

Multi-person Decision Model for Unfinished Construction Project

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Abstract—This paper discusses a proposed model of multi-person decision on prioritizing selection with regard to continuing or terminating unfinished construction projects. This involved multiple steps including determining criteria and sub criteria, selecting and weighting of alternatives, optimizing, and analyzing coalition formation and agreement option. Criteria and sub criteria that were obtained from perspectives of 120 project managers are the first basis to construct decision hierarchy. The model is implemented in one of the biggest private construction projects in Indonesia. The implementation was based on the Analytic Hierarchy Process for multi criteria decision involving coalition and agreement options in a multi-person decision. Goal Programming was used to optimize based on cost constrains. The results demonstrate a process of multi-person decision to select priorities of each alternative to each decision and concluded that some of the projects were continued, postponed or terminated. The new direction of research presented in this paper presents some interesting challenges to those involved in modeling computer-based multi-person decision support utilizing both Multi Agent System and Multi Criteria Decision Making.

Keywords—MCDM, multi-person decision, unfinished construction project, coalition

I. INTRODUCTION

Decision for unfinished construction project is very complicated since there are many parties involved and time is also critical. Where a number of decision makers are involved in choosing a single alternative from a set of possible alternatives, there are different concerns caused by differing preferences, experiences, and background. Therefore, a multi-person decision is required to evaluate and rank the solution alternatives before engaging into negotiation among decision makers [1]. As the process involves multi disciplines and teamwork, negotiation plays an important role for multi-person decision to select unfinished construction project that will be continued, postponed, or terminated.

The research objective presented in this paper is to propose a model of multi-person decision on prioritizing selection with regard to continuing or terminating unfinished construction projects. The objective is attained by combination model of group decision model and coalition formation model for negotiation. This model provides a set of analysis on cooperative game theory to get the best fit decision for agreement option among decision makers.

Negotiation is an interactive communication on a multi-person decision to facilitate a distributed search process. It can be used to effectively coordinate the behavior among decision makers [2] and [3]. Kraus proposed two approaches for the development of

theorems relating to the negotiation process [4]. The first is informal theory, which attempts to identify possible strategies for a negotiator and to assist a negotiator in achieving optimal results. The other approach is the formal theory of bargaining, originating with the work of John Nash, who attempted to construct formal models of negotiation environments. Therefore, negotiation support is useful for negotiation process. Game theory based negotiation and multi-attribute utilizing theory based negotiation [5] are theoretical approaches for negotiation support. Morge and Beaune [6] wrote that a negotiation support system provides three kinds of functionality. Firstly, it facilitates the exchange of information among users. Secondly, it provides decision modeling or group-decision techniques to reduce the noise and uncertainty that occur in the process. Finally, it provides negotiation support. The field of Artificial Intelligence in particular multi-agent methods can be useful for negotiation support on a multi-person decision [7].

Many literatures on unfinished construction project decision describe various methods. In general, they are divided in to four sub-categories; comparative approaches, scoring models, benefit contribution or economic models and optimization methods [8, 9, 10, 11]. However, none of them can be applied in multi-person decision and negotiation. There is also very little research related to the applications of multi-person decision and negotiation support to problems in construction. The researches on negotiation support range from collaborative design to automated claim negotiation [12, 13]. Dzeng and Lin [14] presented an agent based system to help construction contractors negotiate with their suppliers via internet. Kim and Russel [15] developed a conceptual framework for intelligent earthwork systems to enhance the intelligence of constructions equipment. Kim and Paulson [16] presented an agent based compensatory negotiation methodology to facilitate the distributed coordination of project schedule changes. Yan et al [17] used multi-agent system to support project management in a distributed environment. Nassar [18] introduce a framework for managing a distributed project performance system using multi agent systems. Kedro [19] presented a distributed problem solving approach for collaborative multi disciplinary design in general and collaborative facility design and engineering in particular and propose agent based software integration. Halfawy [20] develops and implements a concurrent engineering methodology and a computational infrastructure that would enable these companies to share and exchange design and construction information. From the little amount of the support system applications, none of them applied negotiation support to the problem of multi-person and negotiation in MCDM for unfinished construction project.

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II. UNFINISHED CONSTRUCTION PROJECT

Construction works could be an unfinished project where it was abandoned or on-hold at some stage. Supply and demand problems in real estate market have left many residential and commercial projects "unfinished". The projects are buildings or other architectural structure, as a bridge, a road or a tower. A project becomes unfinished at various stages of development. The stage of the project may be currently being built or which construction work progresses extremely slowly. The work may be finished as a **blueprint** or **whiteprint** and never be realized, or be abandoned during construction.

While owners are hoping to sell, investors are looking for deals. Construction companies are looking for projects to complete. Unfinished construction carries a multiplier effect on job creation that begins with the investor outsourcing to a contractor to develop the construction site. Experience showed that potential buyers are more interested in buying assets, commercial space, or an unfinished construction site rather than functioning enterprises. Cost of unfinished construction will influence to cost of construction project. Issue the actual cost of work already done under the beginning of unfinished construction cost, current actual production costs and the end of unfinished construction costs calculated. Taken after completion of a settlement project, it has finished actual cost of the project.

In this paper, decision to unfinished construction is making the choice on termination decisions and delays, while on the other hand making the selection decision for the continuation of priority projects as part of a property that has been developed. With company's resource limits, then make the decision is not easy because it is very complex and strategic nature, which means the company, will determine the continuation. Therefore it is necessary to construct an alternative optimization that brings the best of existing resources. In addition to practical reality

in the world, from the academic side, the delay of the project is an important part in a project management strategy, especially in an effort to control changes as part of the management integration, with all the causes and strategies to do so. Delays are also to be one discipline in decision making that can be resolved through a quantitative approach [30].

The decision on delays and selection of priorities during the construction phase is a complex problem. It preceded by an assessment of project success as control changes. Studies on these subjects are very rarely found in practical world. It is about exploring facts of the steps undertaken a developer in rescue project or the factors that underlie and influence decision-making, including the development of alternatives. In the academic world, research on the subject is inserted into discussion of project termination as part of project control and project completion [28] but not specifically on the approach to project delays.

