Determination of distribution center location for paper packaging using Center of Gravity method and Analytical Hierarchy Process

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Abstract

Determining the proper location of the distribution center is a strategic plan in maintaining customer service commitment, saving time, transportation costs, and general operational costs. The purpose of this research is to determine the distribution center location in the case of paper packaging products. The method used is center of gravity and AHP. The location recommended by the center of gravity method is right in the center of the North Bekasi toll road which is not feasible (coordinates X: -6.2621505, Y: 107.015805). The priority of distribution center locations in the case of paper packaging products using the AHP method is C location with a weight of 0.3402, A location with a weight of 0.3329, and B location with a weight of 0.3269, respectively. Location C superiors in three of the four criteria, i.e. facility, accessibility, and sustainability.

Keywords

Distribution Center (DC) location, Center of Gravity (COG), Analytical Hierarchy Process (AHP).

1. INTRODUCTION

The pulp and paper industry (PPI) sector has a major contribution to the economy in Indonesia (Regional Economic and Financial Studies, 2020; KEMENPRIN, 2018). Indonesia has an important role as a paper producer ranked 6th and pulp producer ranked 9th in the world. The contribution of the PPI sector to the Gross Demographic Product (GDP) in 2015 reached IDR 87.7 trillion, direct employment of 260,000 workers, and indirect labor of 1.1 million workers (KEMENPRIN, 2018). Various PPI products include packaging.

Packaging is important in protecting products, especially during the distribution process to customers (Coelho et al., 2020; Landi et al., 2020; Pauer et al., 2020). In the case of one of the largest PPI companies in Indonesia, the volume of paper packaging shipments in 2019 was 21.26 million kg with an average distance of 89.69 km to the customer's location. The distribution of paper packaging products was carried out directly from the factory to as many as 71 customers because there was no DC location. The locations of the 71 customers are scattered in the areas of Jakarta, Bogor, Depok, Tangerang, Bekasi, Karawang, and Bandung, which are traffic areas with high levels of congestion (Ministry of Transportation, 2019; DKI JAKARTA Statistics Agency, 2018; Tamara & Sasana, 2017; B. Research & Development, 2016). Mileage and volume of deliveries to customers are shown in Figure 1. According to the previous research, congestion causes problems in supply chain activities, namely delays, economic losses, air pollution, performance achievement, efficiency, customer service levels and even causes risks and threats to the sustainability of the company (Afrin & Yodo, 2020; Kusrini et al., 2020; Boye et al., 2018; Mckinnon, 2018). Based on company data, in the last three years, there was an average delay of 10.80%. Product distribution in serving the level of customer service satisfaction, of course, cannot be separated from a strategy, one of which is the right DC location. Customer service satisfaction is not only limited to the timeliness, quality, and quantity of product arrivals, but also minimal costs. The biggest cost of product is in the supply chain cost, supply chain is the most important aspect in increasing competitiveness (Ikatrinasari et al., 2020).

