Collaborative Decision Model on Stockpile Material of a Traditional Market Infrastructure using Value-Based HBU

C Utomo¹, Y Rahmawati², D L Pararta¹ and A Ariesta¹
¹Department of Civil Engineering, Institut Teknologi Sepuluh Nopember, Indonesia
²Department of Civil and Environmental Engineering, Universiti Teknologi PETRONAS, Malaysia

E-mail: christiono@ce.its.ac.id; yani.rahmawati@utp.edu.my

Abstract. Readiness of infrastructure establishment is needed in the early phase of real estate development. To meet the needs of retail property in the form of traditional markets, the Government prepares to build a new 1300 units. Traditional market development requires infrastructure development. One of it is the preparation of sand material embankment as much as ± 200,000 m³. With a distance of 30 km, sand material can be delivered to the project site by dump trucks that can only be operated by 2 trip per day. The material is managed by using stockpile method. Decision of stockpile location requires multi person and multi criteria in a collaborative environment. The highest and the best use (HBU) criteria was used to construct a value-based decision hierarchy. Decision makers from five stakeholders analyzed the best of three locations by giving their own preference of development cost and HBU function. Analytical Hierarchy Process (AHP) based on satisfying options and cooperative game was applied for agreement options and coalition formation on collaborative decision. The result indicates that not all solutions become a possible location for the stockpile material. It shows the ‘best fit’ options process for all decision makers.

1. Introduction

Mechanical land removal is used by companies to implement business strategies that are preceded by the readiness of infrastructure in the development of traditional market, one of that is the preparation of material of sandstone of ± 200,000 m³. The sandstone can be transported by fleet of dump truck with capacity of 5-7 m³ from the origin to project location. With a distance of 30 km, the fleet of dump trucks can only be operated by two trips (count unit for delivering material using truck) per day. With the assumption that 25 units of dump truck fleets are needed to transport 200,000 m³ sandstones to the project location, it can be calculated that the material delivery takes 571 days. Related with this condition, it will be necessary to select and determine the location of stockpile. The choice of stockpile location depends on the characteristics of each field condition. The implementation of construction project is appeared to be always encountering with time and cost constraints. These constraints are able to cause delay in the project, so that the time required in completing the project will be able to exceed the employment contract. In this research, there are three alternatives of places as the location of the stockpile, these alternatives have different characteristics. Generally, location selection is determined by several factors such as local input, local demand, transferred input, and external
demand [1]. Industrial site selection is based on the principle of cost minimization. Weber [2] stated that the location of each industry depends on the total cost of transportation and labour where the sum of both must be low. The minimum cost of transportation and labour is identical to the maximum profit level. In the concept of the highest and the best use (HBU), the factors are grouped in two criteria which are cost of development and function. This is in accordance with the definition of location that can be interpreted as the science of geographical allocation of scarce resources, and the relationship or influence on the location of various businesses or other activities. Based on the previous problem formulation, this research purposes to choose the best stockpile location that will be used in the project development of traditional market in East Java.

2. Conceptual

2.1. Collaborative Decision
Collaborative design is essential in the design process of project development. Decision for best option for sustainable design should apply this approach [3, 4, and 5]. Collaborative design is an effort to integrate various participants to obtain the best design by concerning the best shared-goal that is suitable with all requirements from the participants [6]. Integration of tangible and intangible aspects is important for collaborative design. There are two main aspects that are needed to be integrated, which are tangible and intangible aspects [7]. During the design process, each expertise is encouraged to share their knowledge. The knowledge is included the intangible aspect, where it is also classified into tacit and explicit knowledge [8], meanwhile the tangible aspect consists of design drawings, and the results of design developments. The two aspects are needed to be integrated in order to achieve successful collaboration. The involvement of various participants makes it difficult to be realized, in which it is not only based on their different backgrounds, but also their different availabilities in conducting the design meetings. Previous studies developed systems and tools to support the design collaboration, especially the virtual design [9, 10, and 11]. Based from review conducted by [7], it is found that decision making and negotiation are two vital activities in supporting the collaboration as well as the integration, especially in finding the best design option for the sustainability. The importance of it also can be found in the previous studies, in which the advance researches or applications of collaboration in decision making and negotiation can also be found [12, 13, and 14].

2.2. Value-based
Value-based design decision is a structural and analytical process that seeks to achieve value by identifying all necessary functions at the lowest cost, while maintaining with the required levels of quality and performance [15]. The decision has been widely adopted in many countries over several decades as a very effective tool to meet the increasing demands for value. Kirk, et al. [16] described value based on approach as new approach and methodology that involves the use of a multidisciplinary team. In the natural characteristic of construction, it means that a tool for decision team is necessary. Cooperation is the nature in team work [17]. Decision analysis techniques can be applied to determine the relative value of the alternative solutions for performing function. Many studies in value-based decision apply multi criteria decision making [12] such as in assessment of exterior building wall, in material design of concrete and in a modification of value engineering in petrochemical industry.

