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Objective and Subjective Integration in DistributionCenter Location Selection: A Case Study of Battery-electric Motorcycle Sales

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Abstract. Determining the distribution center location is a strategic decision for the company to maximize sales and minimize cost. Location decisions are long-term investment decisions. When the demand for products on the market increases but the distribution unbalanced, it can cause high transportation costs. Therefore, it requires the company to make adjustments, one of them by opening the location facility. Product characteristics in the market determine the location selection. The decision can not resolve by one criterion but many criteria, including subjective and objective measures. By using a case study of the distribution center of a battery-electricmotorcycle, this paper offers a model for determining distribution location by integrating objective and subjective factors using the Brown-Gibson model. The objective factor weight is processed using a transportation model to obtain an alternative site with the lowest transportation cost. Furthermore, the number of unit allocation from the factory to the market achieved. The subjective factor weight processed using the Analytical Hierarchy Process (AHP) through identifications, verification of criteria, and questionnaires. Besides, the sensitivity analysis carried out to determine how much to influence the two factors to have on determining the distribution center location selection. The model results show that compared to the initial location, the proposed model decreased by 29.4%. The results of this study could be very beneficial for electric vehicle companies to determine the strategy and location decision criteria in the future to enhance effectiveness and efficiency in distribution performance.

Keywords: *Battery-electric Motorcycle, Distribution Center Location Selection, Brown-Gibson Model, AHP, Transportation Model.*

1. INTRODUCTION

The distribution network aims to fulfill the shifting dynamic market demand by the time. Along with the market product demand increase, the distribution network more expand. That pushed company to be more competitive. Thus, requires industry players to make adjustment, which one by opening a location facility[1].

Determining the distribution location selection is the company's strategic decision to maximize sales but minimize cost [2]. Not only the cost but also, several criteria need to be considered as intangible value [3]. Three advantages will be achievedif the company able to allocate the strategic location facility [4]. Those three advantages are decreasing costs, maximize income, and

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lead time responsiveness. Therefore, location selection is a long term investment that needs to be considered by industry [5].

Previous research discussed facility location selection as Dey et al. [3] and Hariyanto [6] using an integrated model called Brown-Gibson for warehouse location in the manufacturing company. The Brown-Gibson model right to use because able to integrate objective and subjective measures well. This study offers the distribution center location selection in the battery-electric motorcycle company from the chosen candidate by an integrated factor which still rarely studied.

The growth of the battery-electric motorcycle industry is swift [7]. Until the second quarter in 2020, the market demand for battery-electric motorcycles in Indonesia is dominated by a domestic manufacturer industry called Gesits and *Completely Built-Up* (CBU) industry with various brands from China. In contrast, the *Completely Knock Down* (CKD) Industry as Viar that collaborated with Bosch is stagnant. This stagnant also viewed by the product readiness and infrastructure prepared with *Brand Holder Sole Agent* (ATPM). Zero introduced the earlier battery-electric motorcycle in Indonesia. It is a CBU product from the United States that imported by Garasindo in 2010 align by the increasing brand from China was targeting the low-end class. By the time, the potential customer of battery-electric motorcycle increase, so makes Garasindo develop the national battery-electric motorcycle which collaborate with Institut Teknologi Sepuluh Nopember (ITS) called Gesits that targeting the middle class for their first generation [8]. The most rapid development made by Gesits with various features of high-end technology developed in the last five years. Many start-ups are developing battery-electric motorcycle in Indonesia, but their *Technology Readiness Level* still far from the mass production stages [9]. It indicates that battery-electric motorcycle market demand in Indonesia fast grows, so research and start-ups develop battery-electric motorcycle both private and under government. Besides, the Ministry of Reseacrh and Technology (2019) in Indonesia targets the population of battery-electric motorcycle to reach two million units by 2025, which means 20 percent of the total motorcycle production in Indonesia [10].

