Implementation of Ontological-based Decision Support System for Contractor Selection Process

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Abstract: - In construction industry, the level of successful execution of a construction project is heavily depends on the correct and timely decision made when selecting the most qualified contractor. Current decision-making techniques and decision support tools for assessing contractors are focused on quantitative data processing. Furthermore, it requires in depth knowledge of domain experts. In the manner, ontologies are used to formalize information regarding on contractor selection process with respect to the nature relationships that exist among them. In addition, experts knowledge are also modelled using semantic technologies and ontology in order to handle the dynamic and uncertain nature of the domain.

Key-Words: - Ontology, Decision Support System, Contractor Selection, Construction

1 Introduction

In construction industry, making correct decision at the right time in selecting the most qualified contractor heavily contributes as one of the major factors to ensure the successful overall execution of a construction project in terms of time, cost and competency. In practice, contractor selection process is based on two-stages process known as prequalification and evaluation. The former stage is the screening process whereby each candidate is ensured to comply with minimal threshold before proceeding to the latter stage.

Contractor selection is complicated as it involves contrary opinions between multiple authority parties, multi set of criteria, multi objectives and incomplete data [1-3]. Current decision-making techniques and decision support tools for assessing contractors are focused on quantitative data processing in which solely based on crisp values. These includes some researches proposed decision models based on weighting criteria using multi attribute utility theory [4, 5] and analytical hierarchy process [6, 7]. The fundamental challenge of these quantitative-based systems is it lack of capability to confront with incomplete and ill-defined data, thus limiting the scope of data analysis.

The other key challenge is decision-making activity requires in depth knowledge of domain experts. A good decision is not only depends on complicated calculations of various criteria but it also relies on experts knowledge, and experience during analysing contractor competency [8, 9]. Appropriate representation of expert knowledge leads to perform accurate decision analysis. This has lead to various researches in many areas by integrating DSS with qualitative approaches such as evidential reasoning [10], case based reasoning [8] and fuzzy method [11] in which all these researches addressed the need to have uniform knowledge representation in order to establish healthy competition and improve decision quality.

Ontology is one of the most suitable approaches to represent uniform knowledge and infer rules from the knowledge about a domain through reasoning capability. Ontology is an emerging technology for representing domain knowledge in a meaningful way that can be understood and manipulated by machine. It exploits the feature of reasoning with set of inference rules and memory structure of knowledge resources. Ontology benefits in clarifying the domain structure of knowledge as well as enabling knowledge sharing among people who have similar
needs for knowledge representation and knowledge acquisition in that domain [12].

In this research, ontologies are used to formalize information regarding on contractor selection process based on predetermined criteria with respect to the nature relationships that exist among them. In addition, experts knowledge are also modelled using semantic technologies and ontology in order to handle the dynamic and uncertain nature of the domain. The aim of this paper is to discuss on the implementation of ontology-based in order to provide constant and on-going support for decision-making process focusing on contractor selection process.

The organisation of this paper is as follows. Section 2 presents related reviews on current practices of ontology in the context of ontology for supporting decision-making process. Further, the architecture model of ontological-based decision support is discussed with the constructed ontologies in Section 3. Section 4 outlines the model implementation in order to show the effectiveness of the proposed model. Finally, Section 5 concludes with discussions, directions of future research plan and an overall summary of this paper.

2 Related Works

In recent years, ontology has been increasingly used for various different purposes. Here, the use of ontology is discussed in terms of the implementation of ontologies to support decision making process. Some studies have been proposed to model information and rules for covering different business domain applications including product design process, environmental, financial, audit management and geographic information system.

In product design process, ontology-based technology is exploited to solve conflicting situation that could not be handled by current computer-based information system especially when the information is uncertain and exist in different format. Chang and Terpenny [13] proposed ontological-based data integration framework to structure knowledge into general ontology and model specific ontologies for each different heterogeneous data resources. The relationships between both types of ontologies are utilized to guide designer with proper recommendations, thus information conflicts could be avoided in product design. Meanwhile, research done in [14] is also motivated by the successful ontology application in data integration and knowledge representation. They used ontology to support evaluation of design alternatives in Engineering-To-Order product design phase and tested mainly for electrical equipment.

