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Fuel Stations Location Suitability Analysis in Bandar Lampung Using Geographic Information System

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ABSTRACT

Bandar Lampung is identified as one of the densely populated urban centers in Indonesia. As the population increases, the ownership of motorized vehicles using gasoline is also on the rise. This has led to a growth in the construction of fuel stations, which needs to be examined from various aspects, one of which is land suitability. This research aims to identify the distribution of fuel stations, determine the parameters used, and analyze the level of suitability of fuel stations in Bandar Lampung. The spatial data used in this study includes the National Spatial Plan of Bandar Lampung for the period 2021-2041 and the coordinates of fuel stations in Bandar Lampung. Additionally, non-spatial data such as questionnaire results and field validations are also utilized. The methods applied are the Analytical Hierarchy Process (AHP) and overlay. Based on the results obtained, there are 33 fuel station scattered across 17 out of 20 districts in Bandar Lampung and there are three districts that do not yet have fuel stations namely Tanjung Karang Barat, Tanjung Karang Timur, and Teluk Betung Barat. The parameters used in this study are four: road function, distance between fuel stations, distance of fuel stations to residential areas, and areas prone to landslide disasters. The level of suitability of fuel stations is classified into three categories: highly suitable, suitable, and less suitable. Out of the 33 fuel stations, 32 are classified as very suitable, and 1 is classified as suitable.

I. Introduction

According to data from the National Statistics Agency, the population growth in Indonesia continues to increase each year. The population in Indonesia reached 275 million people in 2022 [1]. Alongside the growth in population, the demand for and ownership of motorized vehicles in Indonesia are also considerably high, especially in large cities [2]. As one of the major cities in Indonesia, Bandar Lampung faces similar challenges. Regulation Number 13 of 2017 on Amendments to Government Regulation Number 26 of 2008 concerning the National Spatial Plan designates Bandar Lampung as the capital of Lampung Province with an urban system as the National Activity Center [3]. Bandar Lampung covers an area of 183,627 km^2 with a population of 1,209,937 people [1]. Considering its land area and population, Bandar Lampung is categorized as one of the major cities that is densely populated. This is closely related to the increasing ownership of motorized vehicles and the demand for motor fuel.

With the increasing demand for fuel in the community, especially among those using motorized vehicles with fuel, the construction of fuel station is also rapidly expanding. Fuel station is a public facility provided as infrastructure for the general public to meet their motor fuel needs [4]. The development of fuel stations needs to be considered from the perspective of land suitability used as the location for its construction [5]. If a fuel station is not built in a suitable location, it has the

potential to cause various losses such as accidents involving humans and/or the environment, disruption of public traffic, fires, and so forth [6]. For instance, a fire occurred due to a leak from a tank pipe that released gas and caused a fire at an SPBU located on Soekarno-Hatta Street, Cibadak District, Lebak Regency, Banten [7].

The issuance of building construction approval in a specific area is carried out by the local government, taking into account various aspects suitable for the construction, including fuel stations development [5]. According to Law Number 22 of 2009 concerning Traffic and Road Transportation, before the issuance of PBG, a Traffic Impact Analysis needs to be conducted beforehand to ensure the location is safe and suitable for smooth traffic flow. However, in reality, traffic congestion due to queues of vehicles waiting to refuel often occurs at a fuel station located in the Panjang District [8]. This, of course, disrupts the activities of road users around fuel stations, emphasizing the importance of considering factors that may hinder community activities in the future when selecting fuel station's locations. Additionally, there are two fuel stations located opposite each other on Zainal Abidin Pagar Alam Street, Rajabasa District. The proximity of these two-fuel station is also a consideration for analyzing the suitability of land for fuel stations in Bandar Lampung.

Based on the explanation above, geospatial expertise is required to analyze the suitability of land for existing fuel stations in Bandar Lampung. This analysis can be conducted using the Analytical Hierarchy Process (AHP) method, followed by the overlay method. It is hoped that this research will provide insights into determining suitable fuel station locations. Additionally, the study is expected to serve as an estimation for authorities when making decisions regarding the establishment of fuel station locations in accordance with the land suitability level identified in the research.

