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Determining The Location Of Alternative Industrial Estates Using The Center Of Gravity Method And Factor Rating

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Abstract: South Sulawesi is the gateway to the economy in the eastern part of Indonesia, the Government is trying to develop the Makassar Industrial Estate more broadly. However, the land there has almost been sold out, the Government together with PT. Kima is currently working on an expansion to Maros Regency because it is not far from Makassar. Therefore, this study aims to determine whether the proposed location is optimal, has low transportation costs, meets the criteria for selecting an industrial area location and is in accordance with the National Spatial Structure Plan. In addition, this study also determines alternative locations for industrial estates in South Sulawesi Province using the Center of Gravity method to determine the location of the midpoint of the coordinates based on the location of the district/city and the Factor Rating Method to see between the 2 (two) proposed and alternative locations, which location which has the highest weight. Then considered by calculating the cost of transportation. The results showed that Maros Regency is the location that has the highest weight and the lowest transportation costs.

Keywords: *Determination of Location, Industrial Estate, Center Of Gravity, Factor Rating*

1. Introduction

The government's plan to boost the economy includes the development of Industrial Zones. Referring to the draft of the National Industrial Development Master Plan (RIPIN), it is projected that 36 new Industrial Zones will be built from 2015 to 2035. As of January 2022, there are 135 industrial zone companies with a total land area of 65,532 hectares distributed across Java, Kalimantan, Maluku, Papua, Nusa Tenggara, Sulawesi, and Sumatra. Out of these 135 industrial zones, 46%, or 30,464 hectares, are already occupied by industrial tenants (Ministry of Industry, 2022).

Considering various international trade activities, exports will have a significant impact on the country's income. If imports can be reduced, it will lead to a trade surplus, as mentioned by Dinda Risa in 2021. Export activities can act as an engine of growth for the country by increasing foreign exchange reserves, contributing to added value. In 2019, the total export volume (both oil and gas and non-oil and gas) reached 654,474.40 thousand tons. Indonesia needs more Industrial Zones to continue increasing its export volume.

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To develop these Industrial Zones, there will be three phases: planning, development, and management. Planning involves selecting the location, development includes constructing and improving infrastructure, and management entails ensuring the optimal functioning of the Industrial Zone. Location selection is crucial in the Industrial Zone development process, primarily aimed at enhancing industrial development. Therefore, location strategy is a critical factor in the planning process. Location decisions for Industrial Zones typically involve strategies to minimize transportation costs so that the companies within the area can maximize their profits. Location planning is a strategic activity aimed at maximizing profits for companies (Alfirah, n.d, 2018).

South Sulawesi serves as an economic gateway in the eastern part of Indonesia. Thus, South Sulawesi needs even more extensive Industrial Zones than it has now, with an estimated addition of 1,000 hectares (Annisa Sulistyo Rini, 2019). However, because the land in the Makassar Industrial Zone has nearly been sold out, the South Sulawesi provincial government, in collaboration with PT. Makassar Industrial Zone, is working on expanding a new Industrial Zone in the Maros Regency, South Sulawesi, which is considered a potential area due to its proximity to Makassar (Nur Suhra Wardyah, 2021).

To find the location of facilities and minimize transportation costs, the Center of Gravity (CoG) method can be utilized (Hamdani, 2019). The Center of Gravity (CoG) method is commonly used in inventory and logistics management to determine locations and can be an alternative method for determining the optimal location of the new Industrial Zone with greater accuracy and precision. This research aims to achieve the following objectives:

a. Identify the optimal alternative location for the new Industrial Zone with the lowest transportation costs in South Sulawesi Province.
b. Determine whether the potential alternative locations for the new Industrial Zone meet the location selection criteria outlined in Minister of Industry Regulation No. 40 of 2016 and align with the National Spatial Plan.

2. Literature review

2.1 The determination of location

The determination of a location is crucial for the future sustainability of a company, as choosing the right location will impact the regular expenses incurred, especially concerning production factors, primarily raw materials and labor. It also determines the accessibility to the target market. This is not only about transportation costs but also the speed of delivery. Location has the power to shape a company's business strategy, making it a driver of costs and revenues for the company. Therefore, the right location can be beneficial for the company, whereas an unsuitable location can reduce the company's effectiveness (Alfirah, n.d., 2018). There are three main points in establishing a successful Industrial Zone, and the location is one of the key points. Location plays a vital role in supporting the success of an Industrial Zone. It must be

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http://proceedings.itltrisakti.ac.id/index.php/altr

close to various transportation facilities, such as national highways, railway stations, or even ports. The more diverse transportation modes available, the higher the chances of success for the industrial zone (Karawang New Industry City, 2019).

