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Agreement Options in Multi-person Decision on Optimizing High-Rise Building Columns

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***Abstract*—**This paper presents a conceptual model of agreement options for negotiation support in multi-person decision on optimizing high-rise building columns. The decision is complicated since many parties involved in choosing a single alternative from a set of solutions. There are different concern caused by differing preferences, experiences, and background. Such building columns as alternatives are referred to as agreement options which are determined by identifying the possible decision maker group, followed by determining the optimal solution for each group. The group in this paper is based on three-decision makers preferences that are designer, programmer, and construction manager. Decision techniques applied to determine the relative value of the alternative solutions for performing the function. Analytical Hierarchy Process (AHP) was applied for decision process and game theory based agent system for coalition formation. An n-person cooperative game is represented by the set of all players. The proposed coalition formation model enables each agent to select individually its allies or coalition. It further emphasizes the importance of performance evaluation in the design process and value-based decision.

***Keywords*—**Agreement options, coalition, group choice, game theory, building columns selection.

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I. INTRODUCTION

MANY real-life problems including those confronting building professionals fall within these categories, e.g. selecting a design solution (choice problem) and prioritizing cost of projects (ranking problem). If the problem involves only one decision maker, a few criteria and a few alternatives, one may not find it too difficult to arrive at a solution. But if the problem is more complex and involves multi participant, decision aid may be quite useful. This paper discusses the nature of group judgment and negotiation outlines some popular multi-criteria group decision-making methodologies that may be useful for building professionals [1], [2]. Negotiation is required to enable each decision maker to evaluate and rank the solution alternatives before engaging into negotiation with the other participants. Binding agreements allow groups or players, or coalitions, to commit themselves to actions that may be against the interest of individual players once the agreement is carried out.

A detailed and integrated presentation of the building columns selection in a multi person decision is provided in this present paper. Choosing a building columns design is common in the methodology of group decision in building system selection [3] and [4]. Design frequently involves making tradeoffs to obtain the "optimal" solution to a design problem, often using intuition or past experience as a guide. Since building columns selection is a relatively complex and comparatively new technology to many practitioners, a rational, explicit method to help organize and rank the tradeoffs made during the design process is needed.

This research comprises the creation of a framework diagramming of multi criteria group decision process involved coalition formation among multi person. Ten important evaluative categories are identified and parameters within these categories are addressed in the context of a decision support system for building columns selection. A summation of the total importance of the advantages represented by each alternative is used to determine the most feasible columns design for a particular project. The framework is demonstrated and compared with designers' decision-making processes, programmer for optimizing design, and construction manager who responsible on develop the building and the construction phase of project.

This paper describes a coalition formation model for a cooperative multi agent system in which each agent of user (designer, programmer, construction manager, and agent coordinator) has complete information about its attribute of alternatives. The agent that initiates the coalition needs to determine the task distribution among the members of the coalition and designs its coalition strategy to increase the chance of successfully forming a working coalition

II. FUNCTION AND COST OF HIGH-RISE BUILDING COLUMNS

Columns design decomposes an element into a collection of system components. Columns are one of the most important structural systems in a building. Knowing what technologies to consider on design and construction of columns structure and what building's columns applications are best suited for particular buildings makes selection a complex matter. In new design, the column system selection can be part of the building design. For example, the building can be

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strengthened to support a heavy structural columns system. The selection process is difficult because of the large number of factors, many of which are unrelated or conflict with one another. A computer integrated knowledge-based system would greatly benefit the selection process.

In this case, the optimum column was selected based on four possibility of vary strength, vary size, vary reinforcement and vary shape. In certain stories, the function vary strength was ignored, because the construction manager wanted to use the same strength concrete in the column that was used in the floor above. Also the corner columns were all square, because it simplified the connection of the facing material. In addition, columns adjacent to stairs or elevators were square or rectangular. Nevertheless, in almost every column in every story, the optimization made some change. By having knowledge of all the functions, a proper, reasonable decision was made. In certain stories, vary strength was limited since some concrete strength was desirable in a floor. Also vary shape was not implemented in corner columns, since square columns were desired to fit plan.

With a general understanding of the available design options, consideration of the following technical and non-technical criteria can lead to the selection of the most appropriate design for a project. The criteria are based on value analysis those are function and cost. Considering function, there are eight functions of optimization column design as attribute of decision (Fig.1). Those are satisfying décor, meet capacity and coordinate strength, maximize space, assure constructability, minimize/reduce creep, expedite design, reuse material, and minimize error. It is critical that the selected system sufficiently satisfies all of the criteria.

