Modelling Virtual Enterprises Using a Multi-Agent Systems Approach: Case of Construction Industry for Third World Countries

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Introduction

Recently, large, medium and small sized enterprises are teaming up to enhance their competitiveness in the market-place and adapt to the rapid changes of technological innovation. Organizations enhance their competitive ability by creating effective relationships with others. Technological developments have made it possible for organizations to cooperate seamlessly amongst themselves mediated by information technology systems and applications. The trend where enterprises outsource competencies is getting replaced by strategic alliances, where enterprises work together towards a common goal and share responsibilities as well as their profits. This calls for new ways of organizing work and the technological support that allows flexibility.

A Virtual Enterprise (VE) is a temporary organization that pools together different member enterprise core competencies. VEs offer new opportunities to companies operating within an environment with a growing number of participants, such as, contractors, service providers and agencies. There is need for applications that facilitate these inter-organizational collaborations by monitoring and tracking work progress of partners especially in the construction sector.

The Problem

The construction sector’s potential contribution to the economic growth of third world countries can be enhanced if the challenges facing the sector that include delayed completion of projects, frequent collapse of buildings, lack of ethics, incompetent design, use of inappropriate materials, poor coordination and management of contractors, poor construction procedures, are effectively addressed. These can be attributed to poor choice of partner enterprises for the tasks due to insufficient information available about them and lack of facilitation techniques.

Project initiators use information on company profiles to evaluate enterprises. Information from company profiles is often insufficient and decisions made out of insufficient information are subjective. Furthermore, the choices made by project initiators do not take into account that human judgements during partner evaluation and selection are imprecise which can lead to selection of undeserving partners.

Evaluation and selection of a candidate among many alternative contestants is a multi-criteria decision-making (MCDM) process as is the case with selecting the best partner among many partners for construction projects. Partners' evaluation and selection process reliability for construction projects can be enhanced if decision making techniques that are able to deal with subjective information are employed. Available MCDM techniques cannot be used to select right partners for construction projects given that the profiles used as sources of information used to evaluate potential partners have subjective information.

Incorporating fuzzy logic in decision making techniques can address this reliability issue. This study proposes a framework that incorporates fuzzy logic and machine learning technique in analytical hierarchy process (AHP), a multi criteria decision making technique to be used by construction industry project initiators to effectively evaluate and select right partners for tasks and evaluate or predict the partners' performance, even when information available about the partners is insufficient.

The success of any VE is dependent on the members' performance and influence of the partner attributes on its performance. These members and their attributes need to be carefully evaluated. The competitive advantage of any VE is jeopardized by the time it takes to set it up when information available about the partners is insufficient. Extensive research on the evaluation and selection of partners has been done, but only a few studies have been done in the construction industry. The research evaluates and selects partners to carry out project tasks for large buildings in Nairobi County in Kenya.

Methods

Qualitative and quantitative research methods were used. Themes and categorization was based on deductive approach. Subsequently, quantitative methods, namely, Fuzzy Analytical Hierarchy Process (FAHP) and Group Fuzzy Analytical Hierarchy Process (GFAHP), MCDM algorithms that learns partner attributes (machine learning technique incorporated) were designed and applied. A technique called Partners Selection and Performance Evaluation Technique (PaSPET) is proposed. The technique combines fuzzy approximate reasoning with conventional Analytical Hierarchy Process algorithm, designed to deal with imprecise evaluators' judgement.

A Multi-Agent Systems (MAS) approach was chosen to simulate VEs. A MAS is a computerized system composed of multiple interacting intelligent agents within an environment. Partners can be represented as multiple agents. Prior evidence of MAS to facilitate formation of VEs is lacking. The agent-based approach provides efficient decision-making support for human beings using software agents.

VE MAS ontology has been designed and used in agents interactions. The model can be used in evaluation and selection of partners among many potential ones. This research also proposes a VE MAS model for evaluating and selecting right partners for building construction projects. Partners are represented using software agents and all interactions are achieved through agents' communication protocols (ACPs). The model is used to demonstrate the choice of the most preferred partner. Delegation of partner evaluation and selection to the model, gives partners time to implement the tasks.

Results

Results of the study show that GFAHP is both efficient and effective. Its time complexity is n(n-1) compared to n(n+6) for FAHP. It uses all evaluation criteria unlike FAHP which excludes some criteria when they are assigned zero weights. GFAHP reduces the number of pairwise comparisons required when a large number of attributes are to be compared. Validation of the system, carried out by stakeholders, show that FAHP and GFAHP are approximately 99.7% and 98.6% accurate respectively in the evaluation and selection of partners and partners' performance evaluation.

The research contributes to the development of new techniques for addressing consensus and judgement for group evaluation and selection of partners and partners' performance in the construction industry. This research develops techniques which mimic the way evaluation judgements are done by humans, showing the use of real time multi-criteria decision making algorithm and fuzzy models. The use of fuzzy logic can address the uncertainty, incompleteness of information, randomness of ideas and imprecision of phenomena. Finally, the study contributions include: i) GFAHP is a new algorithm developed and applied to the problem domain together with AHP and FAHP, ii) The research applied AHP, FAHP and GFAHP by developing a proof of concept system using MAS, iii) The research applied JADE, a MAS framework to design a MAS system and iv) The research designed and implemented an ontology for MAS. This study examines multi-criteria decision-making (MCDM) "under uncertainties", in particular the linguistic uncertainties and proposes the incorporation of fuzzy logic in AHP algorithm thus addressing issues of partner evaluation and selection while information available about partners is insufficient and subjective.