There are two approaches on unfinished construction project decision. First is evaluation of success and failure of a project, second is the decision to continue, postpone or terminated. The approach is part of project controlling strategy [29]. In a settlement decision strategy there are four projects strategies including delay [26] namely "with the execution", "made in-house projects", "merger" and "termination" project. This strategy is a decision concerning selection criteria and forecasting [28] and in a case of multi multi-criteria decision research [27]. There are two important decisions in the analysis of project delays [26] which are first, decision on project success through several factors (characteristics of the project, contract, project participation and an interactive process) [25]. All of which are based on performance indicators that include cost, time, value and effectiveness [31]. The second decision is the determination of the delay of the project itself.

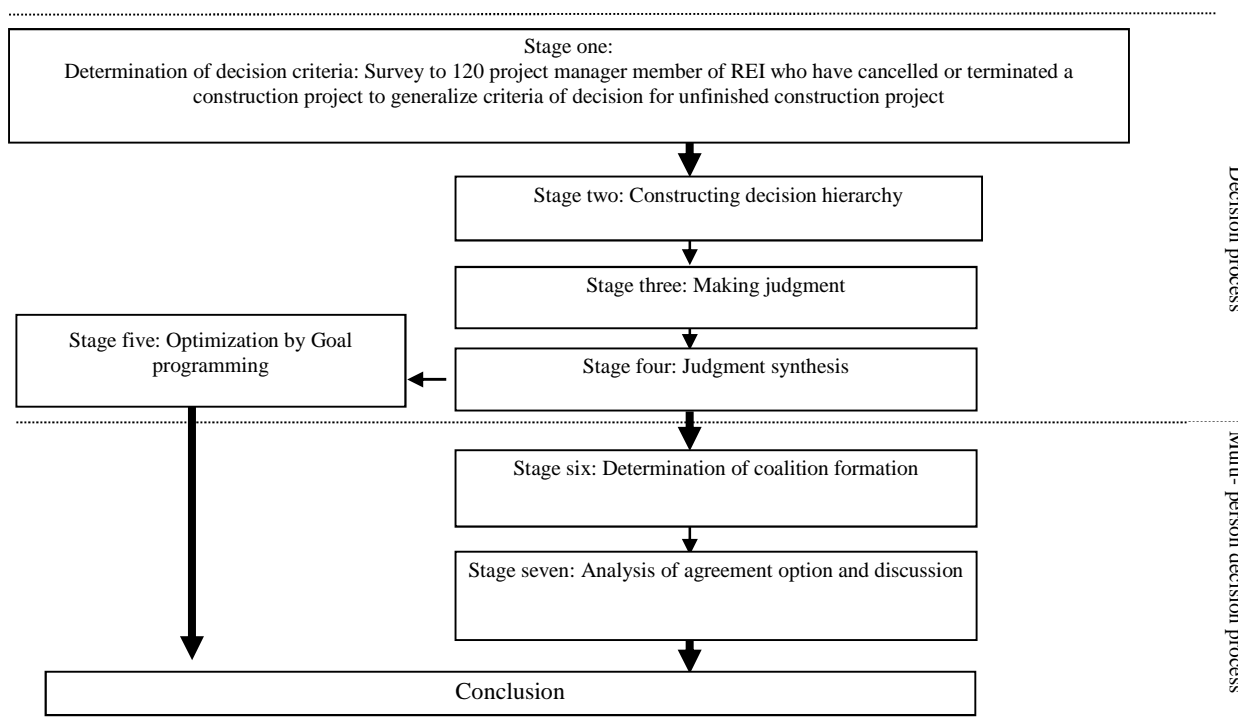


Fig. 1. Process of the group decision and negotiation support

III. METHOD

This paper presents the research objective to develop a model of multi-person decision to fundamental problems involving decision of unfinished construction project. The model is based on a theoretical approach for developing a more effective collaboration and negotiation methodology. This paper also investigates the perspective of decision makers who have cancelled or terminated a construction project. The methodology applied in this paper combines methods for decision process and multi-person process. Analytical Hierarchy Process (AHP) [21] is for decision process. The AHP can be used successfully with a group [22] and negotiation [23]. A Coalition-based Game Theory [24] is for multi-person process. In this research there are five stakeholders as decision makers who give their preference on prioritizing criteria and prioritizing alternative for each criterion. The five stakeholders are Project Manager (PM) representing Client; Estate Manager (EM) who responsible on operational and maintenances of whole Estate and particular project; Architect; in house Design Manager (DM), and Quantity Surveyor (QS).

Fig. 1 represents the process. The process consists of two steps namely decision process and multi-person decision process. It consists of seven stages based on the methodology. The first stage is to determine the criteria for decision hierarchy. These are obtained from a survey study conducted in Indonesia Property Company. Stage two to Stage four are decision process by applying AHP to get prioritization of decision for each decision maker. Stage five is optimization for portfolio analysis. Stage six and seven are multi-person decision process. Result from this process is the group 'best option' for each

project alternative to be decided whether the project is continued, postponed or terminated.

IV. RESULT AND DISCUSSION

The propose model is implemented in one of the biggest private construction projects in Indonesia. The group decision consists of five stakeholders and five project alternatives. In this section the result presented in Stage two to four is only from one stakeholder preference that is Architect. The other stakeholder's preference is analyzed by same way. Results from all stakeholders are analyzed in Stage six and seven for the process of multi-person decision. The result is presented in Table 4. All process of the model (See Fig.1) is discussed in this section.

A. Stage One: Decision Criteria for Unfinished Construction Project

Determination of hierarchical problems is obtained through analyzing and testing of questionnaire survey concerning decision-maker opinions. Opinions were given in a five-point scale (1, not important; 2, slightly important; 3, somewhat important; 4, important; 5, very important). The questionnaire was then distributed to 120 members of REI (Real Estate Indonesia) randomly selected. Table 1 presents list of criteria for unfinished construction project decision. The list of criteria comes from compilation of previous study on project selection [25-31]. These criteria and sub criteria resulted from the survey (Table 1) will be criteria and sub criteria on decision hierarchy (See Fig. 2) and called c1 for cost, c2 for time, c3 for technical, c4 for benefit, c5 for business and risk, c6 for marketing, and c7 for finance.