II. Method

A. Location and Materials

This research was conducted in the city of Bandar Lampung, which consists of 20 districts. The data used in this study includes residential area data, road function data, areas prone to landslide disasters, and fuel stations coordinates in Bandar Lampung.

B. Stages in Reseacrh

The method employed in this research are the Analytical Hierarchy Process (AHP) and overlay. The following are the stages of calculating the weights of parameters and sub-parameters using AHP:

- Determination and arrangement of parameters and sub-parameters to be used in the research, referring to the criteria for fuel station locations by Pertamina such as being on an arterial road, not too close to other fuel stations, more than 150 m away from residential areas, not in an area prone to landslide disasters, and having a land area of 1,998 m^2 [9] and the National Spatial Plan in Bandar Lampung
- Assessment of parameters and sub-parameters is carried out by experts familiar with the research scope using a questionnaire sheet based on comparisons between variables considered to influence the level of suitability of fuel stations.
- Weighting using AHP is conducted by creating paired comparison matrices for parameters and sub-parameters used in the study, based on the data from questionnaires that have been completed by experts.
- Calculate the Consistency Index (CI) and Consistency Ratio (CR) to determine the consistency of the calculations that have been carried out. The values of CI and CR can be calculated using the following equation (1) and (2):

$$CI = \frac{(\lambda\ maks - n)}{n - 1} \quad (1)$$

$$CR = \frac{CI}{IR} \quad (2)$$

CI : Consistency Index

λ max : Maximum Eigen Value

n : Variables

CR : Consistency Ratio

CI : Consistency Index

IR : Index Random

- Determine whether the calculation results are consistent or not. If the CR value ≥ 0.1, a recalculation is performed. However, if the CR value < 0.1, the weights of parameters and sub-parameters can be used.

III. Result and Discussion

A. The Distribution of Built Fuel Stations

Based on data from the Department of Energy and Mineral Resources, the total number of fuel stations in Lampung Province is 146, with 33 of them located in Bandar Lampung. The established fuel stations in Bandar Lampung are spread across 17 out of the 20 existing districts. There are still 3 districts that do not have any fuel station distribution, namely Tanjung Karang Barat District, Tanjung Karang Timur District, and Teluk Betung Barat District. Based on this, it can be said that the distribution of fuel station in Bandar Lampung is not yet evenly spread across every district. Fig.3. show map of the distribution of fuel stations in Bandar Lampung.

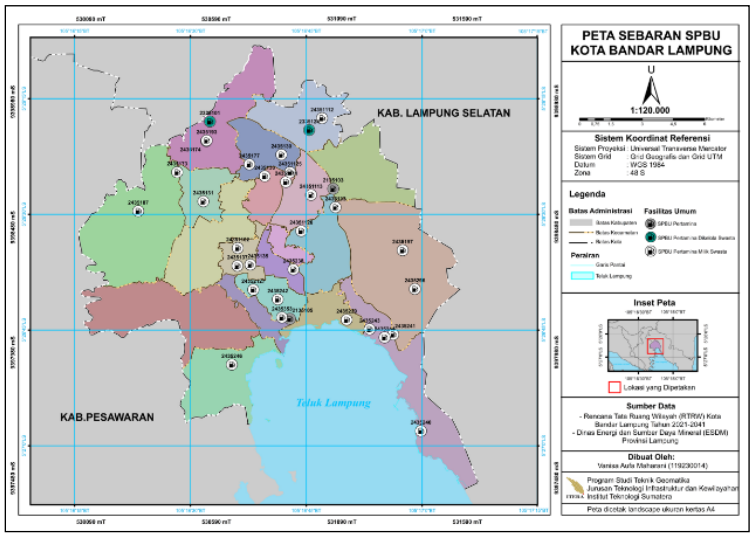

Fig. 1 Map of the Distribution of Fuel Stations in Bandar Lampung

B. Parameters for the Suitability Level of Gas Station

The parameters used in determining the level of land suitability consist of: road function, distance between fuel stations, distance of fuel stations to residential areas, and areas prone to landslide disasters.