2.2 Methods for Determining Facility Locations

ccording to Regulation of the Minister of Industry No. 40 of 2016, it states that "The selection of the location for the development of Industrial Zones is carried out using two approaches: (1) for areas that already have industrial growth based on market orientation, the land demand approach is used. An area can be considered suitable for development as an Industrial Zone if the average annual demand for industrial land in that area is approximately 7-10 hectares or the development of manufacturing industries with a minimum growth rate of five business units, where one manufacturing business unit requires around 1.32 - 1.34 hectares of land; and (2) for areas that have the potential of natural resources as industrial raw materials in order to increase added value, new growth poles need to be created."

Center of Gravity Method

This study employs one of the distribution methods, namely the Center of Gravity Method. This method is a mathematical technique used to find the most suitable location for a single distribution point serving multiple areas. The method takes into account the distance to customer locations, the quantity of goods to be shipped, and the shipping costs. The primary considerations of this method include the transportation costs of products from the factory to the destination, the location of the central distribution facility situated at the center of gravity between the destination locations and the factory, and it is further optimized using a grid (Cartesian coordinates).

Factor Rating Method

The factor rating method is a technique for determining a company's location by assigning scores to each primary and secondary factor for each alternative location (Pradana et al., 2021). The scores typically range from 0 (zero) to 100 (one hundred). For instance, if a primary or secondary factor at a location is considered to be available under very satisfactory conditions, it is assigned a score of 100. Conversely, if a primary or secondary factor is not available at that location, it is given a score of 0. This method allows for a structured evaluation of location options based on these assigned scores, as described by Andayani et al. in 2019.

3. Research method

This research will employ a quantitative research approach. To determine alternative Industrial Zone locations, it requires the calculation of coordinate points for potential alternative

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http://proceedings.itltrisakti.ac.id/index.php/altr

locations, weighting, and assessment of each potential alternative location, and the calculation of transportation cost differences for each potential alternative location.

3.1 Center Of Gravity

It begins with determining the coordinates of alternative locations using the Center of Gravity Method. The first step in the Center of Gravity Method is to place the locations on a coordinate system. The center of gravity is determined using the following equation:

$$C_x = \frac{\sum(Di_x . Wi)}{\sum Wi}$$

$$C_y = \frac{\sum(Di_y . Wi)}{\sum Wi}$$

Where:
C_x = x-coordinate of the center of gravity
C_y = y-coordinate of the center of gravity
Di_x = x-coordinate of location i
Di_y = y-coordinate of location i
Wi = The volume of goods being moved to or from location i.

3.2 Factor Rating

By examining the results of the selection of alternative locations for the new Industrial Zone, the factors influencing location selection are identified. Subsequently, calculations are performed to assign weights to each of the predetermined alternative Industrial Zone locations.

he Factor Rating method for ranking factors consists of six steps in the following sequence (Heizer & Render, 2008):

a. Identifying the Factors Requiring Analysis in the Location Selection or Construction of a Factory
b. In this step, evaluate each factor by assigning weights to them. The principle is that the higher the weight, the more significant the factor in the decision-making process. The total weight typically ranges from 1% to 100%.
c. Selecting alternative locations is a critical step in the decision-making process because the initially planned location may not always be the most suitable due to various unforeseen circumstances. Therefore, it's essential to identify alternative locations to

ISSN: 2622-5778 (online)
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http://proceedings.itltrisakti.ac.id/index.php/altr

anticipate unexpected challenges or changes in the business environment. This step ensures flexibility and adaptability in your decision-making process.

d. Provide an assessment for each of the alternative locations. The scores that will be given will range from 0 to 100.
e. Calculate the total score derived from each alternative location. This can be done by multiplying the weights with the predetermined factors for each location.
f. Now you need to compare which alternative location has the highest score.

Lokasi yang dipilih adalah lokasi yang mempunyai jumlah nilai\(skor) yang paling banyak (untuk faktor keunggulan) dibandingkan dengan jumlah nilai (skor) yang dicapai alternatif-alternatif lokasi lainnya. Bobot diperoleh dari Kuisoner yang telah dibagikan kepada staff Direktorat Perwilayahan Industri Kementrian Perindustrian RI. Lokasi yang terpilih adalah lokasi yang memiliki bobot yang paling tinggi.