This study conducted because the growth of battery-electric motorcycle purchases unbalances in the distribution process. A large number of orders and limited locations cause a lack of distribution sales. Current distribution still a direct channel; thus, several losses and high transportation costs occurred. The delay shipment also occurred due to waiting for the quota of demand in the adjacent area, which made the consumer who paid first get the unit together withwho paid later. In a manufacturing company, the bottleneck can occur anywhere in the distribution process [11].

A previous study discussed the determining location method by integrated *Fuzzy Multi-Criteria* and *Fuzzy Multi-Objective* in a warehouse manufacturing company [3]. Integrated weighted score method and *Modified Distribution* in warehouse material company [6] Integrated *Analytic Network Process* (ANP) and transportation model in selecting representative offices of operating services companies and power plants [12]. Besides, a previous study as Karmaker & Saha [13]**,** Singh et al[14], and Erbiyik et al. [15] using *the Analytical Hierarchy Process* (AHP) method in manufacturing company.

This study evaluates the criteria needs of the battery-electric motorcycle company using integrated AHP and transportation models. AHP can be used to determine location facilities in the supply chain [16]. At the same time, the transportation model used to calculate objective measurement in the Brown-Gibson model. Model formulation shows the alternative location with the lowest cost and unit allocation from the factory to market. So it can be seen whether opening a distribution center can reduce the transportation cost from the initial location. The rest of the article is grouped into four sections. Section two reviews the existing literature related to location selection, objective cost component, and subjective criteria. The following section provides a methodology. In the next section, the research result is conferred and analyzed, the sensitivity analysis tested, and managerial implication also discussed. The last section will summarize the findings and also provides suggestions for future research.

2. LITERATURE REVIEW

1. Location Selection

In general, site selection is determined by a particular area of facility distribution [17]. This site location is under the nature of market conditions. Site selection also has a direct impact on competitiveness and company performance. The purpose of selecting location facilities is to gather associations between businesses and customers to improve business performance and create corporate profit growth [18].

2. Objective Criteria

Wignjosoebroto [19] defines objective factors as factors that are considered and calculate that will affect the costs and benefits derived from site selection. According to Coyle et al. [20], the transportation cost component itself is divided into two, namely fixed costs and variable costs. Fixed costs are costs that must be paid or not during vehicle operation. The fixed cost components include purchasing a vehicle, shipping a vehicle, purchasing interest, renting a vehicle, administration. In comparison, variable costs are costs that vary according to operation. The variable cost components include fuel, depreciation, maintenance, and spare parts. In this study, the objective calculation will use variable cost components, namely gasoline, tolls, and one- time operational costs, the amount following the distance traveled.

3. Subjective Criteria

Subjective factors are factors that influence site selection based on the characteristics considered. The criteria considered must certainly be able to reflect the supply chain strategy and adjust the characteristics desired by the company. Criteria obtained from previous studies are Dey et al. [3], Karmaker & Saha [13], Singh et al. [14] Erbiyik et al. [15], among others:

1. Market: Proximity to customers, lead time and responsiveness, the scope for market growth, market size, competitor competitiveness
2. Infrastructure: Existence of modes of transportation, telecommunication systems, transport & connectivity, land availability, electricity & water supply
3. Labor characteristic: Availability of labor force, skilledlabor
4. Cost: Labor cost, transportation cost, cost of land
5. Macro Environment: Tax policies, incentives, industrialregulations laws

3. METHODOLOGY

The method used in this study consisted of four stages, first the study of literature by identifying problems throughinterviews and data collection. Second, the objective factor processing uses the transportation model. Third, the subjective factor data processing with AHP. Fourth, the integration of objective and subjective factors with theBrown-Gibson model.

a. Objective Factor Measurement

The data are obtained secondary with three-year projections(2021-2023). Data needed includes projected demand from the company, factory production capacity and distribution center, distance between locations, transportation costs. The transportation cost per unit considered from the factory to the distribution center is the sum of fuel, tolls, and one-wayvehicle operations. In comparison, the cost of transportation from the distribution center to the market is the sum of the fuel cost and one-way vehicle operations. So the mathematical formulation of the transportation model can be described as follows:

1. Decision variables are represented by X_{iw} and X_{wj}
2. The objective function of this problem is to determine the amount of unit to be delivered and minimize transportation costs

$$Min\ Z = (\sum_{i=1}^{n} \sum_{w=1}^{p} c_{iw}\ x_{iw}) + (\sum_{w=1}^{p} \sum_{j=1}^{m} c_{wj}\ x_{wj}) \ldots\ldots (2.1)$$

3. Constraint Function:

- Shipments from the factory-i to all the distribution centers-w must be smaller or equal to the factory production capacity.

$$\sum_{w=1}^{p} x_{iw} \leq K_i \qquad \forall i \ldots\ldots (2.2)$$

- The volume of goods received by the distribution center per year is the same as the units delivered from the distribution center.

$$\sum x_{iw} - \sum_{j=1}^{p} x_{wi} \geq 0 \qquad \forall w \ldots\ldots (2.3)$$

- Amounts delivered from distribution centers in one year to all market regions may not exceed the annual capacity of the distribution centers concerned.

$$\sum_{j=1}^{m} x_{wj} \leq K_w \qquad \forall w \ldots\ldots (2.4)$$

- Demand in each market is fulfilled.

$$\sum_{w=1}^{p} x_{wj} = D_j \qquad \forall j \ldots\ldots (2.5)$$

i = index for factories (A)
w = index for distribution centers (a, b, c, ...)
j = index for the market (1, 2, 3 ...)
n = number of factories
p = number of distribution centers
m = number of markets
Dj = annual demand from the market-j
Ki = factory annual capacity-i
Kw = annual capacity of distribution center-w
ciw = cost of shipping one unit of product from factory-i to the distribution center-w
cwj = the cost of shipping one unit of product from thedistribution center-w to the market-j
Xiw = number of products sent from the factory-i to thedistribution center-w
Xwj = number of products sent from the distributioncenter-w to the market-j

b. Subjective Factor Measurement

The objective factor assessment is conducted by interviewing and questionnaires to the company's decision- makers to determine the criteria and sub-criteria needed. Previous criteria were obtained from previous studies, followed by verification. Once obtained, a hierarchical model is built to assess criteria and sub-criteria using a questionnaire to get weight at each alternative location. The calculation valid if the inconsistency index is less than 0.1.

c. Integrated Factor

The integration of objective and subjective factors is done through the Brown-Gibson model with the following stages[21]:

Eliminating any choices that are not feasible and feasible to be chosen. Calculate and determine the performance measurement of the objective factor (OFi)

Determine factors that have a significant influence.This factor is more subjective.

$SFi = \sum Wj.Ri$ ………………………………..(2.7)

Create a weighting, which is better considered, between the objective factor (weight = k) andsubjective factor (weight = 1-k) of the boundary value(0 <k <1)

$LPMi = k\ (OFi) + (1 - k)(SFi)$ ………………(2.8)

Decisions are made based on choices the largest LPMi value.

4. CASE STUDIES

a. Data Analysis

The results of objective factors with nine transportation models for alternative locations of distribution centers in Semarang, Surabaya, and Semarang-Surabaya for the years 2021, 2022, 2023 are covered in table 1 and table 2. From the two candidates, one site needs to be built as distribution centers. The latest distribution center that already exists in East Jakarta. At the same time, there is one factory, two distribution centers, and 30 markets for this model.

Table 1 shows that the lowest cost fell to Surabaya with a total amount of Rp2,850,142,200 in three years projections, followed by Semarang (Rp3,412,459,000). Surabaya's transportation costs are also known to be linear from year to year, lower than Semarang. The proximity of Semarang to suppliers or factories does not guarantee that transportation costs can be cheaper. It was also encouraged that the demand for the East Java region was more dominant than Central Java. So the cost of transportation from Semarang to the market is expensive. It makes the transportation costs of Semarang highest because they have to serve the demand of the dominant East Java region with longer distances, and the capacity of distribution centers that are not as big as in Surabaya. So from the objective calculation, the biggest weight is Surabaya, with a value of 0.544894827408, followed by Semarang(0.455105172592).