2.3. The Highest and the Best Used
The definition of the highest and the best use is a concept of appraisal that can be applied to land or buildings that is usually interpreted as land use [18]. It will maximize the wealth of the owner through the use of the most profitable land. The highest and the best use can also be defined as a possible legal and logical use of land, which allows physically, reasonably, and financially permitting to provide the highest value. To determine the highest and the best use in a plot of vacant land, some testing steps must be performed, the testing process involves four criteria with each requirement that must meet:
legally permissible, physically possible, financially feasible, and maximally productive [19]. Selection process based on these criteria is often done in sequence. The first and second criteria test must be done before the next criteria. This is because it is possible that the use of the financial aspect may be allowed but from legal aspect and physical aspect is impossible. By using this method, the value of the land can be known if the value of the building is also known with certainty because the building is relatively new. The value of the building multiplied by the capitalization rate of the building (the interest rate plus the rate of return on the building) obtained the net income of the building. Net income of property minus net income of buildings acquired net income from land. It is capitalized at the interest rate on the value of the land

2.4. Stockpile
Stockpile management serves as a buffer between delivery and process as a strategic stock against the short-term or long-term disturbances. Stockpile also serves as a process of homogenizing and/or mixing sandstone to prepare the required qualities. Homogenization aims to prepare the product of one type of material where fluctuations in sandstone quality and size distribution are equated. The process of homogenization is done through mixing techniques. According to [20], stockpile management is very important part in the process of handling sandstone either from the side of mining until it is received and used by the user. Generally, the mining industry of sandstone and sandstone users utilize stockpile in its industrial facilities. This becomes part of securing the supply of both quantity and quality of use of sandstone. Stockpiles may account for half of the total land base. In the dense urban areas, stockpile placement requires careful consideration. Handling and storage is a large cost element, therefore, there should be a plan for each project that shows how and where the materials and products will be handled and stored. A storage plan will help to ensure the quality control of the product. When stock is placed between extraction, processing and loading facilities, it will minimize hauling distance, saving time, fuel, and machine maintenance.

3. Method

3.1. Function Analysis of the Highest and the Best Use
Function analysis is a technique that oriented to the required functions on each item or system reviewed to produce the desired product value. The analysis is used to describe the main function of the product, it also describes the classification of the primary functions and the secondary functions to obtain a comparison between cost and worth required. For some functions it may be decided that a set of generic process is needed to perform the function, each of that will increase the associated set of possible specific processes. Based on the process of function analysis system technique (FAST) [21], there are four HBU functions that are legally, physically, financially, and productively maximum. A number of processes identified as being probable alternatives for performing the function

3.2. Life Cycle Cost of Development
Life cycle cost (LCC) is a technique to evaluate the economic value of stockpile location by calculating all relevant costs during the investment period through adjustment to time value of money. The LCC application method involves a combination of managerial, financial and technical expertise in all phases of life-cycle. The main purpose of this LCC is to evaluate alternative solutions to specific design problems. LCC in this paper refers to the development process [22] of a property building. The process follows the development stages in the form of inception, design, formal negotiation, construction, and property management. LCC as development cost consist of capital expenditure, energy cost, operation and maintenance (O&M) cost, and replacement cost. In the collaborative decision, perspective of LCC is different among stakeholders.
3.3. Decision for Material Location
This section deals with the definition of the criteria for evaluating a location of stockpile. In this paper, the criteria are taken from the basic theory of function and cost. The functions will make the technical solutions worth considered and proceed to become attributes of the decision. The determinants of the stockpile location shown are the result of literature studies, previous researches, and discussions with expert taken from practitioners. To obtain a good representation of a problem, it has to be structured into different components called activities. Figure 1 shows three levels of decision hierarchy. The goal of the problem (G = “Select the best value of stockpile location material of a traditional market infrastructure”) is addressed by three alternatives (A = a1; a2; a3). Two evaluation criteria are used to select the best stockpile location. Then, implementation of analytical hierarchy process (AHP) [23] can be started with compilation of the hierarchy model.

![Decision hierarchy for stockpile location](image)

**Figure 1.** Decision hierarchy for stockpile location.

4. Result and Discussion

4.1. Value-based Decision
The technical solution options were categorized into ‘Cost’ that was identified by development cost; and ‘Function’ by the highest and the best use functions. Table 1 shows the selected ability (Ps) and rejected ability (Pr) of a satisficing option [24] that represents function and cost of technical solution for stockpile location respectively. The value of each alternative is calculated based on the value equation that is function/cost. The greater the number the greater the value. The best alternative is alternatives with the highest value. The table presents the difference of best option among stakeholder. The choice of government is different from the choice of tenant. This can be understood because of differences of interest. There are two judgments involved in this decision - the first is criteria judgment for each decision makers and the second, technical solution judgment for each criterion. The process of weighting factor is presented in Table 1.