Calculation of Sub-Factor Weights

In calculating the weights for each sub-factor, the results from the previous questionnaire summary are used. The formula used to calculate the average weight is as follows.

$$Weight = \frac{\sum The\ weight\ of\ each\ respondent}{\sum Respondents}$$

$$Presentase = \frac{Weight}{\sum The\ weight\ of\ each\ sub\ factor\ x\ 100\%}$$

The calculation of the value for each location in the New Industrial Area.

The calculation of the values in the factor rating method is obtained from the weight calculations based on the questionnaires provided to relevant parties in the company. The formula used for calculating the values for alternative locations is as follows.

$$Value = \frac{\sum Assessment\ of\ each\ respondent}{\sum Respondent}$$

$$weight\ = Valuex\ Percentage\ of\ Weight$$

ISSN: 2622-5778 (online)
Advances in Transportation and Logistics Research
http://proceedings.itltrisakti.ac.id/index.php/altr

Transportation cost calculation

After obtaining the alternative Industrial Area locations using the center of gravity method and the factor rating method, the next step is to calculate the distance from the Industrial Area alternatives to the Port. Subsequently, transportation cost calculations are carried out for each potential alternative location .

Transportation cost is calculated by multiplying the vehicle's operational cost per distance by the distance from the prospective New Industrial Area to the Port. Subsequently, a comparison of transportation costs is made for each method of determining the new Industrial Area alternative. The formula to calculate the cost per distance will be as follows.

$$Cost\ per\ Distance = \frac{Vehicle\ Operational\ Cost\ per\ Week}{\sum Total\ Distance\ Traveled\ per\ Week}$$

4. Results and discussion

4.1 Center of Gravity Method Calculation

The calculation using the center of gravity method is done using coordinate points and the quantity of demand that has been obtained. The coordinate points and quantity of demand used for the center of gravity method calculation can be seen in Table 1:

Tabel 1.
Center Of Gravity Method Calculation

Kabupaten/Kota	*Koordinat X(Dix)**	*Koordinat Y(Diy)**	*Berat Volume Ekspor (RibuTon)(W*	*Dix . Wi*	*Diy . Wi*
Bantaeng	-5,49548500	119,8997100	2.525,31	-13877,80323	302783,9367
Barru	-4,3655770	119,672356	2.525,31	-11024,43525	302209,7973
Bone	-4,938585	120,235353	2.525,31	-12471,45809	303631,5393
Bulukumba	-5,601560	120,433352	2.525,31	-14145,67548	304131,5481
Enrekang	-3,462863	119,854308	2.525,31	-8744,802563	302669,2825
Gowa	-5,173664	119,565084	2.525,31	-13065,10544	301938,9023
Jeneponto	-5,591873	119,862054	2.525,31	-14121,21281	302688,8436
Luwu	-3,390109	120,328322	2.525,31	-8561,076159	303866,3148
Luwu Timur	-2,570123	120,803525	2.525,31	-6490,357313	305066,3497

ISSN: 2622-5778 (online)
Advances in Transportation and Logistics Research
http://proceedings.itltrisakti.ac.id/index.php/altr

Luwu Utara	-2,607665	120,606173	2.525,31	-6585,162501	304567,9747
Maros	-5,098337	119,551007	2.525,31	-12874,88141	301903,3535
Pangkajene	-4,738280	119,637651	2.525,31	-11965,62587	302122,1564
Pinrang	-3,936415	119,622544	2.525,31	-9940,668164	302084,0066
Sindrap	3,791681	119,994007	2.525,31	9575,169946	303022,0658
Sinjai	-5,141171	120,211383	2.525,31	-12983,05054	303571,0076
Soppeng	-4,518190	119,800376	2.525,31	-11409,83039	302533,0875
Takalar	-5,409687	119,455546	2.525,31	-13661,13668	301662,2849
Tana Toraja	-3,254789	119,884685	2.525,31	-8219,35121	302745,9939
Toraja Utara	-3,026899	119,875235	2.525,31	-7643,858314	302722,1297
Kep. Selayar	-6,126522	120,472512	2.525,31	-15471,36727	304230,4393
Kab21 Wajo	-3,937449	120,043146	2.525,31	-9943,279334	303146,157
Kota Palopo	-2,999849	120,180475	2.525,31	-7575,548678	303492,9553
Kota Parepare	-4,024318	119,635290	2.525,31	-10162,65049	302116,1942
Makassar	-5,116510	119,442315	2.525,31	-12920,77387	301628,8725
JUMLAH			**60.607**	**-244283,9411**	**7270535,193**

Then, the calculation of the coordinate points for the alternative locations of the new Industrial Area is performed using formulas 8, 9, 10, and 11.