After calculating the alternative location with the lowest cost, the unit allocation is obtained from the factory to the Surabaya distribution center as in table 3. And from the Surabaya distribution center to the market as shown in table 4.

Table 1. Recapitulation of Total Annual Transportation Costs

No	Year	Alternative Location	
		Semarang	**Surabaya**
1	2021	Rp783.464.000	Rp624.054.000
2	2022	Rp1.114.429.000	Rp932.142.200
3	2023	Rp1.514.566.000	Rp1.293.946.000
Total (Ci)		**Rp3.412.459.000**	**Rp2.850.142.200**
	OFi	**0.455105172592**	**0.544894827408**

Table 2. Unit Allocation from Factory to Distribution Center

Purpose of the Distribution Center	Unit Allocation from Factory		
	2021	**2022**	**2023**
Jakarta Timur	2640	4000	5500
Surabaya	1160	1760	2500

Table 3. Unit Allocation from Distribution Centers to Market Demand

pose Demand Location	t Allocation fromEast Jakarta			pose Demand Location	Allocation fromSurabaya		
	2021	**2022**	**2023**		**2021**	**2022**	**2023**
Semarang	160	240	360	Surakarta	0	80	260
Magelang	40	80	120	Surabaya	200	320	400
Purwokerto	40	80	120	Gresik	120	160	200
Surakarta	160	160	100	Sidoarjo	160	240	360
Yogyakarta	160	240	360	Mojokerto	120	160	200
Bantul	120	160	200	Madiun	120	160	200
Jakarta Pusat	200	320	400	Kediri	120	160	200
Jakarta Selatan	200	320	400	Malang	160	240	360
Jakarta Timur	160	240	360	Jember	40	80	120
Jakarta Barat	160	240	360	Banyuwangi	120	160	200
Jakarta Utara	160	240	360				
Bandung	200	320	400				
Bekasi	160	240	360				
Bogor	120	160	200				
Karawang	40	80	120				
Cirebon	40	80	120				
Depok	160	240	360				
Serang	40	80	120				
Tangerang	160	240	360				
Cilegon	40	80	120				
Tangerang Selatan	120	160	200				

Besides objective factor results, the assessment of the subjective factor is allowed. Measurement is done by identifying the criteria through previous studies and obtaining 5 criteria and 18 sub-criteria for location selection in the manufacturing industry. Verification is conducted to the decision-makers in company, 5 criteria and 26 sub- criteria were formulated to assess each candidate. So the AHP hierarchy shown in Figure 1. Based on subjective assessment using the AHP model through a questionnaire by three decision-makers, the weighting results are obtained, as shown in Figure 2. The level of inconsistency is 0.08 (<0.1), which means the expected results can be usedin this research.

AHP calculation show, the first weight falls on the cost criteria (0.3777). Regional minimum salaries are considered to reduce the company's operational cost. The transportation cost aims to increase efficiency in the future. The cost of a strategic place also carried to reduce fixed cost that means a company can cooperate with other parties.

The second rank falls on the market criteria (0.358). Companies need to consider the market condition to determine location. The proximity to the customer makes compensation due to the distance between the distribution center and market. Currently, the highest cost caused by the lack of the number distribution center is in Middle and East Java. By opening a distribution center, it becomes a management step to get closer to the potential market. Lead time and responsiveness considered because the distribution system centralized its make overload. Scope for market growth also affects the efficiency and potential market expansion. Market awareness of renewable energy carried becomes demand projection and forming interest market. Already distributed unit to predict the number of demand projections in the future. Competitor competitiveness also considered for penetration and increase market share in thecompetition environment.

