An Agent Based Approach for Project Management in Construction

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Abstract: Project management has an important role in terms of time, cost and flexibility. An agent-based architecture provides additional robustness, scalability, flexibility that is particularly appropriate for problems with a dynamic and distributed nature. Integrated agent based project management covers design and construction planning. It is combined with plan execution, tolerating both the design and plan, which may be changed as necessary. In this reason, the decision making process requires that the right effects of change need to be propagated through the plan and design in dynamic environment. It is difficult to estimate the operation times and costs exactly. A numerical simulation is presented at the end of this paper to illustrate the procedures of the proposed model.

Key words: Agent systems, construction activities, project management

Introduction

Agent based project management system includes a design agent, planning agent, knowledge agent, cost estimation agent and project manager agent. Agent based system consists of system analysis, program development, testing, installation, and user training skills. Main activities of the suggested system include the control and information flow which are assisting the whole system in every time.

Control activity means by which management control operations. In a project management system, control includes procedures specified for specific tasks, milestones to mark completion of project phases, and the expertise available within the project team to solve problems when they are encountered. Giving information activity provides management with measures of how the system is accomplishing its objectives. Project information systems need to record the current status of activities and list responsibilities, planned and actual durations of activities, and cost expenditures.

We use multi-agent systems as a technique to support project management in a distributed environment. All information relevant to the project as a whole should be passed to the project manager. Information of interest for other team members is often transferred via the project manager as well, even if it is not crucial from the project's point of view. Project Manager agent have been taken on coordinator role. It implements the distribution of the task among the Design Agent, Planning Agent, Knowledge Agent and Cost Estimate Agent.

The next section includes building of model structure in construction activities; then the simulation of the agent based project management in random PERT method presented. The last section reviews the conclusion and results.

Building of Model Structure

The project management is the organizational structure used by the project manager to get things done. The project management system includes the information system to provide project team members with necessary information, because coordination between groups is critical to integrate activities. Organizational structure involves procedures to endure accurate communication and completeness of activities.

Elonen and Artto reviews the problem areas in project management in detail. Love and Irani assessment the quality cost information mechanism in project management. Ugwu et al.(2004) design processes the procurement route selection and effective communication of design parameters between the stakeholders. They reviewed the steel frame structures of the project management. Tserng and Ling are developed an activity based knowledge

management system for contractors. They addressed the application of knowledge management the construction phase with IDEF (Integrated DEFinition function modeling). Sadeghpour at al. modeled the CAD-based construction sites. They defined the tasks and activities in detail. Kasvi et al. defined the managing knowledge competences in project organizations. They determined the several potential outputs. They grouped the knowledge management in four different cases such as knowledge creation, administration, dissemination and utilization. Mahaney&Lederer reviews the information systems of the project management in agency approach. They determined the goal conflicting in the system and task programming type.

Multi agent systems are branch of the Distributed Artificial Intelligence. The term of agent represents a hardware or more usually software-based computer system that has properties of autonomy, social ability, reactivity, and pro-activeness. A stronger notion of the agent adopts mentalistic notions, such as knowledge, belief, intention, and obligation (Wooldridge and Jennings, 1995)

Wu et al. suggested public investment project in Chine with quality self-control and co-supervision mechanism. Udeaja et al. (2008) described a web-based prototype (CAPRI.NET) that was developed to facilitate the live capture and reuse of project knowledge. Xue et al. (2008) suggested the framework, which integrates the construction organizations in construction supply chain and multi-attribute negotiation model into a multi-agent system (MAS), provides a solution for supply chain coordination in construction through multi-attribute negotiation mechanism on the Internet. Kim and Kim (2010) focused on to develop a multi-agent-based simulation system to evaluate the traffic flow of construction equipment in construction site. Adhau et al., proposed A multi-agent system for distributed multi-project scheduling which can solve complex large-sized multi-project instances without any limiting assumptions regarding the number of activities, shared resources or the number of projects. Additionally our approach further allows to random project release-time of projects which arrives dynamically over the planning horizon. Hadikusumo et al. used the e-portal system for the construction material procurement .They proposed the decentralized database system equipped with electronic agents for material procurement.

We represented the multi agent system that is an implementation of a distributed project management tool. Activites, resources, and important functions are represented in a agent‘s task ability. System contains five main agents. Among of the agent relations are modeled and evaluated in random PERT method.