Calculation of X-coordinate Points

$$C_x = \frac{244.283,9411}{60.607}$$

$$C_x = -4,030593292$$

Calculation of Y-coordinate Points

$$C_x = \frac{7270535,193}{60.607}$$

$$C_x = 119,9611004$$

Based on the coordinate point calculations, the potential location for the new Industrial Area is determined to be in the Belawa area, Wajo Regency, South Sulawesi.

ISSN: 2622-5778 (online)
Advances in Transportation and Logistics Research
http://proceedings.itltrisakti.ac.id/index.php/altr

Identification of Factors and Sub-Factors

In the selection of factors for the factor rating method, the process involves evaluating and selecting predetermined factors and sub-factors related to the criteria for choosing the location of the Industrial Area, as outlined in the Minister of Industry Regulation No. 40/M IND/PER/6/2016. The selected factors and sub-factors can be found in Table 2.

Tabel 2
Identification of Factors and Sub-Factors

No.	*Faktor*	*Sub Faktor*
1.	Biaya	Biaya Pengangkutan
2.	Jarak	Jarak Lokasi Alternatif ke Pelabuhan
		Jarak Lokasi Alternatif ke Pusat kota min. 10 km
		Jarak Lokasi Alternatif ke Pemukiman min. 2 km
3.	Waktu	Waktu tempuh ke Pelabuhan
4.	Transportasi	Ketersediaan pengangkutan lainnya
		Kemudahan akses untuk alat angkut besar
5.	Lingkungan	Ketersediaan tenaga kerja di Lokasi
		Persetujuan Masyarakat Sekitar
		Kemudahan perizinan lokasi
		Keamanan lokasi
6.	Infrastruktur	Ketersediaan jaringan listrik
		Ketersediaan sumber air baku
		Ketersediaan jaringan Komunikasi
7.	Kondisi Lahan	Topografi: max. 15%
		Kesuburan tanah relatif tidak subur (non-irigasi teknis)
		Pola tata guna lahan: nonpertanian, nonpermukiman, dan nonkonservas
		Ketersediaan lahan minimal 50 ha
		Harga lahan relatif (bukan merupakan lahan dengan harga yang tinggi di daerah tersebut)

ISSN: 2622-5778 (online)
Advances in Transportation and Logistics Research
http://proceedings.itltrisakti.ac.id/index.php/altr

Assignment of Sub-Factor Weights

The assignment of weights to each sub-factor is done by using a questionnaire distributed to the staff of the Directorate of Industrial Areas of the Ministry of Industry of the Republic of Indonesia. An interval scale, ranging from 1 to 10, will be used to assess the importance level of each sub-factor and determine the order of importance among sub-factors.

Tabel 3.
Recapitulation of the weight calculations for each sub-factor

No.	*Sub Faktor*	*Bobot*	*Presentase*
1.	Biaya Pengangkutan	9,1	5,21%
2.	Jarak Lokasi Alternatif ke Pelabuhan	9	5,15%
3.	Jarak Lokasi Alternatif ke Pusat kota min. 10 KM	9,1	5,21%
4.	Jarak Lokasi Alternatif ke Pemukiman min. 2 KM	9,1	5,21%
5.	Waktu Tempuh ke Pelabuhan	9,3	5,32%
6.	Ketersediaan Pengangkutan Lainnya	8,9	5,09%
7.	Kemudahan Akses untuk Alat Angkut Besar	9,3	5,32%
8.	Ketersediaan Tenaga Kerja di Lokasi	9,1	5,21%
9.	Peretujuan Masyarakat Sekitar	9,6	5,50%
10.	Kemudahan Perizinan Lokasi	9,6	5,50%
11.	Keamanan Lokasi	9,8	5,61%
12.	Ketersediaan Jaringan Listrik	9,7	5,55%
13.	Ketersediaan Sumber Air Baku	9,8	5,61%
14.	Ketersediaan Jaringan Komunikasi	9,5	5,44%
15.	Topografi min.15%	8,9	5,09%
16.	Kesuburan Tanah Relatif Tidak Subur	8	4,58%