The third rank falls on infrastructure (0.185). The existence of modes of transportation becomes a variation mode to efficiency distribution system by compensation cost. Telecommunication systems need to support in and out information facilities. Transport and connectivity affect the effectiveness of distribution by time spending. Land availability becomes a strategic place where the company can offer collaboration, so the cost is reduced, and the location is easy to organize. Electricity and water supply support the sustainable operation and business process. The regional government's renewable energy infrastructure development needs to make Electric Vehicles (EV) mapping infrastructure under its technology settlement in the future. Electric vehicle infrastructure availability and development affect the initiation and availability of EV infrastructures, such as charging stations and EV garage. So that whole kind of sub-criteria supports market projection.

The fourth criterion falls in the macro-environment (0.047). Regional tax policies, such as Transfer of Motor Vehicle Title Fee, cause increased customer interest and unit demand. An incentive that the government gives ease of administration can make market shape. Industrial regulation laws give the EV industry the policy stability to support the layout climate in the supply chain. Eco-friendly policies also support demand projection. Regional government visions about EV to consider the renewal and upcoming regulation to relieve the customer till industry. Regional government eco-friendly vehicle application potential to build a brand image for EV users and encourage market interest.

The last criterion falls on labor characteristics (0.033). The availability of a young labor force (<30 years old) is considered because it affects wages and works ethics to preserve electric vehicles. The skilled labor sub-criteria is considered because of the importance of capability and information delivery about EV.

After obtaining the results of the assessment weights according to the criteria and sub-criteria, and evaluation of each candidate location is conducted. The biggest weighting result of the assessment fell on Surabaya by 0.527, followed by Semarang (0.473). The weighting results are shown in figure 3.

