Modeling a Mining Transportation System using Integrated Methods: A Case Study of PT Vale Indonesia Tbk

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Abstract

Development of an efficient mining transportation system using a combination of AHP and QDF methods as well as QDF and SWOT ones has been widely exercised. However, these three methods have not been interactively applied. Therefore, the present study aimed to determine the mode of mining transportation system using fuzzy AHP, QDF, and SWOT methods in an integrated and sequential manner. To this end, data sources were obtained from in-depth interviews with eight consumer representative respondents, five respondents from PT Vale Indonesia Tbk as a mining company, and three respondents from the Transportation Department in Luwu Timur District in Indonesia. Data analysis began with weighting and determining the hierarchy of product value criteria (i.e. fuzzy AHP), then defining the house of quality of these criteria via QDF, and finally establishing the strategy to achieve the results through SWOT. Ultimately, by land mode was recommended through widening roads and road bends as well as making separate roads and road alignments on Malili-Sorowako Public Road. The strategy that PT Vale Indonesia Tbk can take is to carry out the operation in a one work package, to plan for optimal placement of roadblocks and cat eyes, and to arrange for licensing in an integrated manner.

Keywords: Resource-based Theory; Transportation System; AHP; QFD; SWOT

Introduction

To develop a good transportation system, a large mining company needs planning. All activities; from exploration, development, and exploitation to distribution will thus need transportation facilities from various modes; i.e. by land, sea, and air, to streamline transportation costs as the main goal [1].

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Transportation systems in mining companies in Indonesia are relatively inefficient. The given inefficiency has been induced by various problems such as use of shared roads between communities and mining companies as well as occurrence of cases of blocking public roads by local communities due to road damage caused by road use by mining companies. This transportation system inefficiency can be also seen in PT Vale Indonesia Tbk whose products and raw materials must pass by land which reaches 559 km in length between Makassar and Sorowako with a large fleet moving together with public transportation.

Road quality in some segments is also substandard, causing vehicles move more carefully. Meanwhile, river lane has been also encountered by the problem of narrow, shallow, and winding paths. The only river path that becomes a support is the special Balan tang Port which is on the banks of the Malili River which must be traveled through the winding groove, and has a bend to 180 up degrees. Moreover, vehicle-transporting quarry materials are prohibited across the highway in the public interest, so that commanded make her own way to transport logistics, and these vehicles are required to use non-subsidized fuel. For this reason, determination of a right and strategic transportation system as well as selection of modes with regard to the number of criteria such as company interests, geological conditions, environment, and interests of local communities and the government is of importance for PT Vale Indonesia Tbk, the community, and the government.

However, the main problem is the method used to determine the mode of transportation systems that are appropriate, strategic, and efficient based on the given criteria. To get to the bottom of this problem, researchers aimed to use AHP, QFD, and SWOT methods in an integrative manner.

Literature review

Resource-Based Theory (RBT) and transportation systems

The theory of competitive advantage based on natural resources or RBT emphasizes that company's resources and capabilities are diverse and difficult to copy [2], [3]. Resources are also things that can be considered as a strength or weakness of a company [4]; among them, transportation system [5]. Meanwhile, capability is the ability to do a set of tasks in a coordinated manner using company resources [6]. Accordingly, a transportation system that does not fit operations in a company can lead to loss of opportunities to gain advantages of products or particular results, such as advantages in speed and price. Transportation systems that are not suitable for operations in a company can also give rise to difficult access to mine sites, delays and costs due to damage to vehicles or roads, leakage of raw materials or products carried, as well as vehicle maintenance costs.

AHP, QFD, and SWOT methods

AHP, QFD, and SWOT methods are strategic planning tools that can be utilized to improve a transportation system in a company [7]. In this respect, fuzzy AHP method can be employed in transportation systems. For example, Hus and Nian [7] used an interactive fuzzy assistance system to evaluate the operation of public transportation system. Rossetti and Selandari [8] also utilized AHP method to sort alternative transportation systems that can be implemented to determine hospital delivery systems and found that robotic-based transportation systems could have an end result better than manual ones.

Moreover, QFD method can be exercised in transportation systems. Metri [9], for example, suggested the use of QFD method to develop total quality transportation (TQT), since this method could consider cross-communication and encourage brainstorming by members in transportation organizations or fields to manage transportation problems. Besides, SWOT method can be applied to transportation systems as a consideration to formulate a strategy at a higher level. In this regard;Koo et al. [10], employed various parameters including transportation system, to develop strategies for the Government of the Macau. Meanwhile, Barella [11] used SWOT method to plan a sustainable transportation system with the final results in the form of an evaluation framework as well as a framework for implementation of the strategy for transportation services.