ISSN: 2622-5778 (online)
Advances in Transportation and Logistics Research
http://proceedings.itltrisakti.ac.id/index.php/altr

	(Non-Irigasi Teknis)		
17.	Pola Tata Guna Lahan. Non Pertanian, non pemukiman, dan Non Konservasi	8,9	5,09%
18.	Keterserdiaan Lahan min. 50 Ha	9	5,15%
19.	Harga Lahan Relatif (Bukan Merupakan Lahan dengan Harga yang Tinggi di Daerah Tesebut).	9	5,15%
	Total		**100%**

It can be observed that location security and the availability of raw water sources are sub-factors with the highest level of importance, at 5.61%. Meanwhile, the sub-factor of Relatively Infertile Soil (Non-Technical Irrigation) is the sub-factor with the lowest level of importance, at 4.58%.

Calculation of the Value for Each New Industrial Area Location

In the factor rating method calculation, both proposed locations from the company's existing sites and alternative locations resulting from the center of gravity method are used. As a result, there are 2 locations: Location 1, which is an alternative location determined using the center of gravity method, located in the Belawa area, Wajo Regency, South Sulawesi, and Location 2, proposed by PT. Kawasan Industri Makassar, which is in the Marusu area, Maros District, South Sulawesi. The calculation of values in the factor rating method is derived from the weight calculations obtained from the questionnaires given to relevant parties within the company, using formulas 5 and 6.

ISSN: 2622-5778 (online)
Advances in Transportation and Logistics Research
http://proceedings.itltrisakti.ac.id/index.php/altr

Table 4
Calculation of the Factor Rating Method

			Lokasi 1		*Lokasi 2*	
No.	***Sub faktor***	***Presentase***				
			Bobot	***Nilai***	***Bobot***	***Nilai***
1.	Biaya Pengangkutan	5,21%	0,38	7,2	0,45	8,6
2.	Jarak Lokasi Alternatif ke Pelabuhan	5,15%	0,4	7,8	0,46	8,9
3.	Jarak Lokasi Alternatif ke Pusat kota min. 10 KM	5,21%	0,38	7,3	0,43	8,2
4.	Jarak Lokasi Alternatif ke Pemukiman min. 2 KM	5,21%	0,42	8	0,43	8,2
5.	Waktu Tempuh ke Pelabuhan	5,32%	0,39	7,4	0,48	9
6.	Ketersediaan Pengangkutan Lainnya	5,09%	0,39	7,6	0,44	8,6
7.	Kemudahan Akses untuk Alat Angkut Besar	5,32%	0,38	7,2	0,46	8,7
8.	Ketersediaan Tenaga Kerja di Lokasi	5,21%	0,41	7,9	0,46	8,9

ISSN: 2622-5778 (online)
Advances in Transportation and Logistics Research
http://proceedings.itltrisakti.ac.id/index.php/altr

9.	Peretujuan Masyarakat Sekitar	5,50%	0,46	8,3	0,49	8,9
10.	Kemudahan Perizinan Lokasi	5,50%	0,48	8,7	0,49	9
11.	Keamanan Lokasi	5,61%	0,49	8,7	0,5	8,9
12.	Ketersediaan Jaringan Listrik	5,55%	0,47	8,4	0,49	8,8
13.	Ketersediaan Sumber Air Baku	5,61%	0,46	8,2	0,48	8,6
14.	Ketersediaan Jaringan Komunikasi	5,44%	0,39	7,2	0,48	8,9
15.	Topografi min.15%	5,09%	0,36	7,1	0,43	8,4
16.	Kesuburan Tanah Relatif Tidak Subur (Non-Irigasi Teknis)	4,58%	0,34	7,4	0,37	8
17.	Pola Tata Guna Lahan. Non Pertanian, non pemukiman, dan Non Konservasi	5,09%	0,37	7,2	0,42	8,3
18.	Keterserdiaan Lahan min. 50 Ha	5,15%	0,42	8,2	0,44	8,6

ISSN: 2622-5778 (online)
Advances in Transportation and Logistics Research
http://proceedings.itltrisakti.ac.id/index.php/altr

19.	Harga Lahan Relatif (Bukan Merupakan Lahan dengan Harga yang Tinggi di Daerah Tesebut).	5,15%	0,43	8,3	0,44	8,6
	Total	**100%**	**7,81**	**148,1**	**8,65**	**164,1**

Analysis of Alternative Locations for the New Industrial Area using the Center of Gravity Method

The determination of the coordinate point for the potential alternative location of the new Industrial Area is carried out using Google Maps. To establish the new X and Y coordinates, the existing coordinate points are multiplied by the average weight of the export volume of South Sulawesi Province. The results of this multiplication are then summed and divided by the total export volume to obtain the midpoint or the strategic location result using the Center of Gravity method. The calculation with the Center of Gravity method resulted in the coordinates X = -4.030593292 and Y = 119.9611004. According to the coordinates on Google Maps, this point is located in the Belawa sub-district, Wajo Regency, South Sulawesi.