Project level activities, and applied of the methods, commitment, unclear roles and responsibilities are modeled in agent based structure. Process of project information in construction is reviewed in probability PERT mechanism. Summary of construction activities in MAS system in Table 1, analyzed of the probability PERT approach then obtained the project finish time .This procedure repeated in 100 times, and data are evaluated and system decision mechanism obtained the average project completion time. Suggested system provides the managing of the project scheduling mechanism.

Construction projects are complex and time-consuming, which have usually been characterized by their complexity, diversity and the non-standard nature of the production. Whatever successful and unsuccessful projects have been executed by the general contractors, a valuable record of each one should be kept to identify best and worst company practices. During the construction phase of projects, an effective means of improving construction management is to share experiences among engineers, which helps to prevent mistakes that have already been encountered in past projects. Drawing on experience knowledge, activity-related information or knowledge normally includes specifications/contracts, reports, drawings, change orders and data.

MAS system architecture influences information exchanging patterns and relationships between individual agents. One of the advantages of MAS comes from the cooperation among agents. We adopt multi agent system as information infrastructure to support project management in a highly distributed environment. The project management agent takes the functions of coordinator. Agent-based systems have the advantage of being more robust, flexible and fault tolerant than traditional system. Furthermore, the simple patterns of agent behavior are easier to program. In addition, this approach often provides a means to solve problems that have previously been unsolvable and to address problems in way that is more natural, easy and efficient.

The information and knowledge that relates to the whole project and can be clearly classified into activity units can save the category of the project. Inferred knowledge may include process records, problems faced, problems solved, expert suggestions, know-how, innovations and notes on experience. Information and knowledge is better saved in activity-based units to facilitate classification and searching by the system. Moreover, users may search and refer to related information and knowledge from related activities in past projects.

System decision mechanism are effected the some function as follows;

• Goals, expected results, scope of project.
• Plans and schedules: start date, end date, major milestone activities, data items and reports.
• Management organization: the customer’s organization, their key players, their evaluators, and the decision-makers involved in awarding a contract.

• Operational systems: the procedures of selection of the contractors, what is to be done, when it is to be done, who will do it, and how it will be done.
• Technical approach: technical standards and specications, new technology added and the necessary skills for key persons.
• Related and future work: the importance of the project to the customer, future work and the customer's future capital expenditure.
• Competition for the project: who are the competitors and do they have any special advantages? Customer has biased toward a particular competitor.

Agent based project management includes the processes, tasks and issues to consider in planning and designing for construction of building domain, and formulating the knowledge structures and framework for automated knowledge acquisition, and learning for constructability assessment in infrastructure design and construction. It describes the use of interviewing techniques to understand problem solving and the development of knowledge models for automated constructability assessment.

Constructability assessment is critical to achieving project goals. Consequently, it is often undertaken as part of value engineering exercise. The broad goal of a constructability assessment program is to proactively identify potential sources of problems especially during the construction and/or installation of a designed facility, and to identify measures that would mitigate or minimize the problems and their effects on achieving the project goals. Thus adequate assessment and planning for identify some of these issues.

Upon receiving an order, the project management agent is stimulated, and it activates the system decision mechanism. Within this system, there are choices of building like factories, schools, bridges, houses, blocks, malls, etc. Project management in cooperation with the other agents supervises the working of the system. When it comes to the application, one of the choices is taken as a base model, and the simulation process is run with Random PERT. This way, we obtain information as to when the project is likely to end.

Simulation for Agent Based Project Management

Construction projects are full of the uncertainties, including weather, labor skills, site conditions, and management quality. Therefore many probabilistic scheduling models, including program evaluation and review technique (PERT) have been proposed in a construction project as uncertain in multi-agent system. Simulation is a very valuable tool for analyzing models involving elements described by probability durations. Projects involve interrelated activities, many of which are probabilistic. Agent based project management activities are modeled on spreadsheets in Excel.

Model scheduled earlier involved five agent activities. A through E. Assume that the all activities involve some uncertainty. The best way to proceed is to gather statistics on past agent activities (if possible) so that sound data can be used to estimate the expected durations and probability distribution for specific activities. Uncertain activities are generated using random numbers.