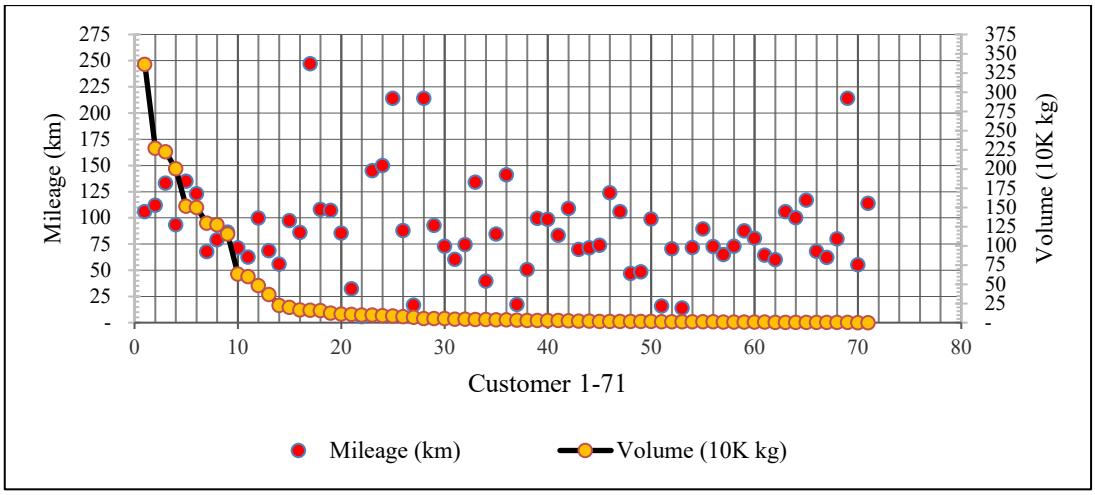

Figure 1. Mileage and volume shipment

According to Chopra (2003), states that the decision to determine location facilities is very useful in long-term strategic planning of the supply chain in each company, a good product distribution strategy is the key driver that will have a direct impact on competitive costs in the supply chain in a company. both suppliers and customers as a form of customer satisfaction response. In fulfilling demand and maintaining the level of customer service satisfaction is very important for the company, a distribution strategy and structure is needed including optimizing transportation costs by determining the right DC location (Onstein et al., 2020). The distribution structure and DC location are very important for companies to optimize logistics costs and service levels (S. Onstein, 2017; Song, 2017). To ensure that the organization's strategic plan is successful in the long term, the DC location plays a very dominant role compared to other alternative solutions in a company (Szeremeta-Spak & Colmenero, 2015).

The choice of distribution centre (DC) location is a very important decision because it is a link between suppliers and customers (Song, 2017). DC location is an operational parameter that greatly affects operational costs (Surin, 2016). Referring to research that to determine an optimal DC location using the COG method (Arivalagan, 2019; Irwanto & Hasibuan, 2018; L. Li & Zhang, 2017; Rajasimeswaran et al., 2018; Sudrajat, 2019; Yang & Li, 2016a). Another supporting method in making a decision in choosing an alternative location is using AHP (Amchang & Song, 2018; Anderluh et al., 2020; S. Li & Wei, 2018; Mensah & Nakkazi, 2018; Roh et al., 2018; Ruiz et al., 2020; Tadesse & Negese, 2020).

2. Literature Review

2.1 Centre of Gravity (COG) Method

The COG method is useful for identifying a suitable geographic location within an area that minimizes the cost of transporting raw materials from suppliers and finished products to customers (Rajasimeswaran et al., 2018) . The COG method is an accurate method in resolving DC locations that have minimal transportation costs (Yang & Li, 2016b). According to Arivalagan (2019) research in the pharmaceutical distribution product industry sector in India, except for the Andaman, Nicobar, and Lakshadweep Islands using the COG method, it was successful in determining the location of Warhouse and Distribution Network in maintaining customer service levels, which is a travel time of 72 hours. Research by Irwanto and Hasibuan (2018) in the pharmaceutical products, the results with the COG method found coordintat X: -6.257108; Y: 106.7315 This location is a residential location for residents that is not feasible to be built as a DC location. So that the DC location was shifted 4 km westward to a feasible location for the T8 Pakulonan Alam Sutera warehouse area, Tangerang City. The results of research by Rajasimeswaran et al. (2018) stated that the Asthra pump company in the Kalarahalli region, Chitradurga Distict, Karnataka state as a new DC location that can save time and transportation costs. Using the COG method, research by L. Li and Zhang (2017)succeeded in determining the location of SF Express near Zhengzhou Railway Station as the optimal DC location. Sudrajat, (2019) using COG determine the location of branch offices the preferred location based on PT. Unilab Perdana, the results showed coordinate centers at 6 ° 27 '15 .0516 'S and 107 ° 20' 2.9364 E E, located in Mulyasejati, Ciampel, Karawang District, District, West Java. The COG method still has limitations in its application, if the found location is not feasible, an alternative location that is feasible is needed. So that in order to determine the choice of an alternative location, a supporting method is needed in making the AHP method decision.

2.2 Analytical Hierarchy Process (AHP) Method

Anderluh et al. (2020) that AHP supports to make decisions in determining the location of a city-hub in Vienna Austria. Research by Ruiz et al. (2020) using the AHP-MCDA method obtained results of 0.07% - 0.03% of the WKP area as the optimal location for solar power plants. Researchers Tadesse and Negese (2020) using the AHP method in their research show the results as a production location of 116.65 ha (28.58%) moderately suitable and 291.47 ha (71.42%) highly suitable. Using the AHP method, Mayou et al. (2019) found results of 4 best selected fuel station locations from 15 fuel locations of Adrar province, 3 high suitable area locations and 1 suitable medium location. Mensah and Nakkazi (2018) also use the AHP Accra-Melcom method which is the best location to build as a DC location. Another researcher Chenikwi (2016) uses the AHP method that the city of Douala was chosen as the best location as a DC location because it not only serves customers in Cameroon but also other customers in the West and Central Africa region.