TABLE 1.
DECISION CRITERIA FOR UNFINISHED CONSTRUCTION PROJECTS

Criteria/ Sub criteria	Mean	Standard Deviation
Time (c2) Construction schedule, construction schedule variance	4.50	0.644
Business and Risk (c5) Consumer image; long term business objectives; adaptation to focus of business; change on project market; Financial risk of development, delay effects to housing market	4.25	0.949
Finance (c7) Available funds for OandM; Probability to capital return; effects to cash flow; financial benefits; time to breakeven; financial competence	4.20	0.834
Benefit (c4) Benefit to project market value; social benefit of the facilities	4.15	0.745
Technical (c3) Possibility to be worked out; contractors arrangements; technical impact of termination; construction material availability; legal aspect of technical matter	4.15	0.856
Cost (c1) Construction cost, construction cost variance	4.10	0.745
Marketing (c6) Potential market; consumer acceptance; effect on housing sale; in compliance with housing.	3.90	0.832

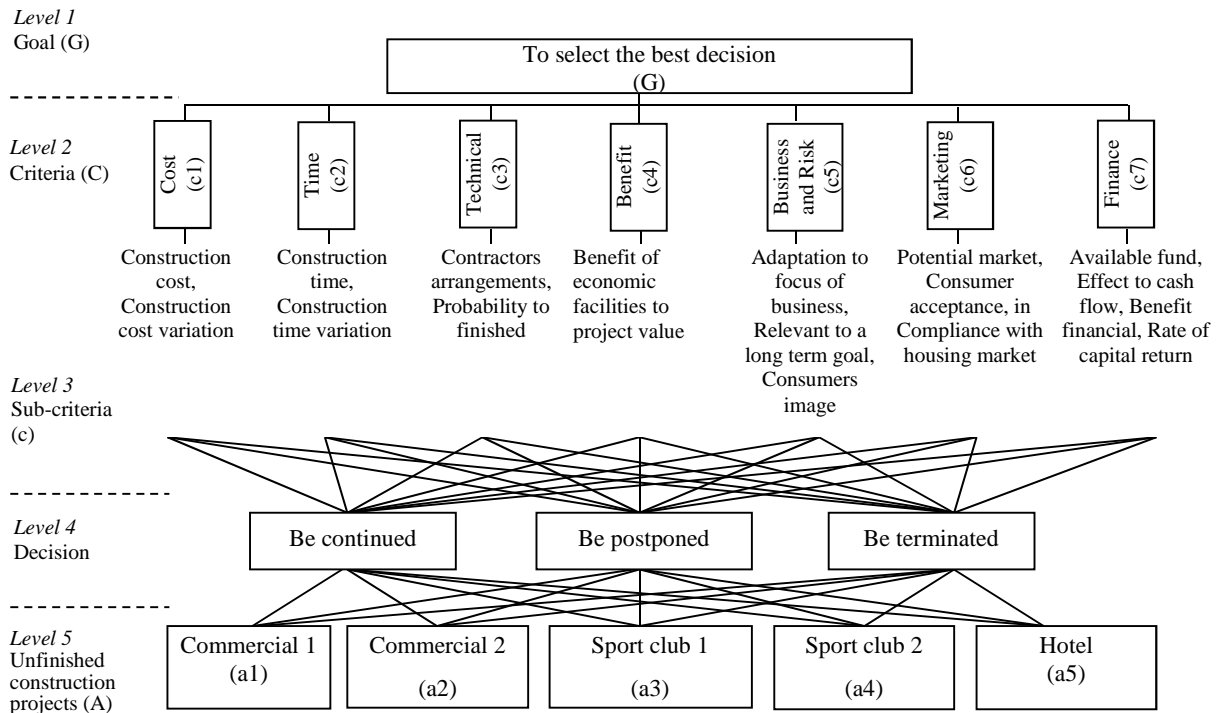


Fig. 2. Decision hierarchy for project selection

B. Stage Two: Constructing Decision Hierarchy

To obtain a good representation of a problem, it has to be structured into different components called activities. Fig. 2 shows five level of decision hierarchy. The goal of the problem (G = "to select the best decision for unfinished constructed project") is addressed by some alternatives (A = a1; a2; a3; a4; a5). The problem is split into sub-problems (c1; c2; c3; c4; c5; c6; c7) which are criteria evaluating alternatives. These criteria (C) are split in sub-criteria. These criteria and sub criteria are determined from Stage one (See Table 1). On fourth level, there are three decision options, whether project will be continued, postponed or terminated. Fifth level of the decision hierarchy is the alternatives of unfinished construction project which are commercial project no.1, commercial project no.2, sport club project no.1, sport club project no.2, and hotel project.

C. Stage Three: Making Judgment for Selecting Alternatives

The first step in any MCDM problem is to define a set of alternatives and a set of decision criteria that the alternatives need to be evaluated with. The task appeals more to an art aspect of MCDM than to a science one [32]. Another very critical step of any MCDM problem is to accurately estimate the pertinent data. In this context, Triantaphyllou [33] argue that "very often in MCDM problems the data cannot be known in terms of absolute values". Therefore many decision making methods attempt to determine the relative importance, or weight, of the alternatives in terms of each criterion involved in a given MCDM problem. AHP [21] decompose a complex MCDM problem into a system of hierarchies. By reducing complex decisions to a series of one-on-one comparison, then synthesizing the result, AHP provides a clear rationale for it being declared the best decision. The AHP [21] is a framework of logic and problem resolving achieved by organizing perceptions,

feelings, judgments, and memories into a hierarchy of forces that influences decision result. The final step in the AHP deals with the structure of an $m \times n$ matrix (where m is the number of alternatives and n is the number of criteria). The matrix is constructed by using the relative importance of the alternatives in terms of each criterion. The vector $(a_{i1}, a_{i2}, a_{i3}, \dots, a_{im})$ for each i is the principal eigenvector of a $n \times n$ reciprocal matrix which is determined by pair-wise comparisons of the impact of the m alternatives on the i -th criterion.