- Road function: Based on Law Number 38 of 2006 concerning Roads, roads are transportation infrastructure and also one of the main factors in carrying out social and economic activities in daily life, providing a means of mobility for the community. Fuel stations can be considered strategically located and meet the criteria if they are situated on busy roads that are easily accessible by vehicles. Based on this aspect, road function is one of the parameters that can be considered in analyzing the level of land suitability for fuel stations in Bandar Lampung. As seen in Fig.2, Bandar Lampung is classified into five road functions: primary arterial road, secondary arterial road, primary collector road, secondary collector road, and local road.

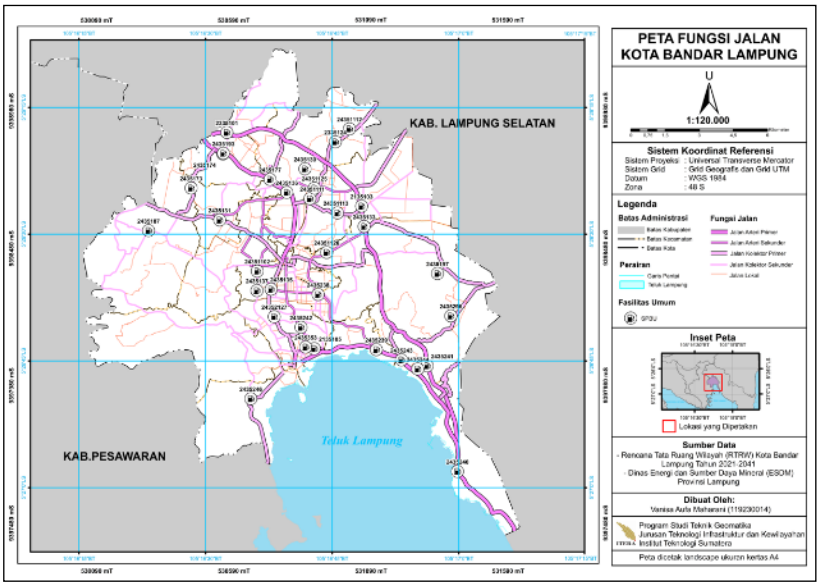

Fig. 2. Map of Road Function in Bandar Lampung

- The distance between fuel stations: One aspect of the criteria for the location of a fuel station is its strategic location. The criterion of a strategic location can be assumed that the construction of a gas station should preferably not be done close to other fuel stations. This makes the distance between fuel station one of the parameters that can be considered in analyzing the level of land suitability for fuel stations in Bandar Lampung. As seen in Fig.3, it displays how close the distance is between fuel stations in Bandar Lampung.