The PERT method is also based on independence of activity durations. However, this is not true in projects. If one activity is late, there is a tendency for management to rush following activities to compensate. This would result in a case of negative correlation between durations. There also can be similar underlying causes of lateness that might be positively correlated, such as skill shortages.
PERT addresses the widely recognized uncertainty involved in project management activities, but it makes a rigid assumption about the distribution of durations, and the calculation of probability of completion by a specified time disregards no critical activities, simulation provides a flexible means of evaluation probability of projects being completed by specific time. Any distribution of duration can be assumed. The distribution used should be based on empirical data if possible. All activity paths are considered in the simple spreadsheet network. For instance, observed data may not be symmetric. The triangular distribution might provide a better fit to such data than does the normal distribution.

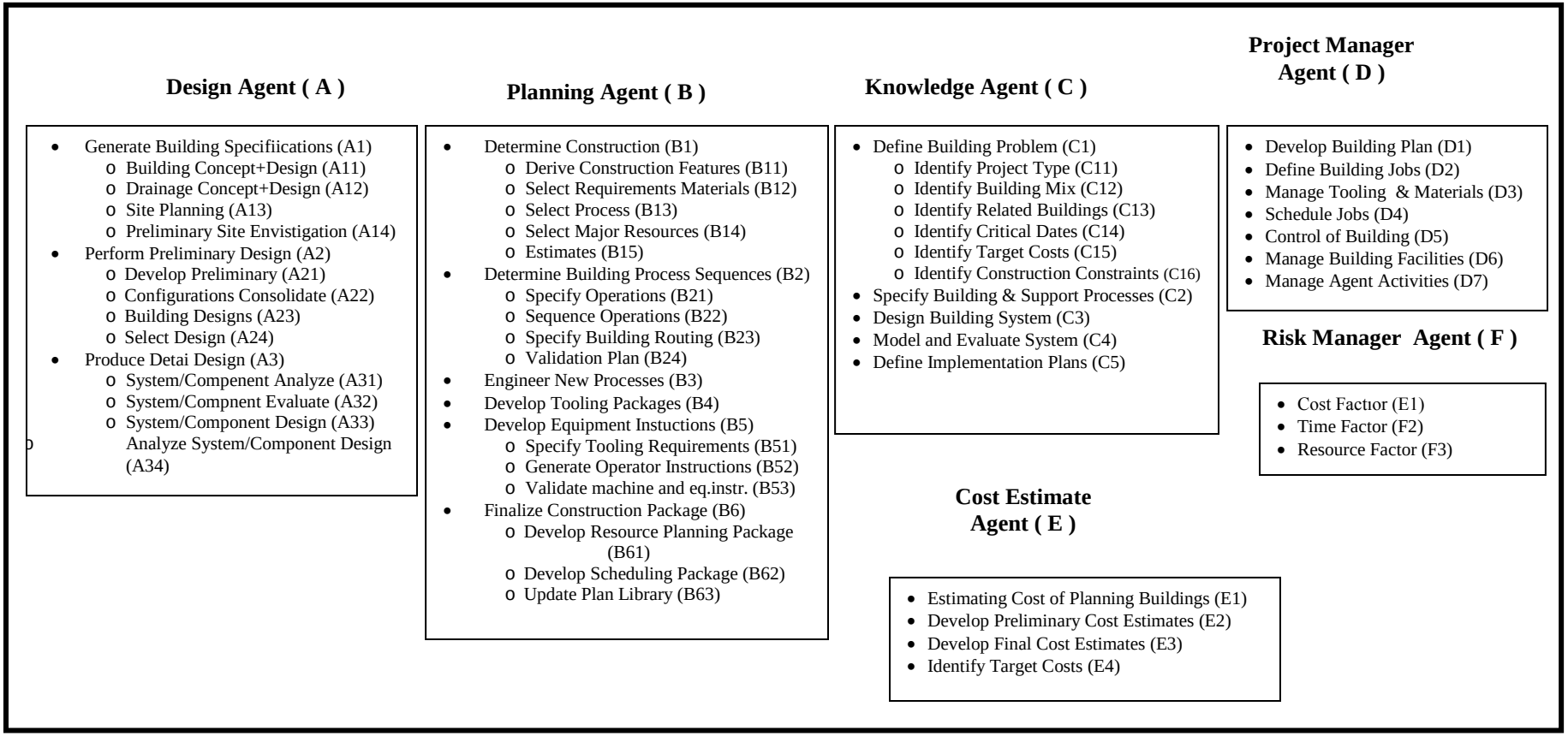

Figure 1. Agent Based Construction Project Management Activities

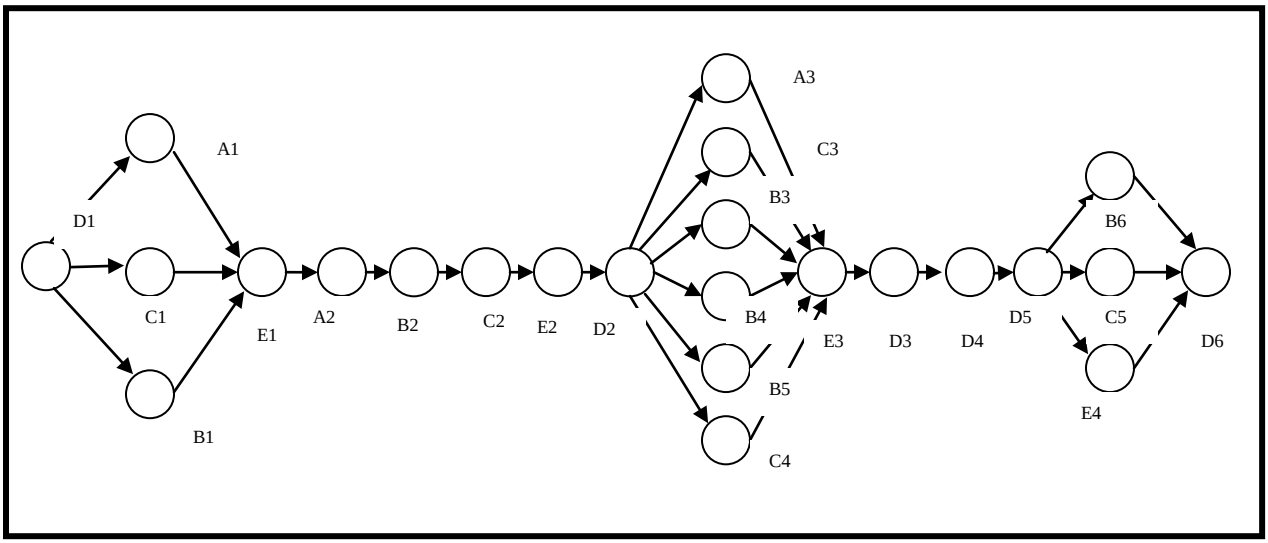

Figure 2. Standart building's process flow diagram

Table 1. Standart building's project process and considering time values.

Task	Min	Mode	Max	Random	Duration	Start	Finish
• Develop Building Plan (D1)	9	8	15	0,4808	10,3303	0	10,33