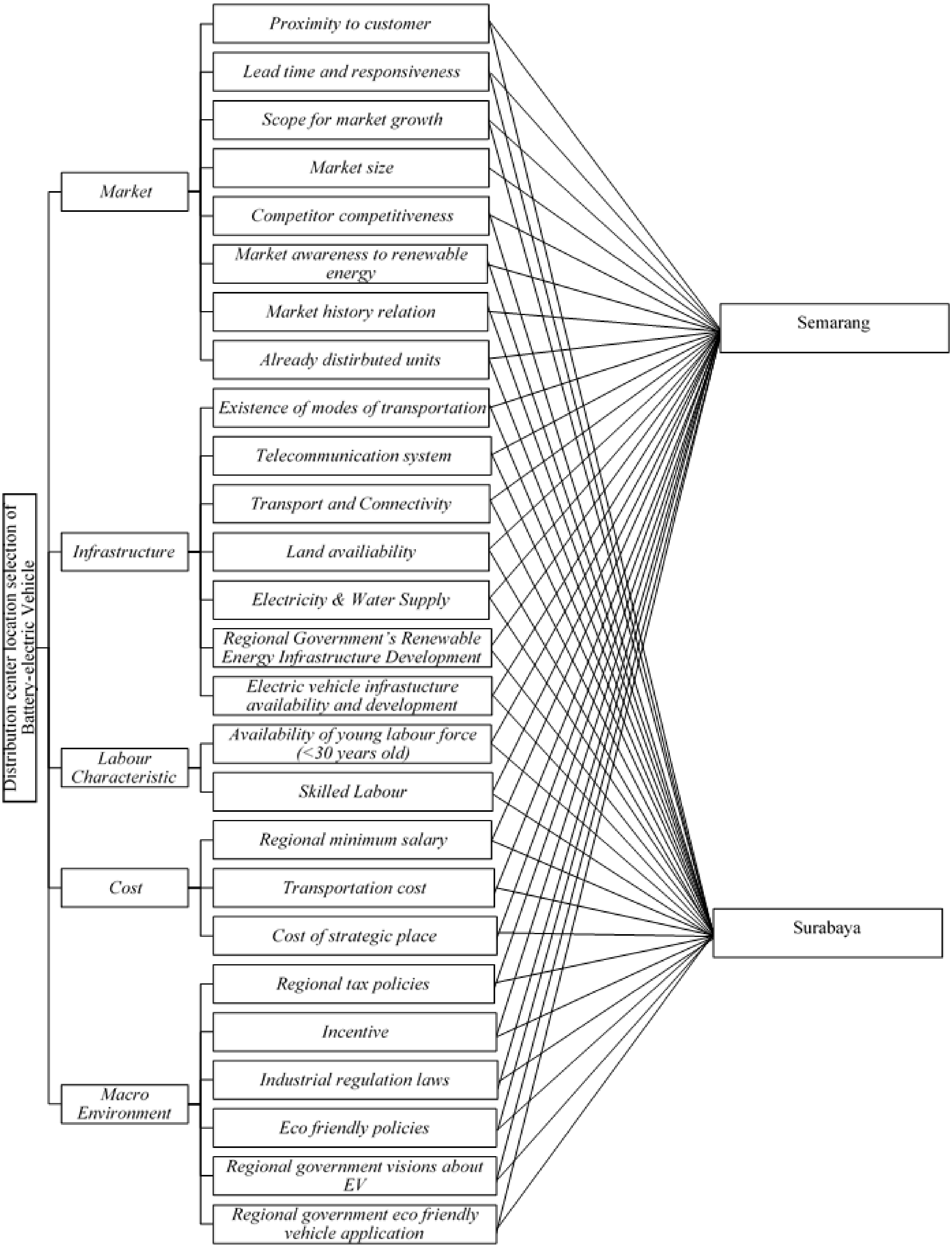

Figure 1. AHP Hierarchy Model Distribution Center Location Selection for EV

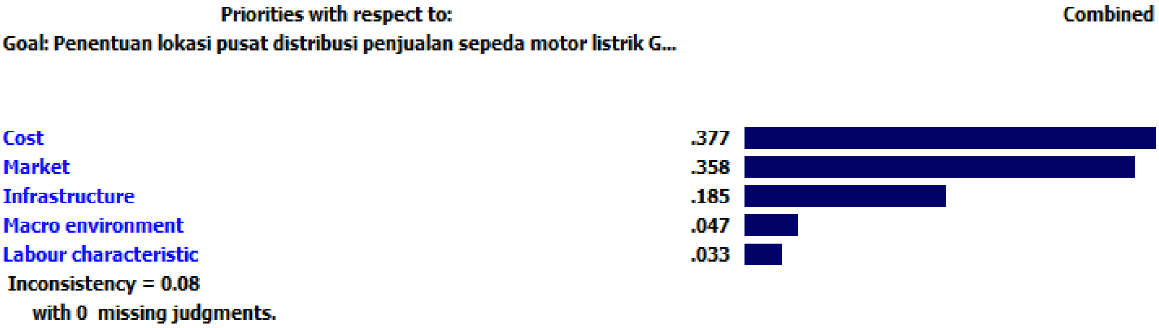

Figure 2. Weighting Criteria Result of Distribution Center Location Selection for EV