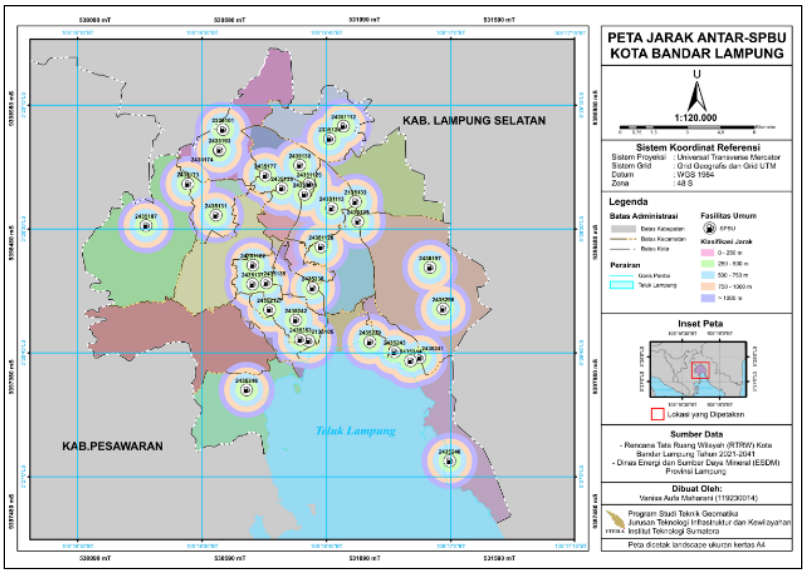

Fig. 3. Map of the distance between fuel stations

- The distance of fuel stations to residential areas: Based on the National Spatial Plan of Bandar Lampung for the period 2021-2041, residential areas in Bandar Lampung are divided into four zones: public and social facilities area (including education, worship, health, sports, and other public facilities), urban infrastructure area, residential area, and non-green open space area. It can be observed that several districts have limited residential areas, including Sukabumi District, Teluk Betung Timur District, Teluk betung Barat District, Panjang District, and Enggal District. The map of the distance between fuel stations and residential areas is presented in Fig.4. One aspect of the criteria for the location of fuel station is a strategic location, which states that fuel stations can be considered strategic if it is a minimum of 100 m away from public facilities.

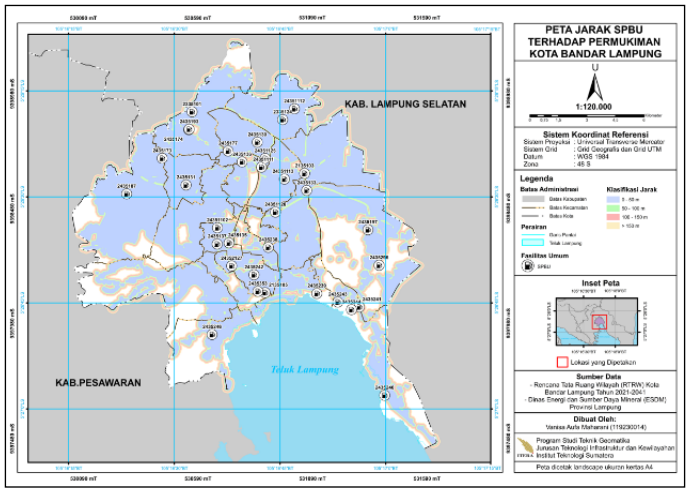

Fig. 4. Map of the distance of fuel stations to residential areas

- The areas prone to landslide disasters: Fig.5 displays areas prone to landslide disasters in the city of Bandar Lampung. One aspect of the criteria for the location of a fuel station is a strategic location or not being in disaster-prone areas such as landslide-prone or flood-prone areas. Referring to this location criterion, susceptibility to landslide disasters is used as one of the parameters in analyzing the level of land suitability for fuel stations.

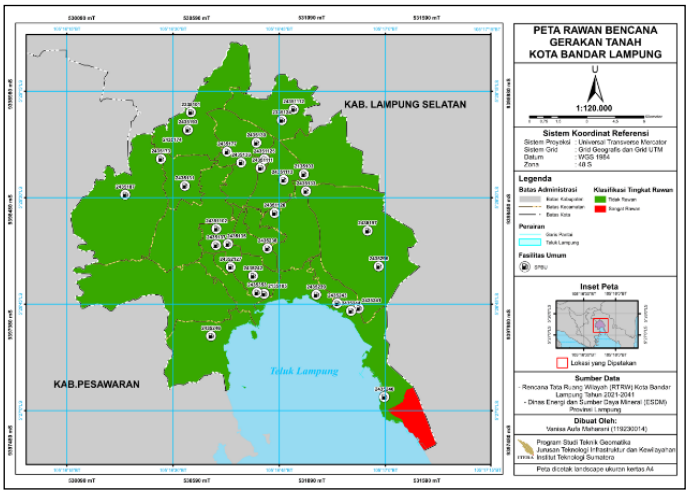

Fig. 5. Map of the areas prone to landslide disasters

C. Results of Weighting Using AHP

The hierarchy structure of priority factors in determining the land suitability level for fuel stations in Bandar Lampung is presented in Fig.6 by [10].