The relative importance of pair-wise comparison [21] could be: equal (1), moderate (3), strong (5), very strong, demonstrated (7) or extreme (9). Sometimes one needs compromise judgments (2, 4, 6, 8) or reciprocal values (1/9, 1/8, 1/7, 1/6, 1/5, 1/4, 1/3, 1/2). For pair-wise comparisons between n similar activities with respect to the criterion c_k , a matrix $A_{ck} = (a_{ij})_{i,j=1..n}$ is a preferred form. If there are "n" items that need to be compared for a given matrix, a total of $n(n-1)/2$ judgments are needed. Then, the product of relative importance for each row of alternatives and criteria is calculated by the following equation:

$$m_i = \prod_{j=1}^n a_{ij} \quad (i = 1, 2, \dots, n) \tag{1}$$

Afterwards, the normalization will determine the weights of alternatives and decision criteria by:

$$w_i = \frac{w_i}{\sum_{i=1}^n w_i} \quad (i = 1, 2, \dots, n) \tag{2}$$

The process of making judgment in the group decision consists of two kinds which are weighting process of each alternative to each criterion and weighting process of each criterion to each decision maker. Table 2 presents a process of making judgment by AHP for each alternative to each criterion for one decision maker that is Architect and one decision that is 'project to be continued'.

TABLE 2.
ARCHITECT'S PAIR WISE COMPARISON FOR ALTERNATIVES TO ALL CRITERIA (PROJECT TO BE CONTINUED)

Cost	a1	a2	a3	a4	a5	a1	a2	a3	a4	a5	\bar{a}	Weighting
commercial 1	1.000	3.000	1.000	0.333	5.000	0.181	0.222	0.181	0.169	0.250	1.002	0.200
commercial 2	0.333	1.000	0.333	0.167	2.000	0.060	0.074	0.060	0.084	0.100	0.379	0.076
sport club 1	1.000	3.000	1.000	0.333	5.000	0.181	0.222	0.181	0.169	0.250	1.002	0.200
sport club 2	3.000	6.000	3.000	1.000	7.000	0.542	0.444	0.542	0.506	0.350	2.385	0.477
hotel	0.200	0.500	0.200	0.143	1.000	0.036	0.037	0.036	0.072	0.050	0.232	0.046
	5.533	13.500	5.533	1.976	20.000							
Time	a1	a2	a3	a4	a5	a1	a2	a3	a4	a5	\bar{a}	Weighting
commercial 1	1.000	0.250	2.000	0.167	0.500	0.074	0.066	0.111	0.083	0.051	0.385	0.077
commercial 2	4.000	1.000	5.000	0.500	3.000	0.296	0.264	0.278	0.249	0.305	1.392	0.278
sport club 1	0.500	0.200	1.000	0.143	0.333	0.037	0.053	0.056	0.071	0.034	0.250	0.050
sport club 2	6.000	2.000	7.000	1.000	5.000	0.444	0.529	0.389	0.498	0.508	2.368	0.474
hotel	2.000	0.333	3.000	0.200	1.000	0.148	0.088	0.167	0.100	0.102	0.604	0.121
	13.500	3.783	18.000	2.010	9.833							
Technical	a1	a2	a3	a4	a5	a1	a2	a3	a4	a5	\bar{a}	Weighting
commercial 1	1.000	0.250	0.500	0.200	0.333	0.067	0.064	0.053	0.085	0.043	0.310	0.062
commercial 2	4.000	1.000	3.000	0.500	3.000	0.267	0.255	0.316	0.211	0.383	1.432	0.286
sport club 1	2.000	0.333	1.000	0.333	0.500	0.133	0.085	0.105	0.141	0.064	0.528	0.106
sport club 2	5.000	2.000	3.000	1.000	3.000	0.333	0.511	0.316	0.423	0.383	1.965	0.393
hotel	3.000	0.333	2.000	0.333	1.000	0.200	0.085	0.211	0.141	0.128	0.764	0.153
	15.000	3.917	9.500	2.367	7.833							
Benefit	a1	a2	a3	a4	a5	a1	a2	a3	a4	a5	\bar{a}	Weighting
commercial 1	1.000	5.000	3.000	7.000	0.333	0.214	0.303	0.315	0.292	0.187	1.310	0.262
commercial 2	0.200	1.000	0.333	2.000	0.143	0.043	0.061	0.035	0.083	0.080	0.302	0.060
sport club 1	0.333	3.000	1.000	5.000	0.200	0.071	0.182	0.105	0.208	0.112	0.678	0.136
sport club 2	0.143	0.500	0.200	1.000	0.111	0.031	0.030	0.021	0.042	0.062	0.186	0.037
hotel	3.000	7.000	5.000	9.000	1.000	0.642	0.424	0.524	0.375	0.560	2.525	0.505
	4.676	16.500	9.533	24.000	1.787							
Business Risk	a1	a2	a3	a4	a5	a1	a2	a3	a4	a5	\bar{a}	Weighting
commercial 1	1.000	0.500	3.000	0.500	3.000	0.176	0.115	0.214	0.197	0.316	1.019	0.204
commercial 2	2.000	1.000	3.000	0.500	2.000	0.353	0.231	0.214	0.197	0.211	1.206	0.241
sport club 1	0.333	0.333	1.000	0.200	0.500	0.059	0.077	0.071	0.079	0.053	0.339	0.068
sport club 2	2.000	2.000	5.000	1.000	3.000	0.353	0.462	0.357	0.395	0.316	1.882	0.376
hotel	0.333	0.500	2.000	0.333	1.000	0.059	0.115	0.143	0.132	0.105	0.554	0.111
	5.667	4.333	14.000	2.533	9.500							
Marketing	a1	a2	a3	a4	a5	a1	a2	a3	a4	a5	\bar{a}	Weighting
commercial 1	1.000	3.000	3.000	5.000	2.000	0.423	0.353	0.429	0.385	0.462	2.050	0.410
commercial 2	0.333	1.000	0.500	2.000	0.500	0.141	0.118	0.071	0.154	0.115	0.599	0.120
sport club 1	0.333	2.000	1.000	2.000	0.500	0.141	0.235	0.143	0.154	0.115	0.788	0.158
sport club 2	0.200	0.500	0.500	1.000	0.333	0.085	0.059	0.071	0.077	0.077	0.369	0.074
hotel	0.500	2.000	2.000	3.000	1.000	0.211	0.235	0.286	0.231	0.231	1.194	0.239
	2.367	8.500	7.000	13.000	4.333							
Finance	a1	a2	a3	a4	a5	a1	a2	a3	a4	a5	\bar{a}	Weighting
commercial 1	1.000	2.000	3.000	2.000	3.000	0.375	0.444	0.400	0.267	0.333	1.819	0.364
commercial 2	0.500	1.000	2.000	2.000	2.000	0.188	0.222	0.267	0.267	0.222	1.165	0.233
sport club 1	0.333	0.500	1.000	2.000	1.000	0.125	0.111	0.133	0.267	0.111	0.747	0.149
sport club 2	0.500	0.500	0.500	1.000	2.000	0.188	0.111	0.067	0.133	0.222	0.721	0.144
hotel	0.333	0.500	1.000	0.500	1.000	0.125	0.111	0.133	0.067	0.111	0.547	0.109
	2.667	4.500	7.500	7.500	9.000							

The result is presented in Fig. 3. For the other decision (project to be terminated and project to be postponed) and the other decision maker (PM, EM, DM, and QS), the process are presented as a result on Table 4.