Furthermore, in environmental domain, OntoWEDSS is an ontological-based architecture that models information and defines semantic meaning of the terminologies in wastewater treatment process [15]. The architecture integrates three different reasoning approaches, rule-based, case-based and ontology-based to diagnose faulty state in treatment plant and propose actions to be taken. Shue et al. [16] utilized ontology to model domain knowledge of accounting items on financial statement and infer decision rules for diagnosing and assessing financial quality of a company. In addition, the advantage of ontology is exploited in management system audit as proposed by Ishizu et al. [17] where they used ontology to acquire, synthesize and verify individual management knowledge according to generic management standards. While, Niaraki and Kim [18] defined qualitative and quantitative criteria into domain specific ontology in order to identify the best planning route for travelling according to user preferences.

3 Research Materials and Methods

This section discusses on the proposed model of ontological-based decision support system for contractor selection process and its ontologies components. The ontologies utilized Methontology and middle-out approach. The construction of decision support engine is based on Malaysian contractor selection case study.

3.1 Model of Ontological-based Decision Support System for Contractor Selection

Fig. 1 depicts the model of ontological-based decision support system for contractor selection process. The abstract model of contractor selection process has several essential components such as generic and specific ontologies that serve as knowledge-based repository and decision support engine. Generic ontology provides knowledge at abstraction level whilst specific ontology inherits any abstraction concepts for its specific domain application. Decision support engine is established to combine and infer information retrieved from knowledge-based for supporting decision-making activity.
3.2 Generic Level Ontology

Generic domain ontology is built to model common information about general tendering processes and clarify semantic data models to capture implicit meaning of domain knowledge. It is generally applicable in any field of tendering processes. Fig. 2 shows the simplified semantic relationships between tendering stages including tender invitation, tender bidding, tender submission, tender evaluation and tender award.

3.3 Domain Specific Level Ontology

Domain specific ontology models knowledge that tailors for solving particular problems that attempt to be solved. Hence, the nature of domain specific is hard to be reused in different applications. A domain specific ontology supplies conceptual structures of contractor selection problem where an ontology is constructed to represent several criteria with respect to construction tender evaluation domain as shown in Fig. 3. Grey boxes represent generic concepts inherited from generic domain ontology of tendering processes. The main aim of construction tender evaluation ontology is to support decision-making process in contractor selection. Interrelated concepts are defined to identify and utilize special meaning that contributes in achieving the purpose of using the ontology. Here, ontology-based approach is employed to imitate the role of experienced experts in screening and evaluating contractor based on personalized criteria by cooperating with ontology-based inference engine.

3.4 Inference Rules

Inference-based system is a powerful mechanism for interpreting and realizing the meaning of information construct. Reasoning engine uses inference rules to infer new information (inferred triples) based on the contents of asserted triples. Table 1 depicts the example of inference rules for inferring enriched information for formulating contractor selection criteria on the screening stage. There are also some rules derived for formulation criteria in the evaluation stage. As noted earlier, ontology-based inference engine is capable to deduce implicit knowledge from explicitly defined concepts, thus emulating human expert judgement analysis.

4 Model Implementation

In this research, Malaysian contractor selection process is selected as a study area. Several criteria and processes have been considered to established the contractor evaluation. These criteria are divided into screening criteria and evaluation criteria. According to Malaysian Department of Work, screening criteria is defined to filter out contractor who has successfully submitted compulsory and supporting documents, passed financial stability requirement and has no “sick” project in hand. Meanwhile, evaluation criteria is identified as bidding price filter, technical resources availability and past performance.