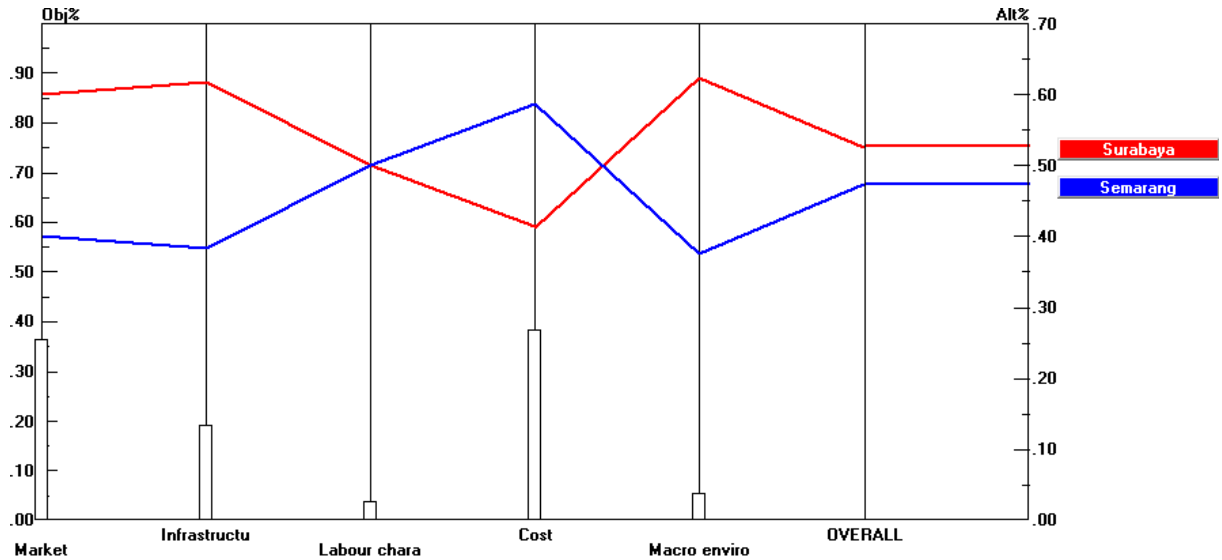

Figure 3. Weighting Distribution Center Candidate by Criteria

The value of each location based on objective and subjective factors is measured; the assessment is further processed and used as input parameters in the Brown-Gibson model. Before the assessment, weighting was carried out through a questionnaire to the decision-makers to obtain the performance of objective (k) and subjective (1-k) factors where the boundary value was equal to 0 <k <1. Weighting is done using the pairwise comparison scale, and the calculation is done using geometric averages. The results of the objective factor performance were 0.696. After that, the calculation is done to get the Location Preference Measurement (LPMi) as in table 5 below.

Table 4. LMPi Results Measurement

No	Location Candidate	Objective Performance (k)	Faktor Objektif (OFi)	Subjective Performance (1-k)	Faktor Subjektif (SFi)	LPMi
1	Semarang	0.696	0.455105172591862	0.304	0.473	0.461
2	Surabaya	0.696	0.544894827408138	0.304	0.527	0.539

To determine whether the location candidates change according to company policy, the author performed a sensitivity analysis. Based on the results of the sensitivity analysis in Figure 4, the location candidate will not change. That is because Surabaya has superior weight values for both factors. With the opening of the location of distribution centers for a battery-electric motorcycle in Surabaya in 2021, the company can reduce transportation costs by 29.4% compared to the initial location (Rp883,740,327).