Methodology

Definitions and assumptions

AHP or Analytical Hierarchy Process is a decision weighting measurement that uses hierarchical construction, priority analysis, and consistency verification [12]. QFD or Quality Function Deployment refers to a structured procedure to translate perceptions of consumer needs into characteristics and appearance of specific products or services, and then into processes and operational characteristics [13]. SWOT or Strength, Weakness, Opportunity, Threat stands for a strategy instrument that reviews internal and external environment of accompany to formulate a strategy by highlighting internal strengths, weaknesses, opportunities, and threats from a company's external environment.

Assumptions and Procedures

a. Fuzzy AHP, QFD, and SWOT methods can be used to plan for development of a strategic transportation system in mining companies.
b. Qualitative data from fuzzy AHP can be utilized to determine the weight of criteria in QFD method.
c. Results of QFD method can be employed to formulate a strategy using the SWOT method.

Sample design and research instruments

The study was conducted sequentially using qualitative data collected at the beginning, followed by quantitative data, and then continued with qualitative data. Data sources were derived from in-depth interviews with eight consumer representatives, consisting of five people from the mining company and three individuals from the Transportation Department in Luwu Timur District. All respondents were selected based on their levels of competence and occupations related to transportation system. The eight respondents were also involved in three stages of data collection, i.e. data collection criteria, weighting, and comparison of products or desired results. The order of data collection and validation was in line with the following stages:

One. Interview/discussion of product criteria with consumer representatives. Interviews were conducted to obtain opinions about value of products they wanted from transportation network needed by PT Vale Indonesia Tbk. The results of the interviews were then transcribed and codified.

Two. Analysis of interview results and preparation of weighting questionnaires. Important values desired by consumers were codified. Criteria were also prepared and the given choices were established based on fuzzy AHP method. The choices were comprised of" equally important, quite important, quite important, very important, and much more important" options representing fuzzy numbers of1, 3, 5, 7, and 9; respectively.

Three. Submission of a questionnaire regarding product weighting to consumer respondents. Consumer stuffing was then analyzed using AHP method to obtain weights to each criterion.

Four. Submission of product comparison questionnaires to consumer respondents. Respondents filled out a product comparison questionnaire whose content was in the form of product quality from the company on each criterion mentioned in the weighting questionnaire. The results of this questionnaire were used to fill in the right column of the house of quality (HOQ) which will together lead to results of the weighting.

Five. Interviews and group discussions for technical specifications relevant to existing criteria. Then, the correlation between technical and functional specifications was determined. The result was a weight for each technical specification in HOQ.

Next, SWOT analysis. In the SWOT stage, interviews/discussions were conducted with managers or leaders to reassess which of the two alternatives were the most strategic values by referring to strengths, weaknesses, opportunities, and threats of the company. The discussion would choose the type of mode based on the weight of the technical specifications. The chosen mode would be also prioritized to be developed to meet consumer criteria.

Data analysis techniques

AHP method

AHP method is used for determining priorities and choices based on weight through three stages; namely, hierarchical construction, priority analysis, and consistency verification. In the hierarchy construction stage, data is collected and then classified according to the criteria in a list. Next, pairwise comparisons are made for all criteria at one level of the hierarchy. The assessment matrix is subsequently defined based on reverse comparison. The basic scale for assessment is 1 for equal, 3 for medium, 5 for strong, 7 for very strong, and 9 for very strong importance. Consistency index (CI) is also used in the consistency verification phase which is formulated as:

$$CI = \frac{h_{mas-n}}{n-1} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

The next CI value is divided by the random index (RI) which is a standard index that depends on the number of criteria(n). The results obtained are CR consistency ratios. The results of the AHP method are concluded to be consistent if the CR value is below 0.10.

QFD method

The application of QFD method consists of six stages. First, voice of customer (VOC) is assessed, followed by evaluating competitiveness of consumers as the second stage. Third, quality characteristics are determined. Fourth, co-relationships are defined. Fifth, the process continues to evaluate strength of relationship between VOC and technical requirements. And finally, as the six stage; technical competitiveness is assessed, as shown in figure 1.