* Generate Building Specifiications (A1)					8,49664	10,33	18,83
o Building Concept+Design (A11)	1	2	3	0,7267	2,26063		
o Drainage Concept+Design (A12)	1	1	2	0,8096	1,56368		
o Site Planning (A13)	1	3	4	0,4957	2,7245		
o Preliminary Site Envistigation (A14)	1	1	2	0,9973	1,94783		
• Define Building Problem (C1)					12,5656	10,33	22,9
o Identify Project Type (C11)	1	1	2	0,1521	1,07918		
o Identify Building Mix (C12)	1	3	3	0,9059	2,90356		
o Identify Related Buildings (C13)	1	2	3	0,8802	2,51045		
o Identify Critical Dates (C14)	1	1	2	0,3568	1,19803		
o Identify Target Costs (C15)	1	3	4	0,7688	3,16711		
o Identify Construction Constraints (C16)	1	2	3	0,2501	1,70727		
• Determine Construction (B1)					9,36559	10,33	19,7
o Derive Construction Features (B11)	1	1	2	0,6111	1,37638		
o Select Requirements Materials (B12)	1	2	3	0,792	2,35508		
o Select Process (B13)	1	1	2	0,8057	1,55926		
o Select Major Resources (B14)	1	3	4	0,4571	2,65602		
o Estimates (B15)	1	2	3	0,0877	1,41885		
• Estimating Cost of Planning Buildings (E1)	2	3	4	0,2675	2,73149	22,896	25,63
• Perform Preliminary Design (A2)					8,8183	25,627	34,45
o Develop Preliminary (A21)	1	1	2	0,8857	1,66188		
o Configurations Consolidate (A22)	1	3	4	0,4314	2,60881		
o Building Designs (A23)	2	3	4	0,7617	3,30957		
o Select Design (A24)	1	1	2	0,4194	1,23804		
• Determine Building Process Sequences (B2)					9,28968	34,446	43,74
o Specify Operations (B21)	1	2	2	0,5826	1,76325		