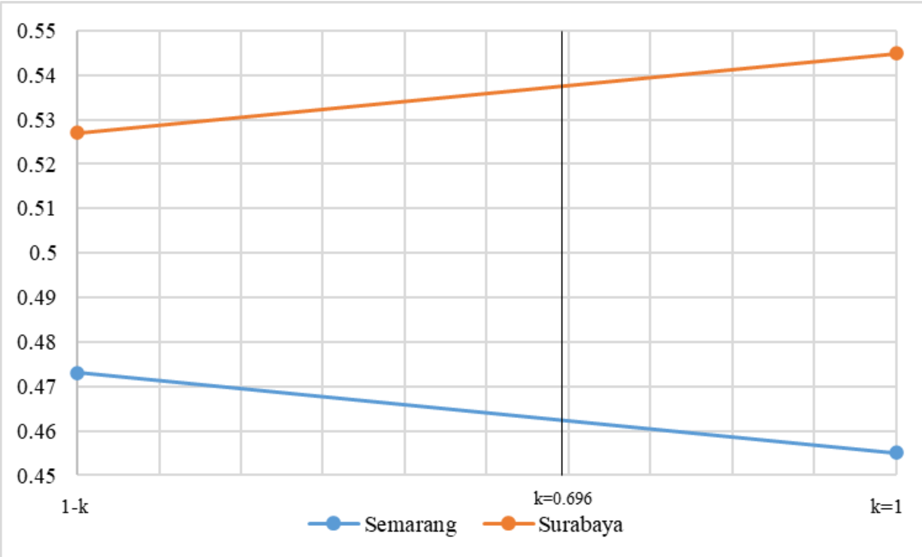

Figure 4. Sensitivity Analysis Graphic

b. Managerial Implication

This study has discussed how the integration of objective and subjective factors can be used to determine the location of battery-electric motorcycle distribution centers and have managerial implications. Based on the analysis of objective factors, Semarang has a lower value than Surabaya, although it is closer to the factory. These results indicate that the capacity of the distribution center and proximity to consumers is very influential in modeling the results. So changing these variables or factors requires the involvement of top-level management policymakers. Measurements must be monitored objectively, and implementation plans are reviewed frequently to meet company projections.

Based on subjective factors, this study also found eight new additional criteria that distinguish the determination of the location of electric vehicles with other locations. This additional indicates that the company needs to change the criteria according to business conditions and consumer demand. So the importance of verifying the criteria and sub-criteria is to adjust the company's needs and the characteristic for the products offered to the market. Besides, the criteria and sub-criteria and their weights can be used as a reference for evaluating the distribution centers location of the EV company.

Based on the integrated factor, the performance weighting of each factor can affect the final results. The weighting of each factor's performance can change according to company policy, so the role of upper-level management involvement as a decision-maker is very important. Besides, communication and education related to criteria and sub-criteria ranking information need to be done to decision-makers, stakeholders, and investors to find out what criteria are the company's priorities in selecting distribution center locations. The aim is that companies can set strategies to improve distribution performance in the short and long term. To support future location projections, companies can apply aggregate data centrally. So, demand data to distribution can be well connected; for instance, the application of *Enterprise Resource Planning* (ERP). From ERP, data flexibility can be processed easily, data security increased, and business forecasts accurate.

Verification results show the additional general criteria refer to the support for renewable energy. Because each region's policies are different, location mapping to areas that support renewable energy has a potential impact on business projections, both for companies and market shape. This mapping also can support government programs in mapping the development of electric vehicles. Furthermore, it can be a reference data for the central government in determining electric vehicle policy; it is hoped that electric vehicle regulations can be uniform nationally.

Furthermore, based on the LPMi result, the company needs to make strategic, tactics, and operational planning. This strategic planning affects distribution performance in the long term. Thus management needs to configure distribution centers both in East Jakarta and Surabaya. Besides, inventory level policies, mode of transportation,

and distribution strategies each distribution center need to consider. So, unit demand in each market can be fulfilled.

These policies suggest management that transportation management efficiency can be done through transportation design, the route, scheduling, and consolidating shipment. Management also needs to consider using the Distribution Center Management System for storage, picking, and goods

5. CONCLUSION

This research conducted a study related to determining the location of distribution centers for battery-electric motorcycle sales through the integration of objective and subjective factors. The transportation model used as an objective parameter and the AHP method as a subjective parameter from the Brown-Gibson model. The model evaluation was carried out through an interview, verification process, and a questionnaire to three decision- makers in the company. Based on subjective factors, there are an additional eight criteria that distinguish the determination of the location of electric vehicle distribution centers with the determination of other locations that make management must consider aspects of these criteria in the future. shipping. Also, inventory control needs to be established through inventory management. Thus this logistic strategy will determine how the company's tactical planning and logistic operation will affect the company's investment andlogistical operational cost.

The results state that Surabaya has the largest LPMi value of 0.539, followed by Semarang (0.461). Besides, the unit allocation is obtained from the factory to the distribution centers in East Jakarta and Surabaya, and the distribution center to the market. The transportation cost of unit allocation in 2021 is 29.4% lower than the initial location. Prove that the addition of a distribution center can reduce transportation costs. Also, the sensitivity analysis results did not change, so the results of the study can be said to be strong *(robust).* The results of this study are also beneficial for other electric vehicle companies in determining the location facility strategy that will be built in the future to create better efficiency and effectiveness indistribution.

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