4.2. Agreement Options and Coalition
The framework of collaborative decision is developed based on agreement option and coalition. It is applied for selection of stockpile location on traditional market. Five stakeholders (Figure 2) were involved to give their own preference. Once every stakeholder is aware of the options, they analyze to determine what they will get, gain or loss if each alternative is selected. This agreement options process provided additional functionality to negotiate a joint representation of the problem. Stakeholder of multi-criteria decision making problems usually evaluates the alternative solution from...
different perspective, making it possible to have a dominant solution among the alternatives. Only promising solution were available to stakeholders for detailed collaboration. Collaboration has coalition formation algorithms. This research employs multiple coalition formation algorithms. The stakeholders are the parties in the stock pile location selection. There are three stages to determine the collaborative decision. The first stage came from individual decision. The results from this first stage are used to determine the agreement options in the last two stages. The stages are:

1. Determining and scoring of every alternative for every stakeholder. Stakeholders had different best option as an alternative solution.
2. Determining the optimal solution (payoff optimum) for each stakeholder in a coalition is based on cooperative multi-person games [25]. A linear programming formula is used to determine the Pareto optimal for each stakeholder in each coalition.
3. Stage three analyzes the best fit options for every coalition and grand coalition. The result is presented on Table 3. The result shows that all solutions became a possible location for the stockpile material. B location (a2) is the best choice of stockpile location for the group. Observed on a3, the result is interesting. Even though this solution has no first priority by any decision maker, this solution is chosen by many coalitions as the best fit option. The best means that the option is the most selected in all individual and also all coalition.

| Table 1. Value of alternatives by each stakeholder. |
|-----------------------------------------------|
| **SH1: Equipment manager**                      |
| Alternatives of material location | Ps (Function) | Pr (Cost) | Value = Function/Cost |
| (a1) Location A   | 0.612698     | 0.309324  | 1.980769            |
| (a2) Location B   | 0.117989     | 0.450973  | 0.261633            |
| (a3) Location C   | 0.269312     | 0.239703  | 1.123524            |
| **SH2: Operational manager**                    |
| Alternatives of material location | Ps (Function) | Pr (Cost) | Value = Function/Cost |
| (a1) Location A   | 0.137288     | 0.093241  | 1.472393            |
| (a2) Location B   | 0.239488     | 0.494470  | 0.484332            |
| (a3) Location C   | 0.623225     | 0.412289  | 1.511622            |
| **SH3: Finance manager**                        |
| Alternatives of material location | Ps (Function) | Pr (Cost) | Value = Function/Cost |
| (a1) Location A   | 0.093382     | 0.093241  | 1.001514            |
| (a2) Location B   | 0.685294     | 0.494470  | 1.385916            |
| (a3) Location C   | 0.221324     | 0.412289  | 0.536817            |
| **SH4: Project manager**                        |
| Alternatives of material location | Ps (Function) | Pr (Cost) | Value = Function/Cost |
| (a1) Location A   | 0.127949     | 0.093241  | 1.372233            |
| (a2) Location B   | 0.784870     | 0.494470  | 1.587296            |
| (a3) Location C   | 0.087181     | 0.412289  | 0.211456            |
| **SH5: Project director**                       |
| Alternatives of material location | Ps (Function) | Pr (Cost) | Value = Function/Cost |
| (a1) Location A   | 0.583152     | 0.109964  | 5.303130            |
| Location | Value 1 | Value 2 | Value 3 |
|----------|---------|---------|---------|
| B        | 0.109964| 0.583152| 0.188568|
| C        | 0.206884| 0.486232| 0.425484|

**Figure 2.** System architecture collaboration.

**Figure 3.** Value of alternatives for each stakeholder.
Table 2. Ranking of stockpile location solution for each coalition.

| Coalition | Alternatives of stockpile location |
|-----------|------------------------------------|
| 1         | a1 a2 a3                           |
| 2 SH 1    | 1st 2nd 3rd                        |
| 3 SH 2    | 2nd 1st 3rd                        |
| 4 SH 3    | 2nd 1st 3rd                        |
| 5 SH 4    | 3rd 1st 2nd                        |
| 6 SH 5    | 1st 3rd 2nd                        |
| 7 Coalition SH1, SH2, SH3, SH4 | 3rd 2nd 1st |
| 8 Coalition SH1, SH2, SH3, SH5 | 3rd 1st 2nd |
| 9 Coalition SH1, SH2, SH4, SH5 | 1st 2nd 3rd |
| 10 Coalition SH1, SH3, SH4, SH5 | 3rd 1st 2nd |
| 11 Coalition SH2, SH3, SH4, SH5 | 3rd 2nd 1st |
| 12 Grand Coalition SH1, SH2, SH3, SH4, SH5 | 3rd 1st 2nd |
| RESULT    | 2nd 1st 3rd                        |

5. Conclusion
The paper deals with a technique during selection of a stockpile location alternative for infrastructure of traditional market. The process was conducted by identifying the agreement options among stakeholders. Value of the best fit option was formed by the comparison between the highest and the best used function and its development cost. Advanced research is needed, primarily in the study of automation on collaborative 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 automated design and automated decision.

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