Table 1. Standart building's project process and considering time values (continue).

o Sequence Operations (B22)	1	3	4	0,4607	2,66266		
o Specify Building Routing (B23)	1	2	3	0,1229	1,49571		
o Validation Plan (B24)	1	3	4	0,8669	3,36806		
• Specify Building & Support Processes (C2)	2	3	5	0,7191	3,70179	43,735	47,44
• Develop Preliminary Cost Estimates (E2)	3	5	6	0,8299	5,28566	47,437	52,72
• Define Building Jobs (D2)	2	3	4	0,9798	3,799	52,723	56,52
• Produce Detai Design (A3)					8,73297	56,522	65,25
o System/Compenent Analyze (A31)	1	2	3	0,6957	2,21992		
o System/Compnent Evaluate (A32)	1	1	2	0,016	1,00801		
o System/Component Design (A33)	1	2	3	0,9968	2,92017		
o Analyze System/Component Design (A34)	1	2	3	0,9138	2,58487		
• Design Building System (C3)	3	4	5	0,7062	4,23339	56,522	60,76
• Engineer New Processes (B3)	3	5	6	0,3623	4,47442	56,522	61
• Develop Tooling Packages (B4)	5	6	7	0,5396	6,04038	56,522	62,56
• Develop Equipment Instuctions (B5)					9,808	56,522	66,33
o Specify Tooling Requirements (B51)	1	2	3	0,2297	1,67774		
o Generate Operator Instructions (B52)	1	1	2	0,7296	1,48003		
o Validate machine and eq.instr. (B53)	1	3	4	0,8785	3,3962		
• Model and Evaluate System (C4)	2	3	4	0,7218	3,25404	56,522	59,78
• Develop Final Cost Estimates (E3)	3	5	6	0,175	4,02464	66,33	70,35
• Manage Tooling & Materials (D3)	2	3	4	0,5113	3,01141	70,354	73,37
• Schedule Jobs (D4)	2	3	5	0,8445	4,03423	73,366	77,4
• Control of Building (D5)	1	2	3	0,3235	1,8043	77,4	79,2
• Finalize Construction Package (B6)					3,37634	79,204	82,58
o Develop Resource Planning Package (B61)	1	1	2	0,3101	1,16942		
o Develop Scheduling Package (B62)	1	3	4	0,0853	1,71521		
o Update Plan Library (B63)	1	2	3	0,9468	0,49171		
• Define Implementation Plans (C5)	3	4	6	0,4107	0,7287	79,204	79,93
• Identify Target Costs (E4)	2	3	5	0,2041	0,81088	79,204	80,02
• Manage Building Facilities (D6)	2	3	4	0,8365	0,83261	82,581	83,41

Conclusions

The main research contributions include the development of conceptual knowledge structures (i.e. concept maps and task models) for (i) distributed management of constructability knowledge, (ii) developing intelligent agents, (iii) collaborative working, and (iv) a framework for automated knowledge acquisition, teaching and learning, for design and construction of steel frames.

Fig3 represents the standart deviation of the project management finish time. Fig.4 shows the project finish time frequency.

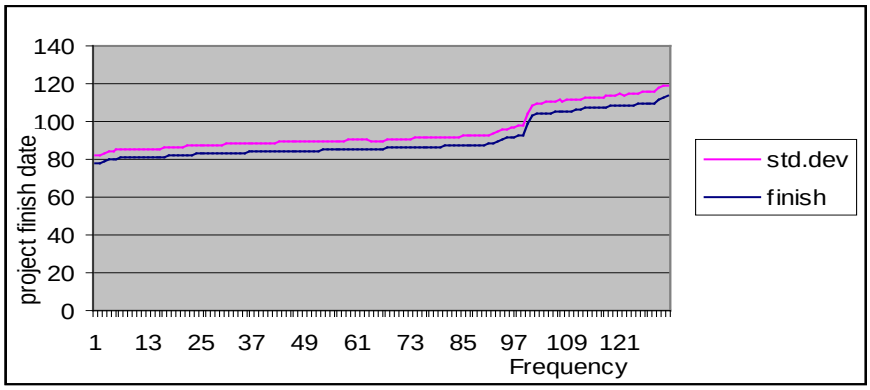

Figure 3. Represents the standart devision for project finish day.