3. Methods

This research is both qualitative and quantitative, by conducting a case study on one of the largest pulp and paper companies in Indonesia (Suryana, 2012; Rahman, 2020). The data required from the company is the address of the customer and the volume of shipments in kg. The x and y coordinates are searched by entering the customer's address into the google map application.

The methods used are COG and AHP. Determination of the DC location using the COG method, the mathematical formula is as follows:

$$\mathrm{Cx} = \frac{\sum_i \mathrm{dix\ wi}}{\sum_i \mathrm{wi}} \tag{1}$$

$$\mathrm{Cy} = \frac{\sum_i \mathrm{diy\ wi}}{\sum_i \mathrm{wi}} \tag{2}$$

Where:
Cx = coordinate point x DC location
Cy = coordinate point y DC location
dix = coordinate point x from the address of the location of the customer-i
diy = coordinate point y from the address of the location of the customer-i
wi = volume of shipments to customer-i (kg)

In this case study, the AHP method is used to determine the best alternative location to build a DC location. AHP method has been selected for application in various industries in determining the priority selection that includes assessment experts both on the proposed criteria (Hutagalung & Hasibuan, 2019). AHP method is formed by creating a hierarchical structure for determining the DC location. The hierarchical structure for determining the location of DC consists of: company objectives (level 0), criteria (level I), sub criteria (level II) and alternative locations (level III). The hierarchical structure of determining the DC location was carried out with discussions, interviews, and the results of questionnaires from experts in the SCM field, company leaders, academic experts, expert practitioners, and community social organizations (NGOs). Besides that, it also refers to the previous research literature. The hierarchical structure in determining DC locations is shown in Figure 2. The criteria consist of 4 aspects and sub criteria consisting of 16 aspects, and each aspect is accompanied by a reference to previous research. Reference to previous research criteria and sub criteria for determining DC locations are listed in Table 1.

Furthermore, pairwaise comparison matrices are prepared between criteria, sub criteria, and alternative locations to obtain Vector Priority (VP) values. The pairwise comparison priority value scale of each aspect can be illustrated as an example of two aspects A and B, so the pairwise comparison priority value scale is shown in Table 2. The VP value is calculated from the results of the respondent's questionnaire in providing a value scale on the comparison matrix using geometric averages. Consistency or inconsistency of respondents in filling out the questionnaire scores was tested by the Consistency Ratio (CR) test. If the CR value is <10%, the respondent's questionnaire filling is consistent. If the CR value is >10%, the respondent's questionnaire filling is inconsistent, so the questionnaire must be repeated (Saaty, 2012). The CR value is calculated by equations (3) and (4).

Consistency Index value (CI):

$$CI = (\lambda max - n) / (n - 1) \quad (3)$$

Consistency Rasio value (CR):

$$CR = CI / RI \quad (4)$$

Where:
CI = Consistency Index
CR = Consistency Rasio
RI = Random Index
N = Matrix Order
λmax = Eigen Value

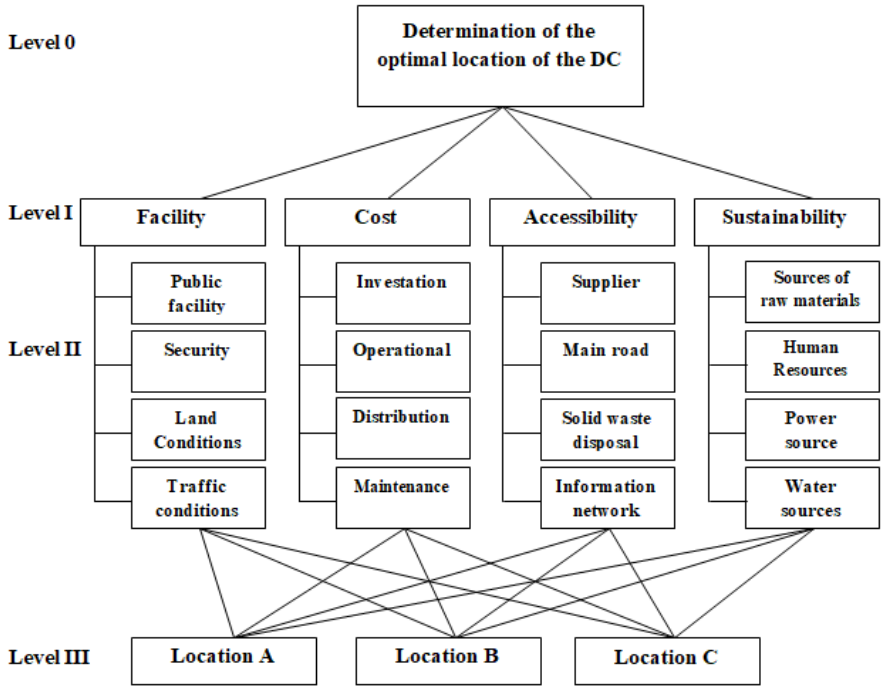

Figure 2. Hierarchical structure for determining DC location

Table 1. Reference previous research criteria and sub criteria for determining DC

