Kumaraswamy and Mathews, 2000); and so on.

While the measures mentioned above could help eliminate any inherently incapable subcontractor and promote a non-adversarial environment (Palaneeswaran *et al*, 2002), researchers believed that the performance of subcontractor should be subjected to regular review to ensure the strategic objectives of a project and / or client expectations are met in the end (Davenport and Beers, 1995). By recording and analyzing the performance of subcontractors, project team can also impose sanctions (Tang, 2001) or rewards on subcontractors, e.g. by regulating their tendering opportunities (Federal Acquisition Streamlining Act of 1994, US).

Unfortunately, main contractor and project team seldom appraisal subcontractor and record their performance in a systematic manner (Buck, 2003). Only certain public clients in the US (e.g. US Department of State, South Carolina State Government, State of Wisconsin, Iowa Department of Transportation, Kentucky Transportation Cabinet, etc.) have been keeping track on subcontractor performance despite using the evaluation frameworks originally devised for main contractor appraisal. What is needed is a system which is dedicated to construction subcontractor performance appraisal so that reliable performance rating can be computed for decision support (*cf:* PCICB, 2002b).

In this paper, the possibility of applying the knowledge-based systems approach is examined. The paper begins by examining the decision structure governing construction subcontractor appraisal. The features of the prototypical knowledge-based system for subcontractor performance appraisal are then highlighted. The paper concludes by explaining how the results of the knowledge-based subcontractor appraisal model can be applied to the decision making process.

2. RESEARCH METHODS

In the absence of any bespoke mechanism or guideline related to subcontractor appraisal, it is difficult if not impossible to determine the structure in which such decision is made. As a result, it is necessary to elicit the knowledge from the experts. To ensure the knowledge is representative and useful, a purportive sampling approach was adopted so that experts were selected according to their knowledge and expertise in construction subcontractor appraisal. Eventually, seven experts in Hong Kong with extensive experience in appraising construction subcontractors were invited for the knowledge elicitation process, and the profile of the experts is shown in Table 1.

Table 1: Profile of experts involved in the knowledge elicitation process

Position	*Type of Company*	*Year of Experience*
Senior Quantity Surveyor	Main Contractor	18
Project Manager	Stone Contractor	18
Director	Small to Medium Contractor	28
Director	Supplier and Contractor	28
Project Manager	Main Contractor	25
Assistant Manager	Developer	23
Director	Small to Medium Contractor	>40

During the knowledge elicitation process, the experts were invited to highlight the procedures for appraising subcontractors, the decision factors they would consider for subcontractor appraisal, the logical sequence when scrutinizing those decision factors, and the standards they would impose to each factor.

Acknowledging a divergence in the appraisal procedures, decision factors, sequence of decision making and standards amongst the experts interviewed, it is necessary to establish a generic process, the most important decision factors and a set of decision rules which can address the interests and concerns of all stakeholders. An evolutionary approach was adopted whereby a decision structure was firstly developed by the researcher based on the knowledge elicited and the information collected, and the preliminary decision structure was then made available to the seven experts involved for critiques and refinement. This would help ensure the final decision structure is representative and acceptable for real application.

3. DECISION STRUCTURE

In general, experts considered that knowledge-based systems should be applicable to subcontractor performance appraisal as it is common to determine how good a subcontractor is according to some salient characteristics. For instance, whether the subcontractor has a good relationship with other stakeholders, are they financially healthy to complete the work, how good is their overall reputation, etc. These factors can be translated into a series of decision factors including:

- Credibility
- Ability
- Financial healthiness
- Relationship with other companies in the same trade
- Larger companies may take reputation of the company into account as well

Experts opined that the credibility of a subcontractor is the most important parameter to determine one's performance. Beside, their ability relevant to the specialized trade and their financial healthiness are also considered influential to the performance of subcontractors. They considered that these five factors must be properly reviewed when scrutinizing a subcontractor. Apart from that, some experts considered that it is also desirable to consider the following aspects if time and resources allow:

- Tender price
- Workload of the subcontractors during the construction period
- Safety or environmental performances
- Procession of any professional qualifications
- Experience of project manger

From the knowledge elicited from the experts, each decision factors can be further decomposed into a series of sub-factors and the detailed consideration. Table 2 shows the level of detail the factor credibility can go into.