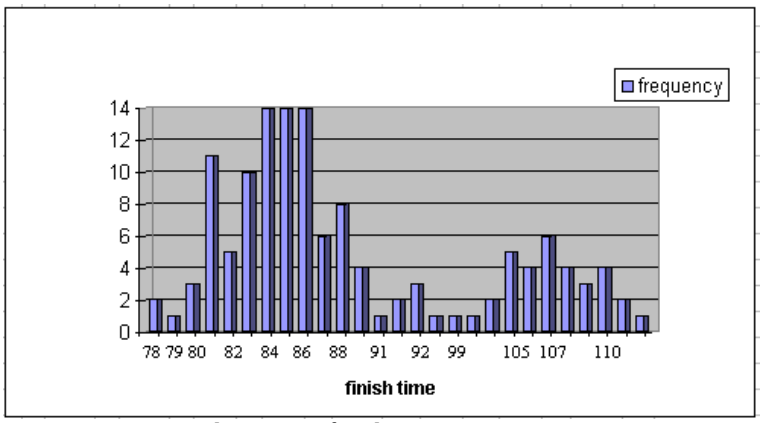

Figure 4. Reprents the project finish time.

Agent based project management activities can: (i) minimize travel time; (ii) decrease time and effort spent on material handling; (iii) increase productivity; and (iv) improve safety, and hence decrease construction cost and time. Agent based planning could be a challenging task that requires good knowledge of different aspects of the construction processes involved, as well as related procurement schedules.

References

Adhau, S., Mittal, M.L., A. (2012). A multi-agent system for distributed multi-project scheduling: An auction-based negotiation approach, *Engineering Applicaions of Artificial Intelligence*, Volume 25, Issue 8, December, Pages 1738-1751.

Elonen, S., Artto, K. (2003), Problems in managing internal development projects in multi-project environment, *International Journal of Project Management*, 21, 395-402.

Hadikusumo, B.H., Petchpong, S., Charoenngam, C. (2005), Construction material procurement using Internet-based agent system, *Automation in Construction*, Volume 14, Issue 6, December, Pages 736‑749

Jennings, N.R. and Wooldridge, M.,(1995) Applying agent technology, *Artificial Intelligence*, 9, 357-369.

Kasvi, J. J., Vartiainen, M., Hailikari, M. (2003), Managing knowledge and knowledge competences in projects and project organizations, *International Journal of Project Management* 21, 571-582.

Kim, K., Kim, K. J., (2010), Multi-agent-based simulation system for construction operations with congested flows, *Automation in Construction*, Vol. 19, Is.7, November, pp. 867-874.

Lin, C.., Chen, Y. (2004), Bid/no-bid decision-making- a fuzzy linguistic approach, *International Journal of Project Management*, 22, 585-593

Love, P. E.D., Irani, Z. (2003), A project management quality cost information system for the construction industry, *Information & Management*, 40, 649-661.

Mahaney, R.C., Lederer, A. L. (2003), Information system project management: an agency theory interpretation, *The journal of Systems and Software* 68, 1-9.

Sadeghpour, F., Moselhi, O., Alkaas, S. (2004), A CAD-based model for site planning", *Automation in Construction*, 13, 701-715.

Tserng, H., Lin, Y. (2004), Developing an activity-based knowledge management system for contractors, *Automation in Construction*, 13, 781-802.

Udeaja, C.E., Kamara, J.M., Carrillo, P.M., Anumba, C.J., Bouchlaghem, N. D., Tan, H.C. (2008), A web-based prototype for live capture and reuse of construction project knowledge, Vol.17, Is.7, October, pp.839-851.

Ugwu, O.O., Anumba, C.J., Thorpe, A. (2004), The development of cognitive models for constructability assessment in steel frame structures, *Advances in Engineering Software* 35, 191-203.

Xue, X., Li, X., Shen, Q., Wang, Y. (2005), An Agent-based framework for supply chain coordiantion in construction, *Automation in Construction*, Vol. 14, Is. 3, June, pp. 413-430.

Wu, Y., Huang, Y., Zhang, S., Zhang, Y. (2012), Quality self-control and co-supervision mechanism of construction agent in public investment project in China, *Habitat International*, Vol. 36, Issue 4, October, 471-480.