No	Criteria	Sub criteria			
		1	2	3	4
1	Facility (Anderluh et al., 2020; S. Li & Wei, 2018; Roh et al., 2018;Georgise et al., 2020)	Public facility (F1) (Aburas et al., 2017; Amchang & Song, 2018; Hakim & Kusumastuti, 2018; S. Li & Wei, 2018; Oktavia et al., 2018; Roh et al., 2018)	Security (F2) (Amchang & Song, 2018; Anderluh et al., 2020; Hakim & Kusumastuti, 2018; Oktavia et al., 2018)	Land Conditions (F3) (Aburas et al., 2017; Hakim & Kusumastuti, 2018; Kazançoğlu et al., 2019; Roh et al., 2018;Georgise et al., 2020)	Traffic conditions (F4) (Amchang & Song, 2018; Kazançoğlu et al., 2019; S. Li & Wei, 2018; Wang, 2017)
2	Cost (Anderluh et al., 2020; S. Li & Wei, 2018; Mensah &	Investation (C1) (Anderluh et al., 2020; Chenikwi, 2016; Kazançoğlu et al.,	Operational (C2) (Amchang & Song, 2018; Anderluh et al., 2020; Wichapa &	Distribution (C3) (Amchang & Song, 2018; Anderluh et al., 2020; Hakim &	Maintenance (C4) (Wichapa & Khokhajaikiat, 2017);

No	Criteria	Sub criteria			
		1	2	3	4
	Nakkazi, 2018; Roh et al., 2018)	2019; S. Li & Wei, 2018; Roh et al., 2018; Wichapa & Khokhajaikiat, 2017)	Khokhajaikiat, 2017)	Kusumastuti, 2018; S. Li & Wei, 2018)	
3	Accessibility (Mensah & Nakkazi, 2018; Wichapa & Khokhajaikiat, 2017)	Supplier (A1) (Roh et al., 2018;Georgise et al., 2020)	Main road (A2) (Aburas et al., 2017; Hakim & Kusumastuti, 2018; Kazançoğlu et al., 2019; Roh et al., 2018)	Solid waste disposal (A3) (Anderluh et al., 2020; Hakim & Kusumastuti, 2018)	Information network (A4) (Oktavia et al., 2018); Georgise et al., 2020)
4	Sustainibility (Korbla & Tofah, 2019; Oktavia et al., 2018)	Sources of raw materials (S1) (Roh et al., 2018;Georgise et al., 2020)	Human Resources (S2) (Chenikwi, 2016; Kazançoğlu et al., 2019; S. Li & Wei, 2018;Georgise et al., 2020)	Power source (S3) (Aburas et al., 2017; Hakim & Kusumastuti, 2018; Oktavia et al., 2018)	Water sources (S4) (Hakim & Kusumastuti, 2018; Oktavia et al., 2018;Georgise et al., 2020)

Table 2. The priority value scale of the pairwaise

Score	Descreptions
1	The two criteria are **equally important**
3	Criterion A is **slightly more important** than criterion B.
5	Criterion A is **more important** than criterion B.
7	Criterion A is **very important** compared to criterion B
9	Criterion A is **absolutely more important** than criterion B.
2, 4, 6, 8	The level of importance falls between odd values

Source: Saaty (2012)

After obtaining the VP value from all the pairwaise comparisons on the criteria (level I), sub-criteria (level II), and alternative location (level III), the calculation of the Global Priority (GP) value can be done. The calculation of the GP value is obtained by the level I VP value multiplied by the level II VP value multiplied by the level III VP value.