Table 2: Detailed considerations pertinent to subcontractor's credibility

Subcontractors / Detailed Consideration
Reliability
Past track record; market feedback; understanding of the contractor
Performance reliability
Degree of monitoring required
Prompt payment to workers
Skipping work procedures, using materials of lower qualities and quantities
Loyalty / responsibility
Observed from daily inspection and long-term communication in various projects, and comments from others
Baseline is set by experience
Deceptive
Compliance of words to foremen and
Willing to do extra work if it is beneficial to the project
Words only but no action
Attitude of sc when talking with them
Friendship
Responsibility to workers / honesty
Prompt payment to workers
Credit
Background of the owner of company
Personality
Market reputation
Financial: complaints of workers to the labor department
Resources and quality of work
Progress: suitability of workers, management level – relevant past experiences
Site safety: prosecution by labor department
Communication: capable management level
Tender price: within market price range and target range set by company
Any occasion of borrowing for wages
Comments on work done
Cooperation with other subcontractors
Industrial relations
Frequency of domestic claims

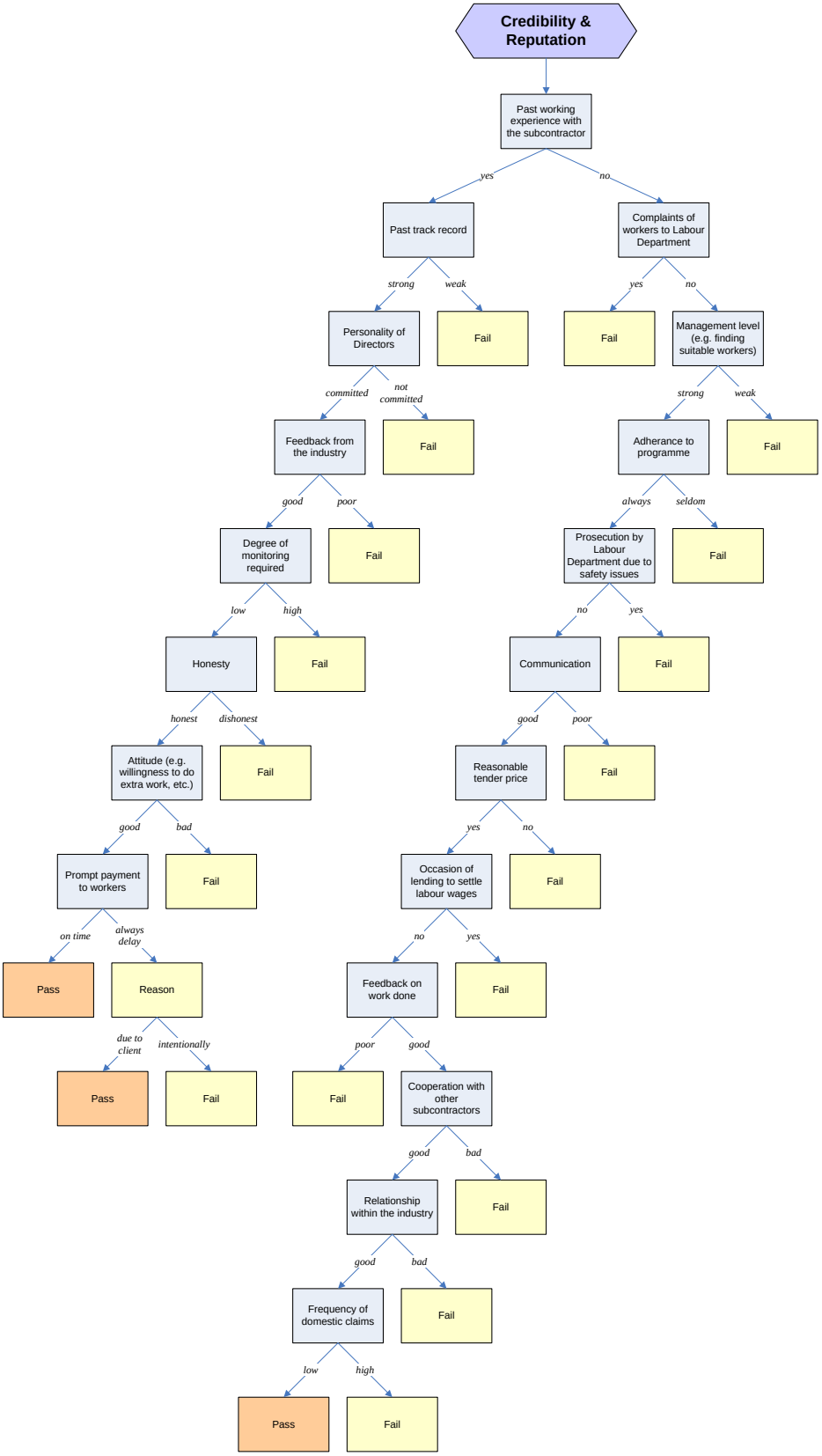

Figure 1: Decision structure regarding the credibility and reputation of subcontractors

With the detailed considerations, decision rules and the logical sequence, a decision tree structure as shown in Figure 1 can be derived. For instance, a subcontractor will be assessed according to their promptness of payment to their workers as a number of project failures are caused by a high turnover rate due to non-payment. If a subcontractor consistently delays paying the salary to their worker, their credibility would be in serious question and should therefore be given a poor performance on this particular decision factors. With suitable modifications, the decision structure can also include answers like “may be” or “not sure” to reflect the reality.