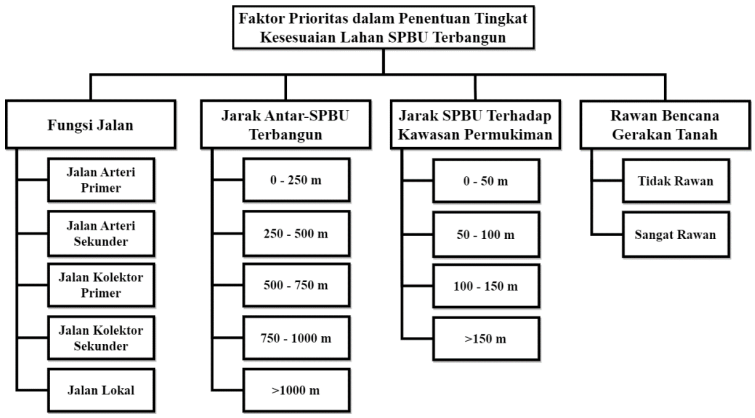

Fig. 6. The hierarchy structure of priority factors

The assignment of weight values to parameters and sub-parameters in Fig.6 is based on the data obtained from the questionnaire responses provided by experts who are considered to understand the scope of the study. The experts serving as respondents in this research have specific criteria. The targeted respondents include officials from the Energy and Mineral Resources Agency of Lampung Province, the Housing and Settlement Agency of Bandar Lampung City, the Transportation Agency of Bandar Lampung City, and lecturers from the Regional and Urban Planning Study Program at the Institute of Technology Sumatera.

The data from the questionnaires filled out by the experts will be used to determine priority parameters in determining the level of land suitability for fuel stations, which will then be organized in the form of a pairwise comparison matrix. After constructing the pairwise comparison matrix, the consistency calculation is carried out. The results of the CR (Consistency Ratio) calculation and the weights of each parameter are presented in Table 1.

Table 1. The Results of Parameter Value Calculation

Parameters	***CR Value***	***Weight***	***Percentage (%)***
Road Function	0.005	0.083	8.3
The distance between fuel stations		0.086	8.6
The distance of fuel stations to residential areas		0.210	21.0
The areas prone to landslide disasters		0.621	62.1
Total		1	100

It can be observed that the CR value in the calculation results of the parameter values meets the standard consistency requirements, with a CR value of 0.055, indicating consistent results. It can also be seen that the parameter with the highest contribution is susceptibility to landslide disasters with a weight of 0.621 or 62.1%. The diagram of priority parameters in determining the level of land suitability for fuel stations in Bandar Lampung is presented in Fig.7.

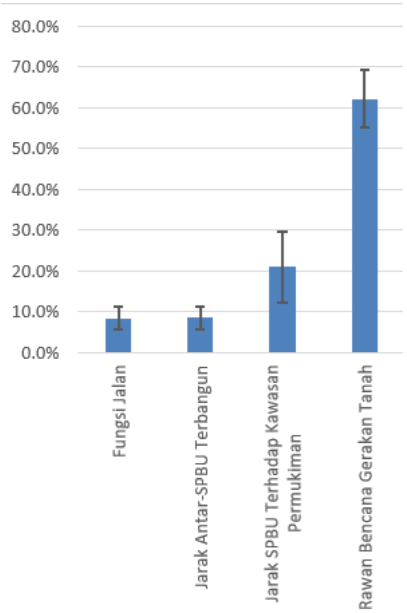

Fig. 7. Percentage Diagram of Parameter Value Calculation Results.