4. Results and Discussion

4.1 Initial determination of DC Location

According to Figure1, the coordinates and volume (kg) with the COG method are obtained using equations (1) and (2) so that the coordinates (X, Y) of DC are as follows:

$$Cx = \frac{\sum_i \text{dix wi}}{\sum_i \text{wi}} = -133,130,100/21,259,485.84 = -6.2621505$$

$$Cy = \frac{\sum_i \text{diy wi}}{\sum_i \text{wi}} = 2,275,101,000/21,259,485.84 = 107.015805$$

DC coordinat location: X: -6.2621505,Y: 107.015805

The COG method recommends a DC location at coordinates X: -6.2621505, Y: 107.015805, in the center of the Bekasi Timur toll road, Jl. National 1, Pengasinan, Kec. Rawalumbu, Bks City, West Java 17115. Located 81.50 km southeast of the factory location. The recommended DC location for the COG method is shown in Figure 3. Because it is not feasible, an alternative DC location is needed, such as researchers Irwanto and Hasibuan (2018) for pharmaceutical products where the COG recommendation is located in residential areas.

Meanwhile, Arivalagan (2019) using the COG method also determines the location for Warehouses and Distribution Networks. Three feasible alternative DC locations as DC locations are as follows:

1. Location A:Coordinates X:-6.2788212; Y:107.048437, Jl. Kalimalang Inspeksi No.2, RT.11 / RW.1, Cibuntu, Kec. Cibitung, Bekasi, West Java 17520. Southeast direction is 4.10 km away from the DC location recommended by the COG method.
2. Location B:Coordinates X:-6.372834; Y:106.9729053, Jl. Pasir Angin Narogong, Kec.Cileungsi, Bogor, West Java 16820. Southwest direction is 13.10 km away from the recommended DC location for the COG method.
3. Location C:Coordinates X:-6.2924825, Y:107.0802173, MM2100 Industrial Estate Jalan Kalimantan Blok G2, Cibitung, Bekasi, West Java Indonesia 17530. Southeast direction is 7.89 km away from the DC location recommended by the COG method.

The three nearest feasible DC alternative locations are shown in Figure 4.

Figure 3. The initial recommendation of DC location using COG method

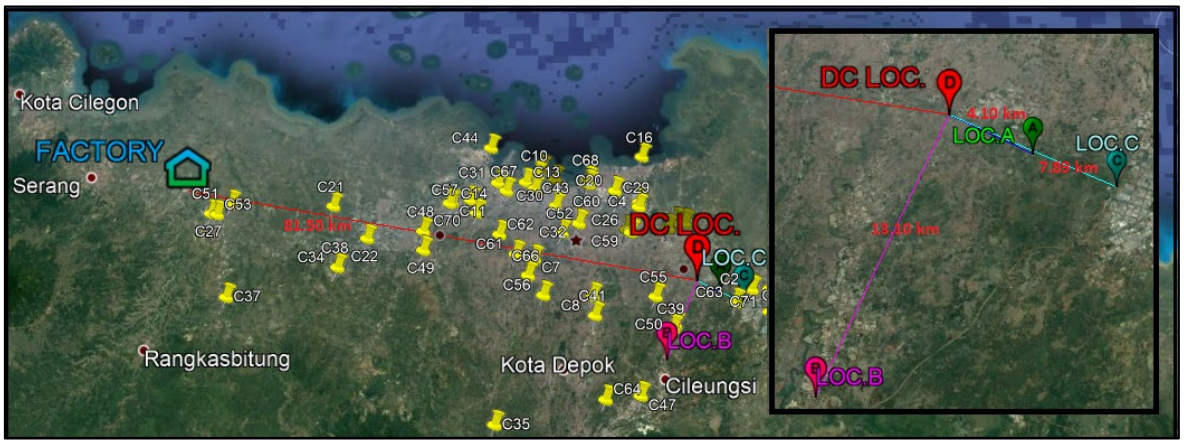

Figure 4. The position of three DC locations alternatives

4.2 Final determination of DC location

Determination of DC locations priority using the AHP method refers to section 3 and Figure 2. To test the validity of the results, it is necessary to test the consistency of CR using equations (3) and (4), of all 25 paired comparisons the highest CR value is the pairwise comparison between criteria, obtained λ_{max}= 3.0539, n = 3, RI = 0.90, so that CR values are as follows:

$CI = (\lambda_{max} - n) / (n - 1) = (3.0539-3)/(3-1) = 0.0539/2 = 0.0269$

$CR = CI/RI = 0.0269/0.90 = 0.0464 = 4.64\%$

It can be concluded that CR <10%, then all pairwise comparison values on the criteria matrix are consistent, so that the calculation of the GP value of the location can be continued. The criterion VP value (level I), the

sub-criteria VP value (level II), the VP value for alternative locations (level III), and the location's GP value are listed in Table 3 as follows:

Table 3. VP value for criteria, sub criteria, alternative locations and GP location values

Level I		Level II			Level III					
		Sub criteria			VP location			GP location		
Criteria	VP	Code	VP	Weight	A	B	C	A	B	C
(a)	(b)	(c)	(d)	(e=bxd))	(f)	(g)	(h)	(i=exf)	(j=exg)	(k=exh)
Facility	0.3353	(F1)	0.3475	0.1165	0.1926	0.4587	0.3487	0.0224	0.0534	0.0406
		(F2)	0.2296	0.0770	0.3137	0.4216	0.2648	0.0241	0.0325	0.0204
		(F3)	0.2308	0.0774	0.2968	0.4155	0.2878	0.0230	0.0322	0.0223
		(F4)	0.1921	0.0644	0.2263	0.2875	0.4861	0.0146	0.0185	0.0313
Cost	0.2459	(C1)	0.2567	0.0631	0.4792	0.3184	0.2024	0.0302	0.0201	0.0128
		(C2)	0.2474	0.0608	0.3037	0.2315	0.4648	0.0185	0.0141	0.0283
		(C3)	0.3097	0.0761	0.3620	0.1978	0.4403	0.0276	0.0151	0.0335
		(C4)	0.1863	0.0458	0.3140	0.2379	0.4481	0.0144	0.0109	0.0205
Accessibility	0.2125	(A1)	0.3065	0.0651	0.3585	0.3322	0.3093	0.0233	0.0216	0.0201
		(A2)	0.3250	0.0691	0.2545	0.3102	0.4354	0.0176	0.0214	0.0301
		(A3)	0.1897	0.0403	0.2281	0.3959	0.3760	0.0092	0.0160	0.0152
		(A4)	0.1788	0.0380	0.4743	0.3299	0.1958	0.0180	0.0125	0.0074
Sustainability	0.2063	(S1)	0.3724	0.0768	0.5496	0.2480	0.2025	0.0422	0.0191	0.0156
		(S2)	0.1840	0.0380	0.3507	0.4306	0.2186	0.0133	0.0164	0.0083
		(S3)	0.2696	0.0556	0.3515	0.1925	0.4559	0.0196	0.0107	0.0254
		(S4)	0.1740	0.0359	0.4135	0.3494	0.2371	0.0148	0.0125	0.0085
							Total GP	**0.3329**	**0.3269**	**0.3402**

According to Table 3, the priority value of importance between the criteria, the highest importance priority is the facility criteria with a value of 0.3353, costs with a value of 0.2459, accessibility with a value of 0.2125, and sustainability with a value of 0.2063. It is concluded that in determining the location of DC, it prioritizes the consideration of the facility aspects of the DC location to be built and subsequently the aspects of cost, accessibility and sustainability. The priority values of importance between the criteria are shown in Figure 5.

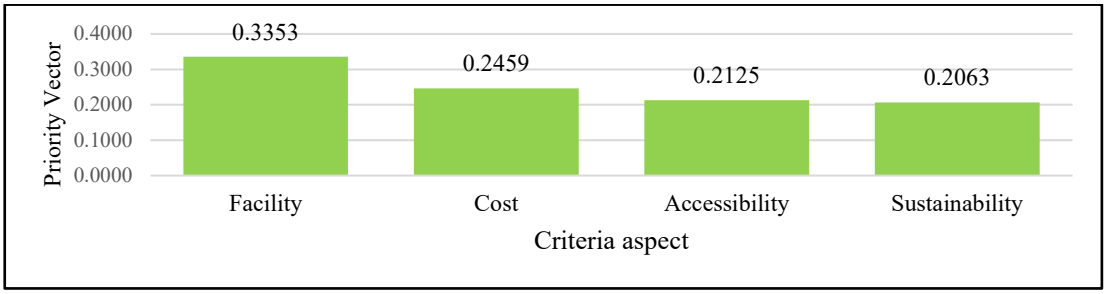

Figure 5. The criteria weight in determining DC locations

The highest priority value between alternative locations is on the criterion aspect of the highest score in order of facility aspects with a value of 0.4800 at location C, accessibility aspects with a value of 0.4310 at location C, sustainability aspects with a value of 0.4212 at location C, and cost aspects with a value of 0.4708 at location B. So it can be concluded that location C is superior in three aspects of facility criteria, accessibility, and sustainability. Location B excels on one aspect of the cost criterion. Important aspect facility i.e: public facility, security and safety, congestion (Anderluh et al., 2020). Accesibility was main factor that decision making location selection (A. T. C. Onstein et al., 2019). Futhemore, the main important aspect sustainability management of raw materials, electricity consumption, water consumption, waste disposal to be implemented simultaneously (Ikatrinasari et al., 2018). The priority values between alternative locations on the criteria aspect are shown in Figure 6.