4. PROTOTYPICAL KNOWLEDGE-BASED MODEL

A prototypical knowledge-based system for construction subcontractor appraisal was developed using Microsoft Visual Basic™ due to the relative simplicity of the knowledge structure and the strength of the programming language in designing professional graphical user interface. As for the data entered by the users, they are stored in Microsoft™ database (mdb) format due to its compatibility with other database management software.

Figures 2 and 3 depicts the input and output interface of the prototypical subcontractor performance appraisal model. Users are asked to provide an answer which best describe each performance attribute related to a contractor. The sequence of the questions is structured according to the decision tree structure as shown in Figure 1. Once all the data is entered, the system will determine whether the performance of a subcontractor is acceptable or not.

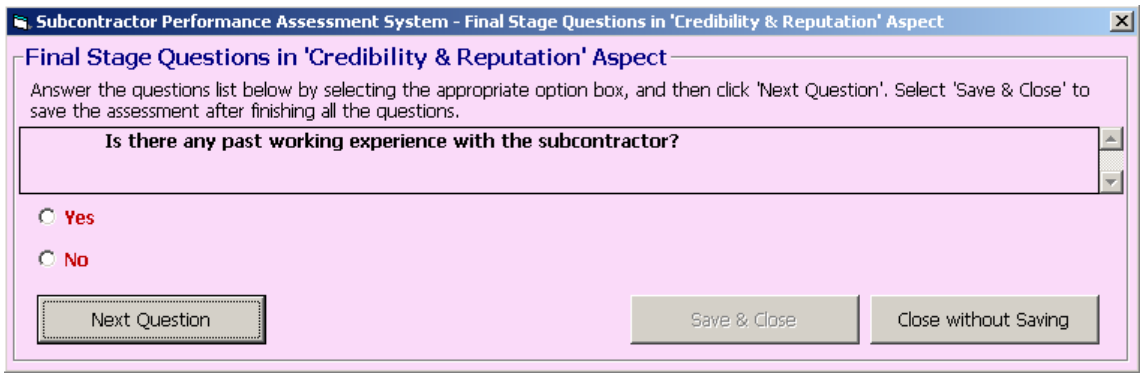

Figure 2: Data input interface related to subcontractor’s credibility and reputation

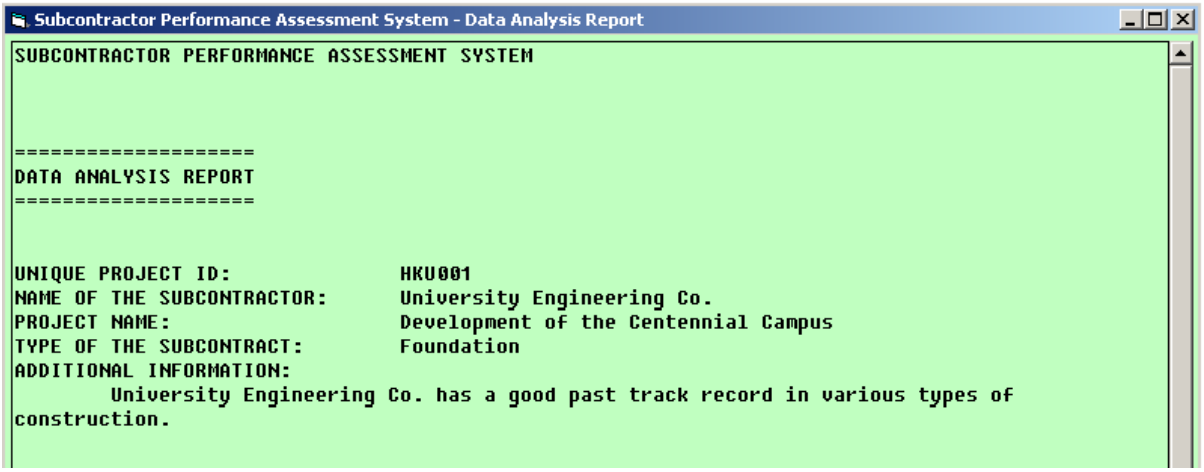

Figure 3: The output of the prototypical knowledge-based subcontractor appraisal system

5. FUTURE DEVELOPMENT

The development of a knowledge-based system is only the first step towards a comprehensive subcontractor performance appraisal model, as the knowledge-based system would be a good mechanism to differentiate the inferior subcontractors from the capable and reliable ones. However, it falls short in establishing how good a subcontractor is. Therefore, it is necessary to extend the incorporate other elements into the subcontractor performance appraisal model such that it can be used for a multiple façade of decision support.