Fig. 4, Fig. 5, Fig. 6 and Fig. 7 show the snapshots of contractors who have passed sufficiency compulsory documents criteria, supporting document criteria, financial stability and current work performance criteria respectively. Here, inference rules as explained in the previous section are derived and deduced to screen out prequalified contractor. Human experts knowledge are transformed into ontology, so that allowing the machine to handle analysis processes. After all the criteria are
formulated for both screening and evaluation stage, the performance of each contractors are analysed using Analytical Hierarchy Process as displayed in Fig. 8 in order to find the optimal performance of contractors.

Figure 3. Simplified Relationships of Construction Tender Evaluation Domain.

<table>
<thead>
<tr>
<th>Rule Name</th>
<th>Description</th>
<th>Expression</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compulsory Document</td>
<td>Every instance of document that has keyword compulsory is a type of compulsory document</td>
<td>if (<a href="?D">Document</a> and <a href="?KC">Keyword Compulsory</a> and [has Keyword](?D, ?KC)) then <a href="?D">Compulsory Document</a></td>
</tr>
<tr>
<td>Supporting Document</td>
<td>Every instance of document that has keyword supporting is a type of supporting document</td>
<td>if (<a href="?D">Document</a> and <a href="?KS">Keyword Supporting</a> and [has Keyword](?D, ?KS)) then <a href="?D">Compulsory Document</a></td>
</tr>
<tr>
<td>Sufficiency Compulsory Documents</td>
<td>Every instance of bidder that has submitted form A, form B, form C, form D, form E, form F, form G and form tender is classified to pass sufficiency of compulsory document</td>
<td>if (<a href="?B">Bidder</a> and <a href="?FA">Form A</a> and <a href="?FB">Form B</a> and <a href="?FC">Form C</a> and <a href="?FD">Form D</a> and <a href="?FE">Form E</a> and <a href="?FF">Form F</a> and <a href="?FT">Form Tender</a>) then <a href="?B">Sufficiency Compulsory Documents</a></td>
</tr>
<tr>
<td>Sufficiency Supporting Documents</td>
<td>Every instance of bidder that has submitted balance sheet, bank statement, bank report, PKK certificate and supervisor report is classified to pass sufficiency of supporting documents</td>
<td>if (<a href="?B">Bidder</a> and <a href="?BS">Balance Sheet</a> and <a href="?SB">Bank Statement</a> and <a href="?BR">Bank Report</a> and <a href="?PC">PKK Certificate</a> and <a href="?SR">Supervisor Report</a> and [has Point](?B, ?CWP)) then <a href="?B">Sufficiency Supporting Documents</a></td>
</tr>
<tr>
<td>Financial Stability</td>
<td>Every instance of bidder that has liquid capital is classified to pass financial stability criteria</td>
<td>if (<a href="?B">Bidder</a> and <a href="?LC">Liquid Capital</a> and [has Capital](?B, ?LC)) then <a href="?B">Financial Stability</a></td>
</tr>
<tr>
<td>Current Work Performance</td>
<td>Every instance of bidder that has point of current work is classified to pass current work performance criteria</td>
<td>if (<a href="?B">Bidder</a> and <a href="?CWP">Current Work Point</a> and [has Point](?B, ?CWP)) then <a href="?B">Current Work Performance</a></td>
</tr>
</tbody>
</table>
Figure 4. Snapshot of List of Contractors Passing Sufficiency Compulsory Documents Criteria.

Figure 5. Snapshot of List of Contractors Passing Sufficiency Supporting Documents Criteria.

Figure 6. Snapshot of List of Contractors Passing Financial Stability Criteria.

Figure 7. Snapshot of List of Contractors Passing Current Work Performance Criteria.

Figure 8. Snapshot of Analytical Hierarchy Process Method.
5 Conclusion
The results of ontological-based decision support system for contractor selection process have been successfully modelled in this work. In this research, knowledge on criteria preferences of experts are represented and derived automatically for supporting decision-making activity based on predefined inference rules. Therefore, analysis of contractors capability is feasible when incomplete and inconsistent historical data and current data available in decision making. This is ongoing research and for future, the ontological-based approach is expected to model knowledge and defined rules for matching the project requirement with the competencies, experiences and skills of a contractor.

References