Column design selection criteria depend on the perspective of the individual decision makers. For example, designer might be more interested in satisfy decor function that will be influenced by column design, whereas programmer is more interested in domain issues related to optimize design such as maximize space, minimize creep and expedite design. This makes it difficult for decision maker to agree on the evaluation criteria. In this paper there are four alternatives of columns design as possible solution to be selected and be evaluated by eight criteria of function and two criteria of cost, and three decision makers. The alternatives are:

1. Alternative a1 (36x36; 6.0; 1.92), size: 36 x 36.
   Strength (KSI) : 6.0
   Percent Steel : 1.92
2. Alternative a2 (40x40; 6.0; 0.95), size: 40 x 40
   Strength (KSI) : 6.0
   Percent Steel : 0.95
3. Alternative a3 (32x32; 9.0; 1.07), size: 32 x 32
   Strength (KSI) : 9.0
   Percent Steel : 1.07
4. Alternative a4 (36 diameters; 9.0; 0.99), size: 36 diameters
   Strength (KSI) : 9.0
   Percent Steel : 0.99

Selecting of high rise building columns design in this paper undergoes the following steps:

Step 1: Each decision maker defines his/her evaluation criteria and sets the weight of each criterion (win condition).
Step 2: Using AHP, every decision maker evaluates and ranks the columns design alternatives based on his/her win conditions.
Step 3: The ranking of the columns design alternatives with respect to different decision makers are generated and compared in order to identify conflict.
Step 4: Identify agreements options, as well as a columns design alternatives ranking that reflects the combined preferences of all decision maker (coalition).

A. Function Analysis

The word function is commonly used, and has many definitions. Kaufman [5] defined as ‘an intent or purpose that a product or service is expected to perform’. The two operative words in the definitions are ‘intent’ and ‘expected’. How a product or service is used does not identify its functions. The classifications of functions as they relate to product performance are: basic function and secondary function. Basic Function is defined as the principal reasons for the existence of the product or service, operating in its normally prescribed manner. Secondary function is the method selected to carry out the basic function or those functions and features supporting the basic function. It sometimes sub classified as ‘required’ function. Furthermore, Kaufman [5] gives rules governing basic functions. These are: 1) a basic function can not change; 2) the cost is usually less than 5% of the total cost.

Based on the function analysis system technique (FAST) that has been applied on this research, it can be identified the function of optimizing high-rise building columns. Fig. 1 shows the FAST diagram. Further the identified function will become the attributes for decision (f1-f8 are c1-c8). The FAST diagram reflect combination of the perception of designer (design column firstly), the programmer (optimize the original column design) and the construction manager (manage the construction of column).

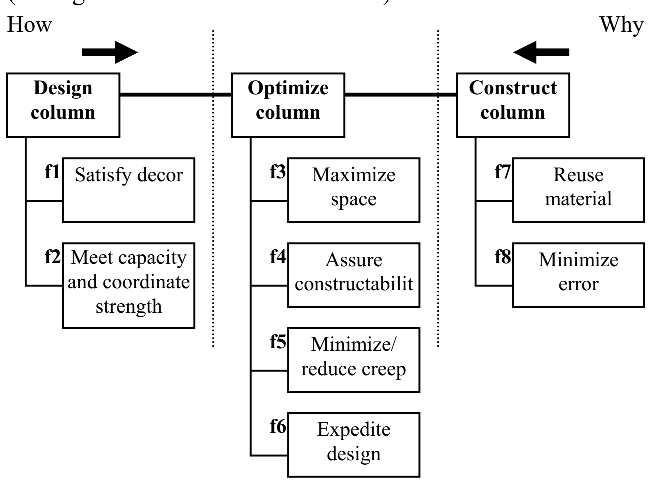

Fig.1 the FAST diagram of the optimizing column

B. Cost

The proper selection of the higher order basic function can affect cost. Major elements that contribute to the cost of a column:

1. Size of concrete column
2. Strength of column
3. Vertical column formwork (temporary)
4. Reinforcement

The major part of the load is carried by the concrete, but for alternative a1, two thirds of the cost is for other items. The cost of reinforcement and temporarily formwork should therefore be reduced proportionality. When project manager instruct their designers, they focus on how to design column that will support the load. On alternative a2 the higher order function design column is changed to optimize column. Cost is inserted in the main critical path rather than as an all-the-time function. Design column fit design criteria such as size, strength and percent of reinforcement. On alternative a3 the higher order function is changed to construct design. The a1, a2, a3 were proposed by designer, programming and construction manager respectively while the a4 is proposed as opponent of previous alternatives. It based on the possibility of vary size, vary strength, vary reinforcement and vary shape.