Figure 4 shows the essential features of the comprehensive subcontractor performance appraisal model. The envisaged model consists of four major components namely: (i) objectives and expectations definition; (ii) criteria and performance indicators formulation; (iii) appraisal; and (iv) feedback and appeal.

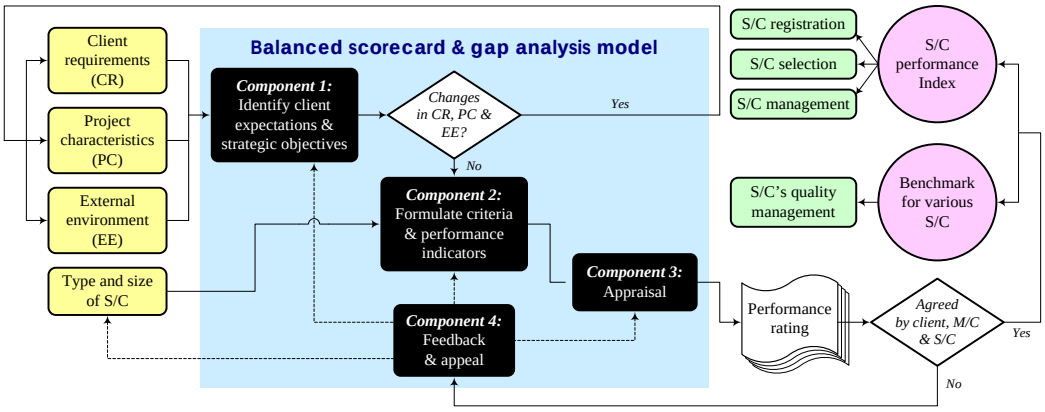

Figure 4: Future extension of the subcontractor appraisal system

"Objectives and expectations definition" (component 1) establishes the client's expectation and strategic objectives that best reflect the distinctive requirements of the client, project and external environment. However, as certain client's expectation and strategic objectives may not be totally apparent while the others could be influenced by design change or unforeseen circumstances, consensus amongst stakeholders is needed to eliminate any unnecessary arguments.

"Criteria and performance indicators formulation" (component 2) aims to formulate a list of performance evaluation criteria and performance indicator based on the type and size of subcontractor. DCAC (1999) pointed out that it is important to ensure that the performance indicator is corresponded to the client's expectation and strategic objectives. Having established the performance indicator, the method of measurement, date source, and time period for measurement would be defined to facilitate subsequent appraisal.

"Appraisal" (component 3) compares the actual quality of subcontractor's works against the performance indicator and computes a performance rating for each subcontractor. The rating of a particular category of subcontractor would then be converted into subcontractor performance index to support subcontractor registration, selection and management. To encourage continual improvement, performance benchmarks are made available to subcontractor.

"Feedback and appeal" (component 4) provides a means for participants to express their opinions regarding the model's reliability and a route for subcontractor to appeal in case they do not satisfy with their performance rating. Careful scrutiny to the client's expectation and strategic objectives, performance indicator and appraisal process is essential to ensure the outcomes are trustworthy enough to assist subcontractor to identify their deficiencies and improve accordingly.

As indicated, the knowledge-based subcontractor appraisal system would be a very important sub-element of the "appraisal" component so as to provide an unequivocal indication as to the problematic issues of a subcontractor. This would allow client, main contractor and subcontractor concerned to address the problem promptly. As for the overall score, it would allow the client and main contractor to compare between different subcontractors to support decisions on future bidding opportunities and/or imposition of other sanctions.

6. CONCLUSIONS

In this paper, the decision factors and the rules elicited from the experts in Hong Kong are highlighted. Using an evolutionary approach, a decision structure has been derived for experts' critiques. Since subcontractor appraisal is conducted in an unstructured manner, the decision structure should provide a foundation for decision-makers to evaluate the performance of subcontractors and thus improve the transparency and fairness of such decisions.

A prototypical knowledge-based subcontractor appraisal system has been presented in this paper. In this paper, the components of the proposed comprehensive subcontractor performance appraisal model are described. It is envisaged that the system should help clients and main contractors to identify the problematic issues of a subcontractor engaged in a project so that remedial actions can be imposed accordingly.

While the knowledge-based approach can provide a very promising avenue for improving the subcontractor performance appraisal decisions, it does not facilitate comparison between subcontractors. Therefore, it is sensible to integrate the knowledge-based systems with the multi-attribute approach so that a final score which represents the overall performance of a subcontractor can be generated for decision support. It is hoping that more research efforts will be directed to this important topic to improve the performance of construction subcontractors.

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