Analysis of Alternative Locations for the New Industrial Area using the Factor Rating Method

The determination of the location for the new Industrial Area in the factor rating method is based on the results of questionnaires where the respondents are the staff of the Directorate of Industrial Areas of the Ministry of Industry of the Republic of Indonesia. Additionally, there are additional alternative locations for the new Industrial Area obtained from the use of the Center of Gravity method. The first alternative location, hereafter referred to as Location 1, is situated in the Belawa area, Wajo Regency. The second alternative location, hereafter referred to as Location 2, is located in the Marusu area, Maros Regency. The selection of Location 2 is due to the fact that it was proposed by PT. Kima for the construction of the new Industrial Area, as it is considered a potential location given its proximity to Makassar. The weighting and assessment conducted indicate that Location 2, Marusu, Maros Regency, South Sulawesi, has the highest weight, which is 8.65.

ISSN: 2622-5778 (online)
Advances in Transportation and Logistics Research
http://proceedings.itltrisakti.ac.id/index.php/altr

Transportation Costs

Transportation cost calculations are performed by multiplying the total distance traveled by the cost per unit distance. The cost per unit distance incurred by the company is Rp 58,701 per kilometer. This cost per unit distance is then used to calculate the transportation cost for the prospective locations of the new Industrial Area. The summary of transportation cost calculations for the new Industrial Area using both the Center of Gravity and Factor Rating methods can be found in Table 5.

Table 5:
Summary of Transportation Cost Calculations

Alternatif Kawasan Industri baru		
BOK Kawasan Industri Lama/RIT	***Center Of Grafity/RIT***	***Factor Rating/RIT***
Rp1.526.239	Rp23.950.216	Rp. 2.406.762

Based on Table 5, it can be observed that the difference in transportation costs between the Center of Gravity method and the Factor Rating method is Rp 21,543,454. Additionally, the total distance in the Center of Gravity method is higher than that in the Factor Rating method. Therefore, the Factor Rating method is chosen as the location for the development of the new Industrial Area because it has the lowest transportation cost and distance compared to the Center of Gravity method. The new Industrial Area location in Marusu, Maros Regency is also close to Makassar and the airport. Furthermore, it aligns with the National Spatial Planning (RTRW) system since Maros is part of the National Activity Center (Pusat Kegiatan Nasional or PKN), an urban area that functions as a center for industrial and service activities. It is also part of the National Strategic Area (Kawasan Strategis Nasional or KSN) of South Sulawesi Province in terms of economic growth interests.

ISSN: 2622-5778 (online)
Advances in Transportation and Logistics Research
http://proceedings.itltrisakti.ac.id/index.php/altr

5. Conclusion

The result of the factor rating calculation, which has lower transportation costs and is closer to the port, will be used as the location for the new Industrial Area in South Sulawesi, specifically in the Marusu area, Maros Regency.

The Marusu area in Maros Regency meets the criteria for selecting an industrial area location as outlined in Minister of Industry Regulation No. 40 of 2016. It is situated 18 kilometers from the city center, 5 kilometers from residential areas, has access to primary arterial roads, a reliable electricity and telecommunications network, and is not far from both the seaport and the airport. There's a nearby river serving as a source of raw water and a location for industrial waste disposal. The topography doesn't exceed 15%, the land is non-irrigated, non-agricultural, non-residential, and non-conservation. Moreover, it offers more than 50 hectares of land, although the pricing is relatively high. Additionally, Marusu in Maros Regency is in close proximity to Makassar and the airport. It aligns with the National Spatial Planning (RTRW) system as it falls under the National Activity Center (Pusat Kegiatan Nasional or PKN), an urban area that functions as a center for industrial and service activities. It is also part of the National Strategic Area (Kawasan Strategis Nasional or KSN) of South Sulawesi Province, supporting economic growth objectives.

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