Formwork is a necessary part of a concrete column that contributes nothing to load carrying capacity. Logically, its cost should be minimized. The shape of a column directly affects the ratio of the amount of formwork (circumference) required to the load carrying capacity (area). Circular and square shapes have equal circumference/area ratio, while rectangular columns have ratio greater than circular or square columns of the same area. Therefore, rectangular columns are less economical. Furthermore, circular columns are now being furnished in one-piece reusable (rentable) units, optimizing the cost of fabrication. Therefore, circular columns are most economical. TABLE I present the cost of each alternative of columns in a high-rise office building based on category of material including concrete column and reinforced (main vertical, dowels, and ties), and category of construction consist of temporary formwork.

TABLE I
COST OF THE HIGH-RISE BUILDING COLUMNS

Cost category	Present Worth (10,000USD)			
	a1	a2	a3	a4
Material	698.3	598.7	521.6	533.9
Construction	272.2	302.4	241.8	98.3
TOTAL	970.4	901.1	763.5	632.2

Cost analysis can be performed on columns design. Programmer is taking into consideration the costs in the selections. While cost is a factor in their decisions, it is not the only factor. Whereby, designer and construction manager is taking consideration in function.

III. DECISION PROCESS

The analytical hierarchy process (AHP) [6] is a powerful and flexible decision process. 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 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 [7]. The AHP also can be used successfully with a group [8] and negotiation [9].

A. First Step: Constructing Decision Hierarchy

To obtain a good representation of a problem, it has to be structured into different components called activities. Fig. 2 shows four level of decision hierarchy. The goal of the problem (G ="To optimize high-rise building columns") is addressed by some alternatives (A = a1; a2; a3; a4). The problem is split into sub-problems c1; c2; c3; c4; c5; c6; c7; c8; c9; c10 which are criteria evaluating alternatives. Decision hierarchy model might possibly be modified by considering factors to be more accurately with flexibility at adjustment of condition of a project. Then implementation of analytical hierarchy can be started with compilation of the hierarchy model.

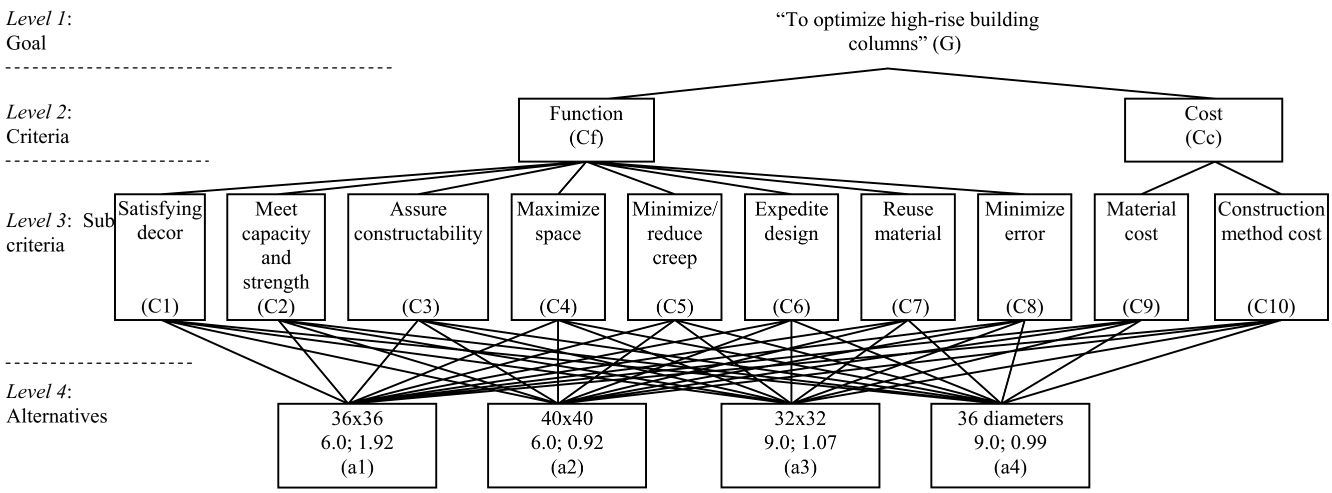

Fig.2 Decision hierarchy to select best choice of high-rise building columns

B. Second Step: Making Judgments

The relative importance of pair wise comparison 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). If there are "*n*" items that need to be compared for a given matrix, a total of $n(n-1)/2$ judgments are needed. For each set of factors, a matrix "A" of pair-wise comparison can be derived:

$$A = \begin{bmatrix} a_{11} & a_{12} & .. & a_{1j} & .. & a_{1n} \\ a_{21} & a_{22} & .. & a_{2j} & .. & a_{2n} \\ . & . & .. & . & .. & . \\ . & . & .. & . & .. & . \\ a_{i1} & a_{i2} & .. & a_{ij} & .. & a_{in} \\ . & . & .. & . & .. & . \\ . & . & .. & . & .. & . \\ a_{n1} & a_{n2} & .. & a_{nj} & .. & a_{nn} \end{bmatrix} = \left(a_{ij}\right)_{nxn} \tag{1}$$

If there are "*n*" items that need to be compared for a given matrix, a total of $n(n-1)/2$ judgments are needed. For each set of factors, a matrix "*A*" of pair-wise comparison can be derived. Then, the product of relative importance for each row of alternatives and criteria is calculated by the following equation:

$$m_i = \prod_{j=1}^{n} a_{ij} \left(i = 1,2,...,n\right) \tag{2}$$

From the pair-wise comparison matrix, the eigenvector and the maximum eigenvalue can be calculated using the right eigenvector method by employing the following equation:

$$\lambda_{\max} = \sum_{j=1}^{n} \frac{AW}{nw_i} \left(i = 1,2,...,n\right) \tag{3}$$

Then the vector $\bar{w}_i$ is derived by the following equations:

$$\bar{w}_i = \sqrt[n]{m_i} \left(i = 1,2,...,n\right) \tag{4}$$

Afterwards, the normalization of vector $\bar{w}_i$ will determine the weights of alternatives and decision criteria by:

$$w_i = \frac{\bar{w}_i}{\sum_{i=1}^{n} \bar{w}_i} \left(i = 1,2,...,n\right) \tag{5}$$

From that equation, the matrix of weights of alternatives (under each decision criterion) and decision criteria, $W = [w_1, w_2,...,w_n]^T$, is formed. Gathering the weights of all alternatives under each decision criterion *i*, for *i* Є [1,*n*], a matrix of weights of alternatives under all decision criteria, *H*, is formed. Matrix *H* is denoted as follows:

$$H = \begin{bmatrix} w_{11} & w_{12} & .. & w_{1j} & .. & w_{1n} \\ w_{21} & w_{22} & .. & w_{2j} & .. & w_{2n} \\ . & . & .. & . & .. & . \\ . & . & .. & . & .. & . \\ w_{i1} & w_{i2} & .. & w_{ij} & .. & w_{in} \\ . & . & .. & . & .. & . \\ . & . & .. & . & .. & . \\ w_{m1} & w_{m2} & .. & w_{mj} & .. & w_{mn} \end{bmatrix} \tag{6}$$

In addition, a matrix R is also formed for all decision criteria: $R = [w_1, w2,..., wi,...,w_n]^T$. 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 ($s_1, s_2, \ldots, s_n$)

Where,

A = pair-wise comparison matrix

a_{ij} = relative importance of alternative/decision criteria "*i*" compared to alternative/decision criteria "*j*"

n = number of alternatives in the set

m = number of alternatives in the set

S = matrix of alternative final score

H = matrix of weight of alternatives under all decision criteria

R = matrix of weights of decision criteria

H = matrix of weight of alternatives under all decision criteria

W = matrix of weights of alternatives (under each decision criterion) and decision criteria.

w_i = weights of alternatives (under each decision criterion) and decision criteria.

w*ij* = weight of alternative j under decision criterion *i*

$\bar{w}_i$ = n^{th} power root of m_i

i = 1,2,…,*n*

j = 1,2,…,*m*

m_i = product or relative importance for each row of alternatives and decision criteria

λ_{max} = largest eigenvalue of matrix *A*

C. Judgment Synthesis

The AHP [6] measures the overall consistency of judgments by means a consistency ratio: $CRA_{ck} = CIA_{ck} = RC_n$. 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.