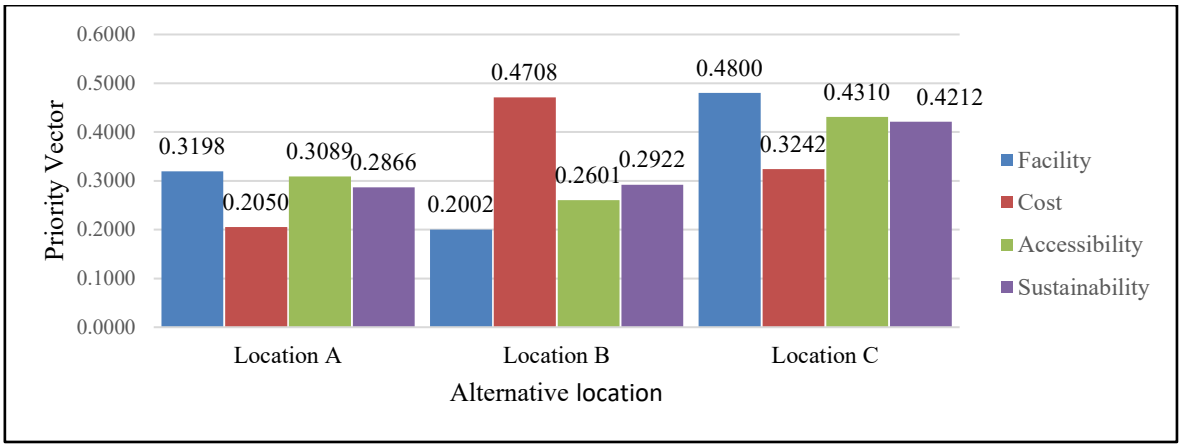

Figure 6. Priority values among alternative locations based on the criteria

The total value of the GP location from the three alternative locations that has the highest value for location C is 0.3402 location A is 0.3329, and location B is 0.3269. The total GP value for the locations of the three alternative locations is shown in Figure 7.

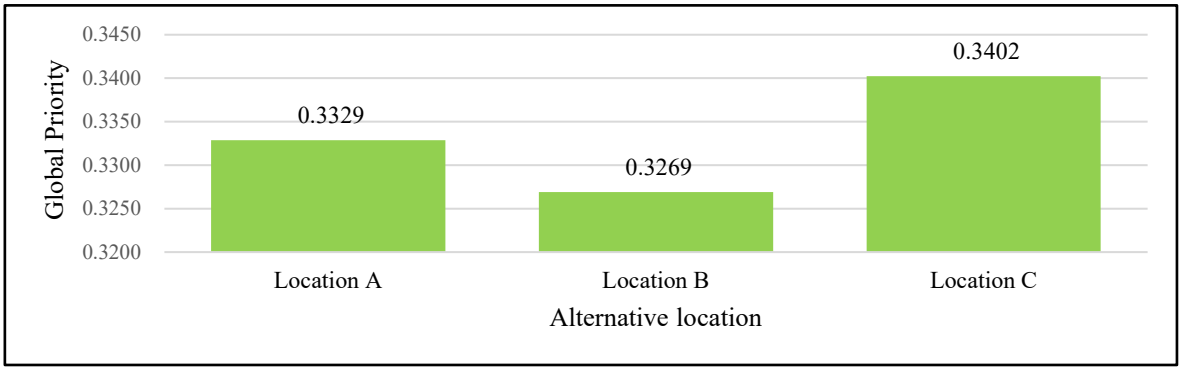

Figure 7. The global priority of DC location

According to the priority vector between locations alternative based on the criteria (Figure 1.6) location C is superior in three criteria i.e. facilities, accessibility, and sustainability, location C has the highest total value of GP location from the three alternatives using the AHP method. Tadesse and Negese (2020) using AHP method in determining the optimal location for production sites, Mayou et al. (2019) determine the optimal location as a fuel station, while Chenikwi (2016); Mensah and Nakkazi (2018) determine the location of DC locations (Figure 7) so location C is an alternative location best as the selected DC location. Location C is located at coordinates X: -6.2924825, Y: 107.0802173, MM2100 Industrial Estate Kalimantan Blok G2 Street, Cibitung, Bekasi, West Java Indonesia. Southeast direction is 7.89 km with the DC location recommended by the COG method, and southeast is 89.39 km from factory location.