The parameters used have sub parameters with different roles in analyzing the level of land suitability for fuel stations. Based on the data from the questionnaire responses provided by experts, weight values for each sub parameter were obtained in determining the level of land suitability for

fuel stations in Bandar Lampung. The following are the results of the assessment of the weights for each sub parameter used:

- Road function It can be seen from the table above that the calculation of the road function sub parameter is consistent with a CR value of 0.068. The weight values shown in the table indicate that the classification of the primary arterial road function is a sub parameter that has the highest contributing role compared to other road functions. The weight value for the primary arterial road function sub parameter is 0.435 or 43.5%. This also indicates that the primary arterial road function is the most suitable road function for the location of fuel stations. Arterial roads are designed with a minimum road width of 11 meters, so it can be said that this will not disturb the mobility of consumers visiting the Gas Station. In addition, the arterial road function will not significantly disrupt traffic flow when the demand for fuel from consumer increases, thus avoiding traffic congestion. The classification of road function can be seen in Table 2.

Table 2. The classification of road function

Sub parameters	***CR Value***	***Weight***	***Percentage (%)***
Primary arterial road	0.068	0.435	43.5
Secondary arterial road		0.271	27.1
Primary collector road		0.128	12.8
Secondary collector road		0.109	10.9
Local road		0.057	5,7
Total		1	100

- The distance between fuel stations: It can be seen from the Table 3 that the calculation of the fuel stations distance sub parameter is consistent with a CR value of 0.025. The weight values in the table indicate that the classification of the nearest distance >1000 m between fuel stations is a sub parameter that has the highest contributing role compared to other distances between fuel stations. The weight value for the >1000 m distance sub parameter is 0.422 or 42.2%. If fuel stations are located close to each other, it can be assumed that the level of competition between fuel stations owners will be higher. However, this is different for the two fuel stations opposite each other in the Rajabasa District. According to experts, this is efficient because the two fuel stations are on different road segments, so they will not disrupt traffic or cause congestion. Drivers on both the left and right sides of the road can purchase fuel at the nearest fuel stations on the road they are currently on.

Table 3. The classification of the distance between fuel stations

Subparameters	***CR Value***	***Weight***	***Percentage (%)***
0 – 250 m	0.025	0.066	6.6
250 – 500 m		0.105	10.5
500 – 750 m		0.149	14.9
750 – 1000 m		0.258	25.8
>1000 m		0.422	42.2
Total		1	100

- The distance of fuel stations to residential areas: It can be seen from the Table 4 that the calculation of the sub parameter "distance from fuel stations to residential areas" is consistent with a CR value of 0.092. The weight values in the table indicate that the classification of the distance >150 m from the Gas Station to residential areas is a sub parameter that has the highest contributing role compared to other distances from fuel stations to residential areas. The weight value for the >150 m distance sub parameter is 0.554 or 55.4%.

Table 4. The classification of the distance of fuel stations to residential areas

Sub Parameters	*CR Value*	*Weight*	*Percentage (%)*
0 – 50 m	0.092	0.050	5
50 – 100 m		0.098	9.8
100 – 150 m		0.298	29.8
>150 m		0.554	55.4
Total		1	100

References [11] states that residential areas should be equipped with a public facility environment that provides services to meet the needs of the community. Given the high population density that corresponds to the increasing number of motorized vehicles fuel stations become one of the public facilities that need to be built near residential areas. However, fuel stations should not be built too close to residential areas because if unfavorable events like fires occur at fuel stations, it can also adversely affect and pose a threat to the surrounding residential areas. Therefore, a distance >150 m is considered the optimal distance for fuel stations from residential areas.

- The areas prone to landslide disasters: It is evident that the results of the calculation for the sub parameter susceptibility to landslide disasters are consistent with a CR value of 0.000. The location of fuel stations must consider areas that are potentially prone to natural disasters, including landslide disasters. Looking at the weight values in the table above, it is clear that the classification of the non-prone class is the sub parameter with the highest contribution, with a weight of 0.889 or 88.9%. If a fuel station is built in a location classified as highly susceptible to landslide disasters, it can cause losses for the business and the company by potentially damaging the fuel pump equipment at that fuel station. Additionally, areas prone to landslide disasters are closely related to steep locations and have many hilly areas, such as in Panjang District. This could disrupt the mobility of consumers visiting the fuel station, especially heavy-loaded vehicles like trucks or buses.