The AHP does not require decision makers to be perfect consistent, but rather provides a measure of consistency. This is achieved by the use of consistency ratio (CR) [10]. This was proposed by Saaty [6] to measure the inconsistency in the pair wise comparison using the following formula:

$$CR = \frac{CI}{RI} \tag{7}$$

Where

CR = consistency ratio; CI = consistency index

RI = random consistency index, for n = 8, the value of RI is 1.41.

Besides, CI is defined as:

$$CI \frac{\lambda_{\max} - n}{n-1} \tag{8}$$

Where

CI = consistency index;

n = number of alternatives in the set

$\lambda_{\max}$ = largest eigenvalue.

TABLE II shows the result from decision makers' judgment and the synthesis from AHP.

TABLE II
WEIGHTING FACTOR OF EACH ALTERNATIVE TO EACH STAKEHOLDER

SH1 Designer	Weighting factor each alternative to each criteria for designer (λ=8.688172, CI=0.09831, CR=0.069724)											
	C1 (0.289)	C2 (0.217)	C3 (0.080)	C4 (0.144)	C5 (0.040)	C6 (0.057)	C7 (0.025)	C8 (0.023)	C9 (0.104)	C10 (0.021)	Σ	Ranking
a1 (36x36; 6.0; 1.92)	0.1299	0.0597	0.0134	0.0242	0.0091	0.0148	0.0049	0.0056	0.0090	0.0018	0.2724	1st
a2 (40x40; 6.0; 0.92)	0.0522	0.0841	0.0184	0.0169	0.0191	0.0256	0.0068	0.0120	0.0148	0.0011	0.2511	2nd
a3 (32x32; 9.0; 1.07)	0.0814	0.0430	0.0093	0.0334	0.0046	0.0068	0.0035	0.0036	0.0493	0.0044	0.2393	3rd
a4 (36dia; 9.0; 0.99)	0.0260	0.0303	0.0386	0.0699	0.0066	0.0097	0.0096	0.0020	0.0310	0.0135	0.2373	4th
SH2 Programmer	Weighting factor each alternative to each criteria for programmer (λ=8.853712, CI=0.121959, CR=0.086496)											
	C1 (0.010)	C2 (0.007)	C3 (0.032)	C4 (0.022)	C5 (0.019)	C6 (0.016)	C7 (0.012)	C8 (0.007)	C9 (0.583)	C10 (0.292)	Σ	Ranking
a1 (36x36; 6.0; 1.92)	0.0046	0.0018	0.0054	0.0037	0.0043	0.0041	0.0024	0.0018	0.0506	0.0258	0.1044	4th
a2 (40x40; 6.0; 0.92)	0.0018	0.0025	0.0075	0.0026	0.0090	0.0070	0.0034	0.0038	0.0831	0.0153	0.1360	3rd
a3 (32x32; 9.0; 1.07)	0.0029	0.0013	0.0038	0.0051	0.0022	0.0019	0.0017	0.0011	0.2759	0.0617	0.3575	2nd
a4 (36dia; 9.0; 0.99)	0.0009	0.0009	0.0157	0.0107	0.0031	0.0027	0.0047	0.0006	0.1737	0.1889	0.4021	1st
SH3 Construction manager	Weighting factor each alternative to each criteria construction manager (λ= 8.793054, CI=0.113293, CR=0.08035)											
	C1 (0.078)	C2 (0.029)	C3 (0.139)	C4 (0.031)	C5 (0.030)	C6 (0.050)	C7 (0.155)	C8 (0.238)	C9 (0.031)	C10 (0.219)	Σ	Ranking
a1 (36x36; 6.0; 1.92)	0.0351	0.0080	0.0233	0.0053	0.0069	0.0129	0.0307	0.0574	0.0027	0.0194	0.2016	3rd
a2 (40x40; 6.0; 0.92)	0.0141	0.0112	0.0321	0.0037	0.0144	0.0223	0.0426	0.1232	0.0045	0.0114	0.2796	2nd
a3 (32x32; 9.0; 1.07)	0.0220	0.0058	0.0163	0.0073	0.0035	0.0060	0.0216	0.0367	0.0148	0.0462	0.1802	4th
a4 (36dia; 9.0; 0.99)	0.0070	0.0041	0.0673	0.0152	0.0050	0.0085	0.0600	0.0204	0.0093	0.1417	0.3386	1st
Aggregation	C1 (0.126)	C2 (0.084)	C3 (0.084)	C4 (0.066)	C5 (0.029)	C6 (0.041)	C7 (0.064)	C8 (0.089)	C9 (0.240)	C10 (0.177)	Σ	Ranking
a1 (36x36; 6.0; 1.92)	0.0565	0.0231	0.0140	0.0111	0.0068	0.0106	0.0127	0.0216	0.0208	0.0157	0.1928	4th
a2 (40x40; 6.0; 0.92)	0.0227	0.0326	0.0194	0.0077	0.0142	0.0183	0.0176	0.0463	0.0341	0.0093	0.2222	3rd
a3 (32x32; 9.0; 1.07)	0.0354	0.0167	0.0098	0.0152	0.0034	0.0049	0.0089	0.0138	0.1133	0.0374	0.2590	2nd
a4 (36dia; 9.0; 0.99)	0.0113	0.0118	0.0406	0.0319	0.0049	0.0069	0.0248	0.0077	0.0714	0.1147	0.3260	1st