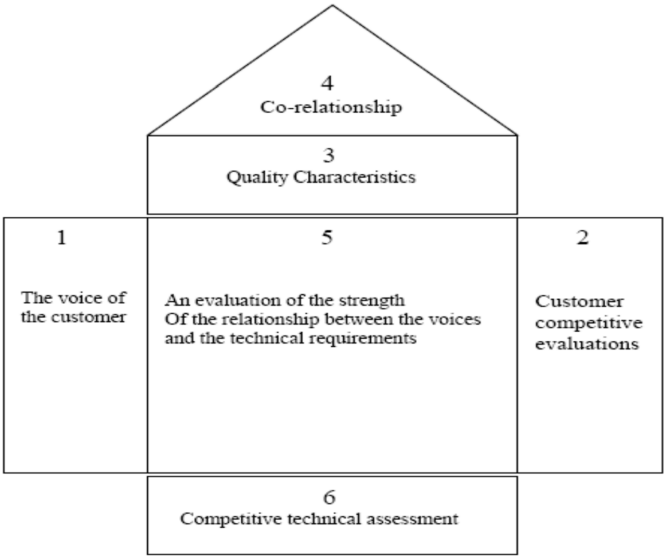

Figure 1. QFD Matrix [14]

SWOT method

In SWOT method, Strength refers to the strength of an organization from the point of view of consumers, both internal and external. It was also identified from QFD method by looking at three things [15]; namely,(a) unique or distinct advantages that make organizations excel in competitiveness, (b) reason that makes consumers choose companies rather than competitors, and (c) core expertise on product characteristics that competitors cannot compete with. Weakness is also considered as the opposite of Strength. In this respect, weaknesses can be deepened by observing the following issues; i.e. operations or procedures that must be streamlined, awareness and knowledge of the field to be avoided, and aspects and reasons why competitors are better [15]. Besides, Opportunity is related to how companies can continue to grow and develop in the future such as seeing and looking for opportunities in the market as well as observing trends that can appear in the market [15].Threats are also regarded as the opposite of opportunity. The thing to note is the existence of alternative technologies, changes in consumer demands, and variances in competitive strategies that can put pressure on organizations. The results of SWOT matrix can consequently produce four combinations; namely, maxi-maxi, maxi-mini; mini-maxi, and mini-mini [15].

Result and Discussions

Description of the Case and VOC Identification

The case study in this study was PT Vale Indonesia Tbk, as a nickel mining company, located at a distance of 559 km road from the city of Makassar, capital of South Sulawesi Province. There was also an alternative route from Makassar to Malili by passing through the central mountains of the South Sulawesi Peninsula and turning, so it was inefficient and high risk. The Malili route to Sorowako also passed public roads and through a special 36 km road. The special Malili-Sorowako Public Road was not only used by PT Vale Indonesia Tbk and the surrounding residents, but also accessed the public bus fleet to and from Sorowako. There were also potentials for landslides on this road. There was also Balantang Port for river transportation.

VOC identification

Based on the results of the interviews and FGD above, there were 15 criteria of interest to consumers, in this case for the transportation system of PT Vale Indonesia Tbk; namely (1) loose or quiet roads, (2) hard roads, (3) roads that are not easily damaged/perforated, (4) roads with clear traffic signs, (5) paths with clear borders and cat eyes, (6) roads without potential landslides, (7) houses, stalls, and trees far from the road, (8) no cable above the road, (9) no citizen livestock crossing, (10) deep river, (11) a lonely road, (12) wide river, (13) sea port replacing Balantang, (14) a special route to replace Malili-Sorowako Public Road, and (15) fast licensing system for road and river renovation.

Fuzzy AHP method

Based on the results of the eigenvalues and the consistency test, the CI value was calculated and then divided by random index (RI) which was 1.5838 for 15 criteria, according to recommendations by Zadeh [16]. The results also produced a consistency ratio (CR). If CR<0.10, it was considered consistent, according to the equation by Zadeh [16]. The results of the calculation of the CR value were 0.095 and 0.091. Both of these values were<0.100, so it was called a consistent matrix. Then, fuzzy synthetic extent was determined to calculate the probability level of each criterion relative to other criteria. After that, they were weighted by means of fuzzy AHP method, then ranked, and served as a reference for subsequent analyses. A summary of criteria based on weight and ranking is presented in table 1 below.