Table 2 and Fig. 3 show a sample of Architect's judgment. Architect's pair wise comparison to all criteria presents the best project to be continued to each criterion. Observe that in criteria cost, the best project to be continued is sport club 2, mean while hotel is the best project to be continued for criteria benefit.

D. Stage Four: Judgment Synthesis

From equation (2), the matrix of weights of alternatives (under each decision criterion) and decision criteria, $W = [w_1, w_2, \dots, w_n]^T$, is formed. Gathering the weights of all alternatives under each decision criterion i , for $i \in [1, n]$, a matrix of weights of alternatives under all decision criteria, H , is formed. In addition, a matrix R is also formed for all decision criteria $R = [w_1, w_2, \dots, w_i, \dots, w_n]^T$. The matrix of alternative final score, S , is calculated by

the product of the two matrices H and R . Finally, the best solution of a problem is determined by finding the maximum value of S matrix, i.e. $\max (s_1, s_2, \dots, s_n)$. If n is the size of the pair wise comparison matrix $A_{ck} = (a_{ij})_{i,j \in n}$, the Eigen vector which is associated represents the priorities of the activities with respect to $ck (W_{ck} = (w_i)_{i \in n})$. The AHP [21] measures the overall consistency of judgments by means a consistency ratio: $C.R.A_{ck} = C.I.A_{ck} = R.C_n$. The higher the consistency ratio, the less consistent the preferences are. The value of the consistency ratio should be 10% or less. Under this condition the priorities can be calculated. Table 3 presents the process of judgment synthesis of one decision maker that is Architect. From the Table, it can be concluded that Architect prioritizes the Commercial 1 to be continued and the Hotel to be postponed or terminated.

By same method, the decision from the other four stakeholders can be calculated. The result is presented in Fig. 4 and Fig. 6.

TABLE 3.
SYNTHESIS OF PREFERENCE OF AN ARCHITECT

Decision 1: To be Continued									
The Unfinished Construction Project	Criteria and the Weighting							Weight	Rank
	Cost (0.05399)	Time (0.02794)	Technical (0.15332)	Benefit (0.19394)	Business (0.15329)	Marketing (0.36413)	Finance (0.05341)		
Commercial 1	0.1404	0.12428	0.5049	0.2856	0.2313	0.23645	0.4426	0.2891	1 st
Commercial 2	0.0759	0.24219	0.2586	0.1182	0.3319	0.2935	0.2791	0.2461	3 rd
Sport Club 1	0.4583	0.50158	0.1274	0.2273	0.1854	0.30693	0.0999	0.2479	2 nd
Sport Club 2	0.2529	0.07136	0.0546	0.3212	0.1566	0.11301	0.1334	0.1586	4 th
Hotel	0.0725	0.06059	0.0546	0.0477	0.0949	0.05011	0.0449	0.0584	5 th

Decision 2: To be Postponed									
The Unfinished Construction Project	Criteria and the Weighting							Weight	Rank
	Cost (0.05399)	Time (0.02794)	Technical (0.15332)	Benefit (0.19394)	Business (0.15329)	Marketing (0.36413)	Finance (0.05341)		
Commercial 1	0.2603	0.17711	0.0521	0.0390	0.2589	0.09718	0.0820	0.1140	4 th
Commercial 2	0.4484	0.09467	0.2746	0.1443	0.0944	0.11708	0.1711	0.1632	2 nd
Sport Club 1	0.1618	0.04592	0.1505	0.1986	0.0946	0.08863	0.1088	0.1242	5 th
Sport Club 2	0.0797	0.22288	0.0838	0.1085	0.1745	0.19925	0.1927	0.1540	3 rd
Hotel	0.0496	0.45953	0.4387	0.5093	0.3774	0.49789	0.4451	0.4444	1 st

Decision 3: To be Terminated									
The Unfinished Construction Project	Criteria and the Weighting							Weight	Rank
	Cost (0.05399)	Time (0.02794)	Technical (0.15332)	Benefit (0.19394)	Business (0.15329)	Marketing (0.36413)	Finance (0.0534)		
Commercial 1	0.09156	0.17631	0.0435	0.0677	0.1584	0.09014	0.0636	0.0902	5 th
Commercial 2	0.56444	0.06778	0.0840	0.2350	0.1067	0.07331	0.0779	0.1380	4 th
Sport Club 1	0.23227	0.03482	0.1674	0.1144	0.1593	0.12513	0.2036	0.1422	3 rd
Sport Club 2	0.05711	0.21827	0.2860	0.0799	0.1407	0.20619	0.1977	0.1757	2 nd
Hotel	0.05463	0.50282	0.4189	0.5028	0.4346	0.50522	0.4570	0.4537	1 st

E. Stage Five: Optimization

Goal Programming (GP) [34] is used for decision optimization before decision makers form a coalition for a negotiation. GP is an approach to optimize a set of objective function subject to constraint. The outcome is perceived as indicating the tradeoffs that need to be made in terms of reducing a certain objective in return for an increase in some other objectives [35]. Based on the values of aggregation five decision makers, by project decomposition and decision alternatives, optimization variables can be set as the following result:

- X_{1,1} (commercial 1 project will be continued);
- X_{1,2} (commercial 1 project will be postponed);
- X_{1,3} (commercial 1 project will be terminated);
- X_{2,1} (commercial 2 project will be continued);
- X_{2,2} (commercial 2 will be postponed);
- X_{2,3} (commercial 2 project will be terminated);
- X_{3,1} (sport club 1 project will be continued);
- X_{3,2} (sport club 1 project will be postponed);
- X_{3,3} (sport club 1 project will be terminated);
- X_{4,1} (sport club 2 project will be continued);
- X_{4,2} (sport club 2 project will be postponed);
- X_{4,3} (sport club 2 project will be terminated);
- X_{5,1} (hotel project will be continued);
- X_{5,2} (hotel project will be postponed);
- X_{5,3} (hotel project will be terminated).