D. Multi-person Decision

Multi-person decision is the process of making a judgment based upon the opinion of different individuals. The group members have their own attitudes and motivations, recognize the existence of a common problem, and attempt to reach a collective decision. Moving from a single decision maker to a multiple decision-maker setting introduces a great deal of complexity into the analysis. The group decision making concept can be applied to MADM (Multi Attribute Decision Making) techniques [11].

In this system, the method of calculating the group utility (group composite performance score) of alternative A_i (for i=1,2,…,N) is as follows: For each attribute B_j (for j=1,2,…,M) the individual weights of importance of the attributes are aggregated [12] into the group weights w_j (for j=1.2,…,M):

$$w_j = \frac{\sum_{k=1}^{n} 1_{g(k)} w_j}{\sum_{k=1}^{n} 1_{g(k)}} \qquad j=1, 2,\ldots,M \qquad (9)$$

The group qualification Q_{ij} of the alternative A_i against the attribute B_j is:

$$Q_{ij} = \frac{\sum_{k=1}^{n} 1_{g(k)} m_{ij}}{\sum_{k=1}^{n} 1_{g(k)}} \qquad j=1,2,\ldots,M;\ i=1,2,\ldots,N \qquad (10)$$

The group utility P_i of alternative Ai is determined as the weighted algebraic mean of the aggregated qualification values with the aggregated weights.

$$P_i = \frac{\sum_{j=1}^{M} w_j Q_{ij}}{\sum_{j=1}^{M} w_j} \qquad i=1,2,\ldots,N \qquad (11)$$

The best alternative of group decision is the one associated with the highest value of P_i. TABLE II presents the judgment analysis based on three decision makers' aggregation in an equal value among them. This is the condition before conduct negotiation

IV. AGREEMENT OPTIONS AND COALITION FORMATION

Kraus [13] gives a comprehensive previous literature review on coalition formation, afterwards Wanyama [14] on his study of multi criteria group-choice involving multi agent system applied a coalition formation based on a game theory model of n-person general sum game with complete information that involves forming coalitions among sub group members. Creating coalitions is an important way for agents to cooperate [15], [16]. Game theory techniques for coalition formation can be applied to this problem. Work in game theory describes which coalition will form in n-person games under different settings and how the players will distribute the benefits of the cooperation among themselves. However, the game-theory solutions to the coalition formation problem do not take into consideration the constraint of a multi agent environment, such as communication cost and limited computation time, and they do not present algorithms for coalition formation.

Negotiation support is the interactive communication to facilitate a distributed search process. It can be used to effectively coordinate the behavior of agents in multi agent system [17]. Kraus [13] wrote that two approaches use to the development of theorems relating to the negotiation process. The first is informal theory, which attempt 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.

Formation of coalition [18] for executing tasks is useful both in multi agent system (MAS) and distributed problem solving (DPS) environments. It is common for the stakeholders to form coalition during negotiation in order to increase their individual welfare. Game theory techniques for coalition formation have been applied. Work in game theory describes which coalition will form in n-person games under different setting and how the players will distribute the benefits of the cooperation among themselves. Instead of the strategic approach that uses equilibrium analysis, coalition formation is often studied in a more abstract setting called a characteristic function game.