Table 1. A summary of Criteria Based on Weight and Ranking

Criteria	Weight	Ranking	Meaning
C1	0.22	1	Loose or quiet roads
C2	0.17	2	Hard roads
C3	0.07	7	Roads that are not easily damaged/perforated
C4	0.06	8	Roads with clear traffic signs
C5	0.11	5	Paths with clear borders and cat eyes
C6	0	0	Roads without potential landslides
C7	0.15	3	Houses, stalls, and trees far from the road
C8	0.10	6	No cable above the road
C9	0	0	No citizen livestock crossing
C10	0	0	Deep river
C11	0.12	4	Loose river
C12	0	0	Wide river
C13	0	0	Replacement of sea port
C14	0	0	Special roads as a substitute
C15	0	0	Fast licensing

QFD Method

Rating competition

Since PT Vale Indonesia Tbk had relatively no competitors in nickel business in Indonesia, competition rating was defined as initial situation and objective situation of a criterion. Respondents also rated scores from 1-5 regarding the initial situation of the relevant criteria. The results of the competition rating are presented in table 2 below.

Table 2. Rating Objectives of Criteria [17]

Criteria	Weight	Initial situation	Objective situation	Improvement ratio	Important ranking
Loose or quiet roads	0.22	2	5	2.50	0.55
Hard roads	0.17	4	5	1.25	0.21
Roads that are not easily damaged/perforated	0.07	5	5	1.00	0.07
Roads with clear traffic signs	0.06	4	5	1.25	0.08
Paths with clear borders and cat eyes	0.11	3	5	1.67	0.18
Houses, stalls, and trees far from roads	0.15	3	5	1.67	0.25
No cable above the road	0.10	4	5	1.25	0.13
Deep river	0.12	2	5	2.50	0.30

**The data is processed.*

The results of the assessment indicated that loose or quiet roads were still included in the criteria with the highest rating because the initial situation currently in the field was still 40% of the ideal one. A similar situation was also faced on the road through the river, so that ranking up from the low position into the second position. Despite having a high weight at AHP method, the assessment of the hard road gave a low value because the initial situation was moderate (60%

Technical Requirements

Technical requirements were only on criteria that have weights. Accordingly, there were eight criteria; namely, (1) the road is lonely and quiet, (2) the road is solid and hard, (3) the road that is not easily damaged/perforated; (4) the road with clear traffic signs; (5) the road with borders and cat eyes; (6) houses, stalls, and trees far from the road; (7) no cables above the road; (8) and the lonely river. Furthermore, the average weight of the alternative road (0.126) was higher than that of water alternatives, only represented by a single criterion; namely, the river that swings (0.120).

House of quality

Overall, HOQ revealed that eight main criteria were needed by consumers from transportation system of PT Vale Indonesia Tbk. The three criteria with the highest weights were loose roads, hard roads, and houses, stalls, and trees far from the road. If the initial situation was considered in these three criteria, the loose road was the criterion with the highest importance, followed by the lonely river and houses, stalls, and trees far from the road. The summary of the results of the fuzzy AHP- QFD relationship is presented in figure 2 below.