Constraint of goal objective function is decision cost of each project.

Fifteen functions of cost are presented in Equation (3). The value of each decision is calculated based on engineering estimation.
(In Million USD)

(3)

- X_{1,1}+ d₁⁻ - d₁⁺ = 10.4 if project of commercial 1 is continued
- X_{1,2}+ d₂⁻ - d₂⁺ = 5.24 if project of commercial 1 is postponed
- X_{1,3}+ d₃⁻ - d₃⁺ = 1.8 if project of commercial 1 is terminated
- X_{2,1}+ d₄⁻ - d₄⁺ = 10.5 if project of commercial 2 is continued
- X_{2,2}+ d₅⁻ - d₅⁺ = 4.37 if project of commercial 2 is postponed
- X_{2,3}+ d₆⁻ - d₆⁺ = 6 if project of commercial 2 is terminated
- X_{3,1}+ d₇⁻ - d₇⁺ = 3.5 if project of sport club 1 is continued
- X_{3,2}+ d₈⁻ - d₈⁺ = 7 if project of sport club 1 is postponed
- X_{3,3}+ d₉⁻ - d₉⁺ = 2.5 if project of sport club 1 is terminated
- X_{4,1}+ d₁₀⁻ - d₁₀⁺ = 6.25if project of sport club2 is continued
- X_{4,2}+ d₁₁⁻ - d₁₁⁺ = 3.9if project of sport club 2 is postponed
- X_{4,3}+ d₁₂⁻ - d₁₂⁺ = 1.5if project of sport club 2 is terminated
- X_{5,1}+ d₁₃⁻ - d₁₃⁺ = 23.75 if project of hotel is continued
- X_{5,2}+ d₁₄⁻ - d₁₄⁺ = 12.5if project of hotel is postponed
- X_{5,3}+ d₁₅⁻ - d₁₅⁺ = 1.25if project of hotel is terminated

Where d_i⁻, d_i⁺ ≥ 0

Function of cost for all project alternatives is,

$$X_{1,1} + X_{2,1} + X_{3,1} + X_{4,1} + X_{5,1} + X_{1,2} + X_{2,2} + X_{3,2} + X_{4,2} + X_{5,2} + X_{1,3} + X_{2,3} + X_{3,3} + X_{4,3} + X_{5,3} + d_{16}^- - d_{16}^+ = 32.25 \text{ Million USD.} \tag{4}$$

Objectives function with preemptive priority,

P1= Total cost function and

P2 = function of goal constraint every project is

Minimize:

$$P_1 (d_{16}^+) + P_2 (A_1 d_{1}^- + A_2 d_{2}^- + A_3 d_{3}^- + B_1 d_{4}^- + B_2 d_{5}^- + B_3 d_{6}^- + C_1 d_{7}^- + C_2 d_{8}^- + C_3 d_{9}^- + D_1 d_{10}^- + D_2 d_{11}^- + D_3 d_{12}^- + E_1 d_{13}^- + E_2 d_{14}^- + E_3 d_{15}^-) \tag{5}$$

By entering preference synthesis of project to alternative of decision (tables 3) the goal objective function can be formulated as follows:

Minimize:

$$P_1 (d_{16}^+) + P_2 (0.289041d_{1}^- + 0.114027d_{2}^- + 0.090200d_{3}^- + 0.246093d_{4}^- + 0.163208d_{5}^- + 0.138061d_{6}^- + 0.247877d_{7}^- + 0.12423d_{8}^- + 0.142237d_{9}^- + 0.158576d_{10}^- + 0.154046d_{11}^- + 0.175759d_{12}^- + 0.058413d_{13}^- + 0.444489d_{14}^- + 0.453743d_{15}^-) \tag{6}$$

Solution of the optimization was concluded for each project: commercial 1 project is decided to continue; project of commercial 2 is decided to continue, sport club 1 is selected and decided to continue; sport club 2 is decided to postpone; and hotel is decided to terminate. The total cost is 29.55 Million USD. The decision and solution has been based on cost constraint. The constraint was limited to a project total cost of 32.25 Million USD.

F. Stage Six: Determination of Coalition Formation

Decision makers may choose to cooperate by forming coalitions. Coalition is formed in order to benefit every member of the coalition so that all might receive more than they could individually on their own. Coalition has been used in many researches in negotiation. In this paper, the coalition formation process consists of determination of coalition formation and analysis of agreement options. It considered a game in which the players (decision makers) may choose to cooperate by forming coalitions. Coalition has been used in many researches in cooperative games such as [36] for cooperative information agent-based systems and [23] for COTS selection. Cooperation is the nature in team work on operation and construction management [27], [37] and [38]. A coalition [22] is any subset $C \subset N$, or numbered collection of players in which there are $n > 1$ player numbered 1, 2... n and set of all the players $N = \{1, 2, \dots, n\}$. Coalition is formed by making binding agreements in order to benefit every member of the coalition so that all members might receive more than they could individually on their own. Von Neumann and Morgensten [39] express the characteristic function called *super-additive* as follow:

$$v(S \cup T) \geq v(S) + v(T) \text{ For all } S, T \subset N, S \cap T = \phi \quad (7)$$

Since there are 2^n possible subsets of N, there are 2^n possible coalitions. In every coalition [22] and [40] note that there is empty coalition that is a coalition made up of no members (the null set ϕ) and a grand coalition N consisting of all the players. The benefit of a coalition can be quantified through the use of characteristic function. The characteristic function of a coalition $C \subset N$ is the largest guaranteed payoff to the coalition. A characteristic function of an n -person cooperative game can be denoted by equation as follow:

$$v(\phi) = 0 \text{ and } v(N) \geq i = \sum_{i=1}^n v(i) \quad (8)$$

A coalition structure is a means of describing how the players divide themselves into mutually exclusive coalitions.

It can be described by a set $S = \{S_1, S_2, \dots, S_m\}$ of the m coalition that is formed.

The set S is a partition of N that satisfies three conditions:

$$S_j \neq \emptyset, j = 1, \dots, m$$

$$S_i \cap S_f = \phi, \text{ for all } i = j, \text{ and}$$

$$\bigcup_{S_j \in S} S_j = N \quad (9)$$

It means that each player belongs to one and only one of the m nonempty coalitions within the coalition structure and also none of the players in any coalition m is connected to other players not in the coalition. This axiom is an axiom that the characteristic function in all must be super-additive, with the assumption of super-additive, the players have the incentive to form and joint the grand coalition N.