A. Distributed Rational Decision Making

In this system, negotiation consists in an exchange of proposals between agents. The agent *i* propose its alternative to agent *j*. This alternative should be the most preferred alternative for agent *j* (with the highest priorities with respect to the goal) to be immediately accepted. If not, agent *j* tries to change the preference order of alternatives by adjusting judgments in pair wise comparison matrixes. If the proposal is not accepted, it will send a counter-proposal. The negotiation will be stopped, when an alternative is approved unanimously.

Three decision makers are involved and gave their own preference. Fig. 3 illustrates the system architecture negotiation between designer, programmer and construction manager, adapted from Morge and Beaune [19]. Here, SH1 is agent for designer domain, SH2 is agent for programmer domain and SH3 is agent for construction manager domain. In the system, there is one coordination agent. Decision makers present different side of preference. Nevertheless the protocol of negotiation in this group decision was developed as a cooperative environment.

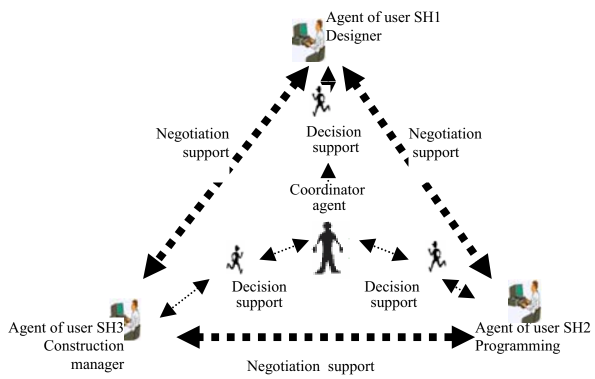

Fig.3 System architecture negotiation
(Adapted from Morge and Beaune [19])

B. Determination of Agreement Options

As the negotiation progress, the agent user preferences of the evaluation criteria change, leading to changing score of the roof system alternative, and changing membership and size of the set of agreement options. Three stages are conducted to determine agreement options that are;

1) Determine the weighting factor (weight of preferences) of criteria for each decision-maker. Fig.4 and 5 reveals different preferences between decision-maker. In contrast to programmer who put the material cost, designer put satisfying decor as the most preference, meanwhile construction manager put minimize error. The difference presents rationality among decision maker.

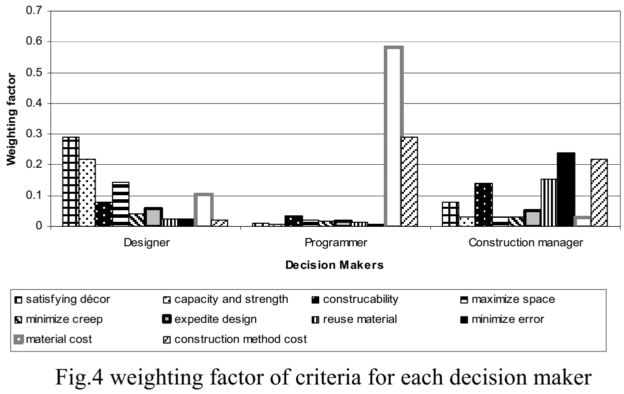

Fig.4 weighting factor of criteria for each decision maker

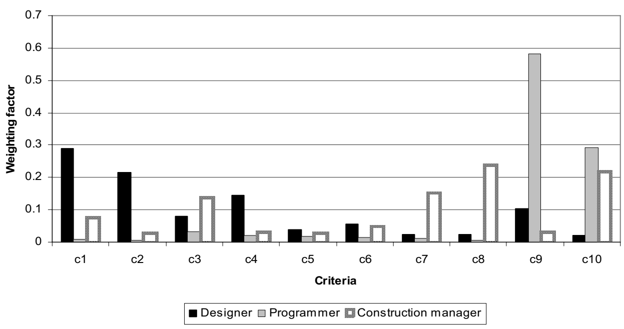

Fig.5 weighting factor of decision maker on each criteria

2) Grade of alternative for each evaluation criteria. Fig.6 presents that a2 is the 'best fit' for c2, c5, c6, and c8. The 'best fit' solution for c1 is a1; a3 is best fit for criteria c9 that is material cost; meanwhile a4 is the 'best fit' for c3, c4, c7 and c10.