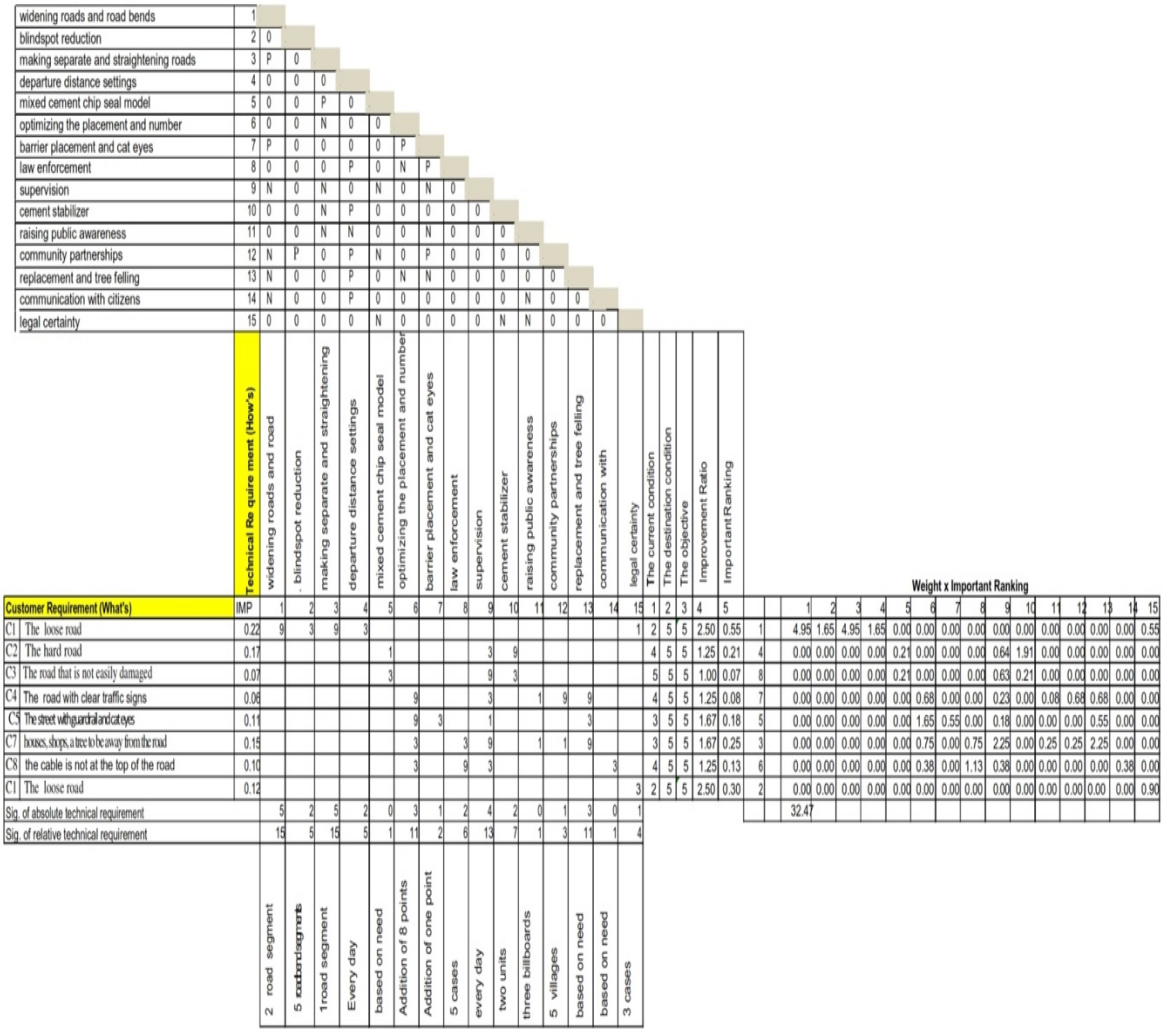

Figure 2. Overall Overview of Fuzzy AHP-QFD [17]

The final results that have regarded consumers' interests and technical criteria of placing widening lines and bends and making roadways and alignments were the most important technical specifications to meet consumer needs. In line with this, the SWOT method was then directed at efforts to assess external and internal situations to formulate a strategy for widening lines and bends and making separate roads and straightening roads on Malili-Sorowako Road.

SWOT Method

After it was concluded that the widening of the road and the bends were the most important technical specifications to meet consumer needs, FGDs were conducted to prepare SWOT method. The main goal of SWOT method was to identify internal and external determinants of the success of efforts to widen roads and bends on Malili-Sorowako Road. The results of the analysis in the form of a SWOT matrix are presented in table 3 below.

Table 3. Results of SWOT Analysis [17]

	Opportunit (O)	Threat (T)
.	-Facilitated creation of separate roads and alignments -Making it easy to place roadblocks and paint eyes -Increased smooth access from Malili to Soroako	- More and more road users from the community - Environmental impacts - Rebound effect - Increased risk of accidents - Disruption of soil stability - Disruption of traffic flow during construction

Strength (S)	Strategy SO	Strategy ST
- Having experience and competence in road management -Having competent contracting partners Financially strong - Studies for widening of several waypoints	- Widening, making separations, and alignment in one work package Planning optimal placement of roadblocks and cat eyes	Placement markers for accident-prone areas or the like Traffic flow management plan during construction - Soil sample collection and land reuse

Weakness (W)	Strategy WO	Strategy WT
. Completion of a slow road project . - Geographical factors of hilly and mountainous roads . - Problem of land acquisition . - Licensing for area ownership	- Complete planning of widening, separating, and straightening - Socialization from the beginning - Integrated licensing	Work during holidays and evenings - Collaboration with community institutions for traffic management - Choosing an optimal road width that makes it difficult to build additional structures

**The data is processed.*

Conclusion

An efficient model of mining transportation system fort PT Vale Indonesia Tbk is by land through widening the road and road bends and making a separate road and straightening the road on Malili-Sorowako Public Road. The strategy that the company can take to expand lanes and bends is widening and making roads as well as making road alignment in one work package,

planning for optimal placement of roadblocks and cat eyes, managing licensing in an integrated manner.

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