The quantitative representation of a player's outcome at the end of a game is called payoff. The collection of payoffs to all players may be expressed as the row vector $\bar{x} = (x_A, x_B, \dots, x_n)$ of each player's payoff. As the negotiation progress, the preferences of the evaluation criteria change, leading to changing score of the solution of alternative decision for unfinished construction project, and changing membership and size of the set of agreement options. Three stages are conducted to determine agreement options which are;

1. Determining the weighting factor (weight of preferences) of criteria for each stakeholder. Fig.4 reveals different preferences among decision makers (SH1-SH5).
2. Grading of alternative for each evaluation criteria. Fig.5 presents that a5 is the 'best fit' for c2, c3, c4, c5, a6 and c7. The 'best fit' solution for c1 is a2.
3. Scoring of every alternative for every decision maker. Fig.6 shows that decision makers have different best option as a solution project for the decision to terminate.

G. Stage Seven: Analysis of Agreement Options and Discussion

Game theory [22] techniques for coalition formation have been applied. Works in game theory describe which coalition will form in n -person games under different setting and how the players will distribute the benefits of the cooperation among themselves [41]. The proposed coalition formation model enables each agent to select individually its allies or coalition. Table 4 shows the alternative ranking from possibility of coalition among decision makers for each decision. Firstly, individually all stakeholders have their own best solution. Finally, as shown on Table 4, a4 is found to be the 'best fit' solution for all stakeholders to be continued, a3 is the best option to be postponed, and a5 is the best option to be terminated.

Coalition formation in characteristic function game includes three activities which are coalition structure generation, solving the optimization problem of each coalition, and dividing payoff/the value of the generated solution. This game with five decision makers, there are 32 possible (subset of $5 = 2^N$) coalitions including empty coalition and five singleton coalitions. The coalition's objective is to maximize value. In this case, coalition is happen in three condition of decision which is to be continued, to be postponed, and to be terminated for each alternative of unfinished construction project.

To maximize value also means that each alternative can only be decided in one decision.

TABLE 4.
RANKING OF ALTERNATIVES FROM POSSIBILITY OF COALITION FOR EACH DECISION

Ranking of Alternatives for Each Person and Their Coalition	Be Continued					Be Postponed					Be Terminated				
	a1	a2	a3	a4	a5	a1	a2	a3	a4	a5	a1	a2	a3	a4	a5
Decision Maker (SH) 1 (Architect)	1 st	3 rd	2 nd	4 th	5 th	4 th	2 nd	5 th	3 rd	1 st	5 th	4 th	3 rd	2 nd	1 st
Decision Maker (SH) 2 (PM)	4 th	2 nd	4 th	3 rd	1 st	5 th	1 st	3 rd	2 nd	4 th	2 nd	5 th	3 rd	4 th	1 st
Decision Maker (SH) 3 (DM)	3 rd	2 nd	5 th	4 th	1 st	4 th	1 st	3 rd	2 nd	5 th	1 st	4 th	3 rd	5 th	2 nd
Decision Maker (SH) 4 (EM)	4 th	2 nd	3 rd	5 th	1 st	1 st	3 rd	2 nd	5 th	4 th	3 rd	5 th	1 st	4 th	2 nd
Decision Maker (SH) 5 (QS)	5 th	3 rd	4 th	2 nd	1 st	5 th	1 st	3 rd	2 nd	4 th	5 th	3 rd	1 st	4 th	2 nd
Coalition SH 1,2	4 th	2 nd	3 rd	1 st	5 th	5 th	4 th	2 nd	1 st	3 rd	2 nd	3 rd	4 th	5 th	1 st
Coalition SH 1,3	4 th	2 nd	3 rd	1 st	5 th	4 th	2 nd	1 st	3 rd	5 th	3 rd	4 th	2 nd	5 th	1 st
Coalition SH 1,4	4 th	2 nd	3 rd	1 st	5 th	4 th	2 nd	1 st	3 rd	5 th	3 rd	4 th	2 nd	5 th	1 st
Coalition SH 1,5	4 th	2 nd	3 rd	1 st	5 th	4 th	1 st	2 nd	3 rd	5 th	4 th	3 rd	2 nd	5 th	1 st
Coalition SH 2,3	5 th	3 rd	4 th	2 nd	1 st	2 nd	5 th	1 st	3 rd	4 th	4 th	3 rd	4 th	5 th	2 nd
Coalition SH 2,4	4 th	2 nd	3 rd	1 st	5 th	5 th	4 th	1 st	3 rd	2 nd	5 th	3 rd	4 th	2 nd	1 st
Coalition SH 2,5	1 st	3 rd	4 th	2 nd	5 th	5 th	4 th	1 st	3 rd	2 nd	1 st	5 th	4 th	3 rd	2 nd
Coalition SH 3,4	5 th	3 rd	2 nd	1 st	4 th	5 th	2 nd	1 st	3 rd	4 th	5 th	3 rd	2 nd	4 th	1 st
Coalition SH 3,5	5 th	4 th	3 rd	2 nd	1 st	5 th	4 th	1 st	3 rd	2 nd	5 th	3 rd	4 th	2 nd	1 st
Coalition SH 4,5	5 th	4 th	3 rd	1 st	2 nd	5 th	4 th	1 st	3 rd	2 nd	3 rd	5 th	4 th	2 nd	1 st
Coalition SH 1,2,3	4 th	5 th	3 rd	2 nd	1 st	4 th	5 th	1 st	2 nd	3 rd	1 st	4 th	5 th	3 rd	2 nd
Coalition SH 1,2,4	3 rd	5 th	2 nd	1 st	4 th	5 th	1 st	3 rd	2 nd	3 rd	1 st	2 nd	5 th	4 th	1 st
Coalition SH 1,2,5	2 nd	3 rd	4 th	1 st	5 th	5 th	1 st	3 rd	2 nd	4 th	3 rd	3 rd	1 st	4 th	2 nd
Coalition SH 1,3,4	2 nd	4 th	3 rd	1 st	5 th	4 th	5 th	1 st	3 rd	2 nd	2 nd	3 rd	5 th	4 th	1 st
Coalition SH 1,3,5	4 th	3 rd	2 nd	1 st	5 th	3 rd	5 th	1 st	4 th	2 nd	4 th	3 rd	5 th	2 nd	1 st
Coalition SH 1,4,5	4 th	3 rd	2 nd	1 st	5 th	4 th	5 th	1 st	3 rd	2 nd	4 th	2 nd	5 th	3 rd	1 st
Coalition SH 2,3,4	3 rd	2 nd	4 th	1 st	5 th	4 th	5 th	1 st	3 rd	2 nd	3 rd	4 th	5 th	2 nd	1 st
Coalition SH 2,3,5	5 th	2 nd	4 th	1 st	3 rd	3 rd	4 th	1 st	5 th	2 nd	3 rd	4 th	4 th	2 nd	1 st
Coalition SH 2,4,5	4 th	2 nd	3 rd	1 st	5 th	4 th	5 th	1 st	2 nd	3 rd	4 th	2 nd	5 th	3 rd	1 st
Coalition SH 3,4,5	4 th	2 nd	3 rd	1 st	5 th	5 th	4 th	1 st	2 nd	3 rd	1 st	5 th	4 th	3 rd	3 rd
Coalition SH 1,2,3,4	4 th	3 rd	2 nd	1 st	5 th	4 th	2 nd	1 st	3 rd	5 th	4 th	3 rd	2 nd	5 th	1 st
Coalition SH 1,2,3,5	4 th	3 rd	2 nd	1 st	5 th	3 rd	2 nd	1 st	4 th	5 th	3 rd	5 th	2 nd	4 th	1 st
Coalition SH 1,2,4,5	4 th	2 nd	3 rd	1 st	5 th	4 th	1 st	2 nd	3 rd	5 th	4 th	3 rd	1 st	5 th	2 nd
Coalition SH 1,3,4,5	4 th	2 nd	3 rd	1 st	5 th	2 nd	5 th	1 st	3 rd	4 th	4 th	3 rd	5 th	2 nd	1 st
Coalition SH 2,3,4,5	5 th	3 rd	2 nd	1 st	4 th	5 th	4 th	1 st	3 rd	2 nd	5 th	3 rd	4 th	2 nd	1 st
Grand Coalition	3 rd	2 nd	4 th	1 st	5 th	5 th	2 nd	1 st	3 rd	4 th	3 rd	5 th	2 nd	4 th	1 st
Result	3 rd	-	-	1 st	2 nd	3 rd	2 nd	1 st	-	-	-	3 rd	2 nd	-	1 st