The advantages of the MM2100 area are that it can meet the required criteria, from criteria for public facilities such as a place to eat, shopping, security, security, land conditions according to warehousing standards, smooth traffic conditions, access to suppliers, main roads/toll roads, waste management, information networks, sources of raw materials and human resources are easily available, electricity and water networks are readily available. However, it has the disadvantage of high investment, operational and maintenance costs.

The existence of a DC location (selected location C), the distance to the customer resulted in a savings of 47.82%, i.e. previously the average shipping distance from the factory as far as 89.69 km decreased to 46.81 km if the shipment was from the DC location. Decreasing of the distance traveled comparison between the factory and the DC location in Figure 8.

The results of this study have implications for the paper packaging industry, contributing to savings in shipping mileage to customers of 47.82%, thus saving time and transportation costs. The limitation of this study is that it does not make a nominal calculation of the transportation cost savings.

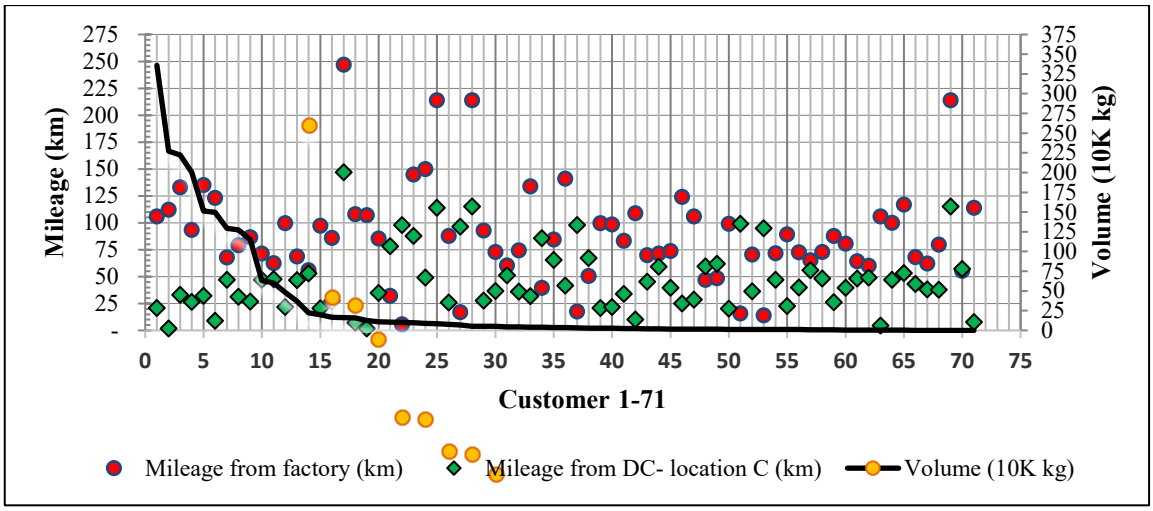

Figure 8. Decreasing of the distance traveled comparison between the factory and the DC location

5. Conclusion and Suggestion

5.1 Conclusion

1. The COG method recommends that the DC location is in the center of the Bekasi Timur toll road which is not feasible (coordinates X: -6.2621505, Y: 107.015805), Jl. National 1, Pengasinan, Kec. Rawalumbu, Bks City, West Java 17115. Located 81.50 km southeast of the factory location.

2. The priority of DC location in the case of paper packaging products uses the AHP method, respectively, location C is 0.3402, location A is 0.3329, and location B is 0.3269. Location C excels in three of the four criteria for facility, accessibility and sustainability. Location C is located at coordinates X: -6.2924825, Y: 107.0802173, MM2100 Industrial Estate Jalan Kalimantan Blok G2, Cibitung, Bekasi, West Java Indonesia 17530. Southeast direction is 7.89 km with the DC location recommended by the COG method, and southeast is 89.39 km from factory location.

3. The existence of a DC location can prove that there is a savings in shipping mileage to customers of 47.82%, that is, previously the average shipping distance to customers from the factory as far as 89.69 km decreased to 46.81 km if shipping from a DC location, so it will save time and transportation costs.

5.2 Suggestion

This research should be further developed using the transportation method so that the nominal cost savings of transportation can be known.

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