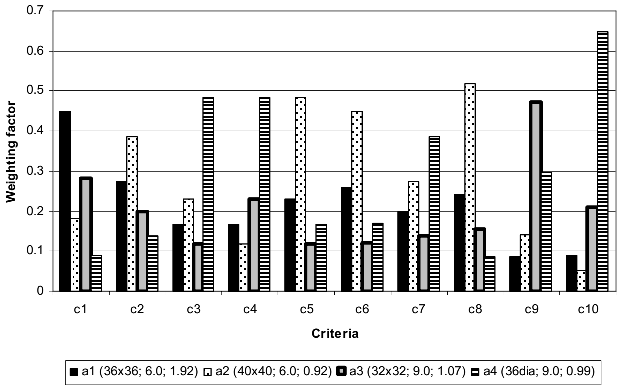

Fig.6 weighting factor of alternative for each criteria

3) Score of every alternative for every stakeholder. Fig.7 shows that stakeholders have different best option as a solution alternative. Before a coalition, designer chooses 36x36 columns as the best solution, meanwhile programmer and construction manager choose a cylinder column.

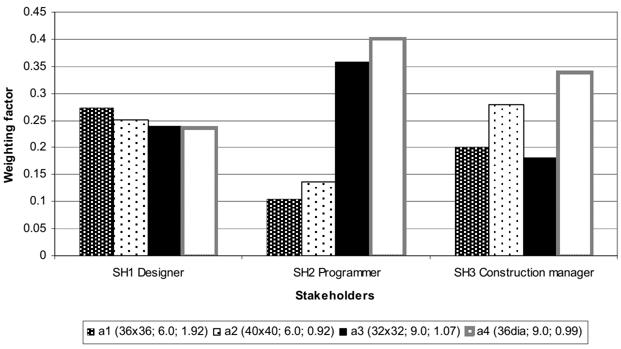

Fig.7 weighting factor of alternative for each decision maker

C. Analysis of Agreement Options and Coalition

Coalition formation in characteristic function game includes three activities:

1. Coalition structure generation:
   Agents within each coalition coordinate their activities, precisely this means partitioning the set of agents into exhaustive and disjoint coalition. This partition is called a coalition structure (CS). This game with three agents, there are seven possible coalitions: {1}. {2}. {3}. {1,2}, {2,3}, {3,1}, {1,2,3} and five possible coalition structure: {{1}.{2},{3}}, {{1},{2,3}}, {{2},{1,3}}, {{3},{1,2}}, {{1,2,3}}.
2. Solving the optimization problem of each coalition.
   This means pooling the tasks and resources of the agents in the coalition, and solving this joint problem. The coalition's objective is to maximize value. Under unlimited and costless computation, each coalition would solve its optimization problem, which would define the value of that coalition.
3. Dividing payoff/the value of the generated solution among agents in a fair and stable way so that the agents are motivated to stay with the coalition structure rather than move out it. Several ways of dividing payoffs have been proposed in the literature [13], [18].

By adapted model of coalition formation from Wanyama [14] and Wanyama and Far [20], on this paper, coalition formation model works in the context of multi-criteria group decision making. Agents select the solutions with the highest score as the offers to their negotiation opponents. At the end of every negotiation round, each agent 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. The proposed coalition formation model enables each agent to select individually its allies or coalition. All decision makers share the same goal but each of them has its own set of activities, alternatives (ai) or criteria (Ci). Wanyama and Far [21] wrote that sets of activities could move, expand and, retract during negotiation. Table III shows the alternative ranking from possibility of coalition between stakeholders.

TABLE III
WEIGHTING FACTOR OF EACH ALTERNATIVE TO EACH STAKEHOLDER

Alternative ranking and coalition	Priorities			
	a1	a2	a3	a4
SH 1 (Property manager)	1st	2nd	3rd	4th
SH 2 (Project Manager)	4th	3rd	2nd	1st
SH 3 (Designer)	3rd	2nd	4th	1st
Coalition SH1 and SH2	4th	3rd	2nd	1st
Coalition SH1 and SH3	3rd	1st	2nd	4th
Coalition SH2 and SH3	2nd	3rd	4th	1st
Grand coalition SH1,2,3	4th	3rd	2nd	1st

V. CONCLUSION

The result of the implementation demonstrates a process to select priorities of each alternative solution based on agreement options and coalition formation among decision makers in a multi-person decision and negotiation environment. Each person needs to identify the goals that can be optimized, and those that can be compromised in order to reach agreement with other decision makers.

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