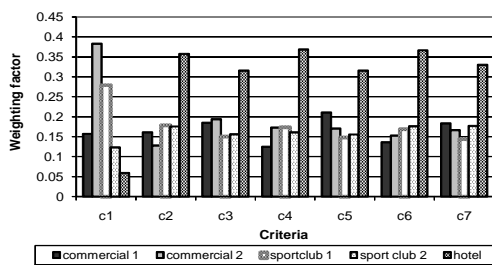


Fig. 3. Weighting factor of each criterion for each alternative (Architect's)

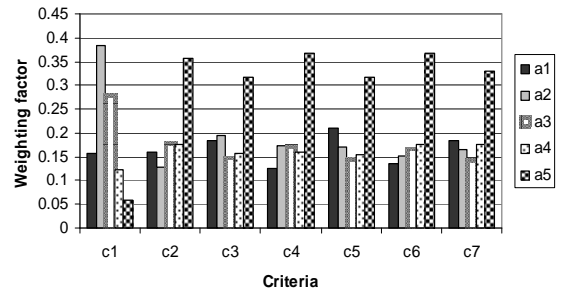


Fig. 5. Weighting factor of every alternative for each criterion

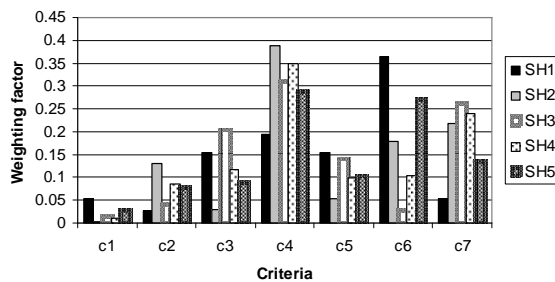


Fig. 4. Weighting of preferences for each stakeholder

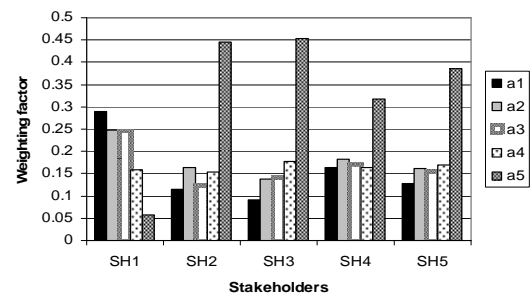


Fig. 6. Weighting factor of every alternative for each decision maker (SH1-SH5)

All decision makers work in a fair and stable way so that they are motivated to stay with the coalition structure rather than move out it. Negotiation could be considered as a process of distributed rational decision making [6]. The greater the number of person involved in the hierarchy construction, the greater is the range of ideas. The enumeration of alternatives and the development of decision hierarchy help the group to debate the problem. The judgments remain subjective. Wanyama and Far [7] wrote that sets of activities could move, expand and, retract during negotiation. By adapted model of coalition formation from [22] and [42], the model works in the context of multi-criteria group decision making. Each person evaluates the available solution option individually based on the preference model using an AHP model. Thereafter, they select the solutions with the highest score as the offers to their negotiation opponents. At the end of every negotiation round, each person adjusts its preference value function in a way so to increase the utility associated with the solution that the agent regards to be the “best-fit” for its coalition.

V. CONCLUSION

The proposed model for multi person decision on unfinished construction project can help decision makers to evaluate and rank the solution alternatives to each decision. Results (optimization based goal programming, and negotiation based coalition formation) are expected. Both analyze are going concern where optimization not only consider function of overall cost but also consider preference weight of each project to each decision as the preference value of each decision maker. Follow up research is particularly required, primarily in the study of an agent-based negotiation on multi criteria group decision. Future research in the application of this methodology in many field of decision will build a wide range of knowledge to solve the theoretical and practical gap in multi person decision and negotiation in construction project.

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