Table 5. Classification of the Level of Susceptibility to Landslide Disasters

Sub Parameters	*CR Value*	*Weight*	*Percentage (%)*
Not Vulnerable	0.000	0.889	88.9
Highly Vulnerable	0.000	0.111	11.1
Total		1	100

D. The Level of Suitability of Fuel Stations in Bandar Lampung

After calculating the weight values based on the questionnaire data, the classification of the level of fuel stations land suitability will be obtained. This classification is derived from the overlay results of parameters and sub-parameters that have been determined. The parameters overlaid include road function, distance between fuel stations, distance of fuel stations to residential areas, and susceptibility to landslide disasters. The level of suitability of fuel stations in Bandar Lampung is classified into three classes, as presented in Table 6.

Table 6. Classification of Fuel Stations Land Suitability Level

Class Interval	*Classification*	*Area (ha)*	*Percentage (%)*
0 – 1.218	Less Suitable	2,228.580	12.136
1.218 – 2.436	Suitable	10,021.523	54.575
2.436 – 3.766	Very Suitable	6,122.631	33.288
Total		18,362.734	100

Based on this classification, the map of the suitability level of fuel stations in Bandar Lampung is obtained, as presented in Fig. 8.

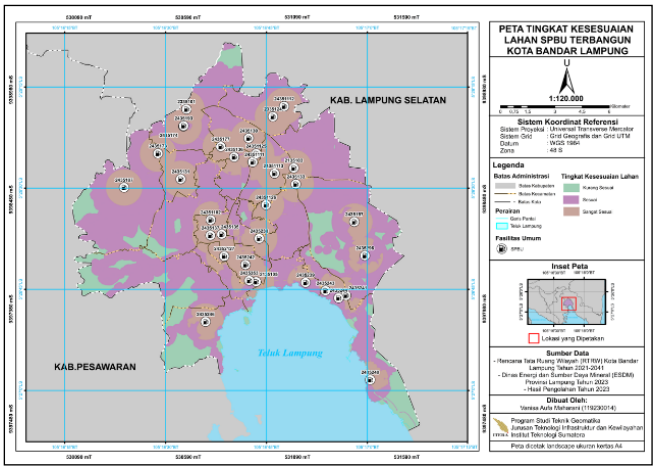

Fig. 8. The map of the suitability level of fuel stations in Bandar Lampung

The total number of fuel stations in Bandar Lampung are 33. As seen in Fig.8 and the results of the land suitability analysis, the fuel stations in Bandar Lampung are only classified into two levels of land suitability: suitable and very suitable. Specifically, there are 32 fuel stations classified into the very suitable level and 1 fuel station classified into the suitable level, as shown in Table 7.

Table 7. The classification of the suitability of fuel stations in Bandar Lampung

No	*District*	*Latitude (°)*	*Longitude (°)*	*Classification*
1	Sukarame	-5.727	105.648	Highly Suitable
2	Teluk Betung Selatan	-5.445	105.288	Highly Suitable
3	Rajabasa	-5.359	105.235	Highly Suitable
4	Rajabasa	-5.368	105.234	Highly Suitable
5	Rajabasa	-5.368	105.234	Highly Suitable
6	Tanjung Senang	-5.363	105.278	Highly Suitable
7	Tanjung Senang	-5.358	105.283	Highly Suitable
8	Labuhan Ratu	-5.374	105.266	Highly Suitable
9	Labuhan Ratu	-5.378	105.252	Highly Suitable
10	Langkapura	-5.394	105.232	Highly Suitable
11	Kedamaian	-5.397	105.289	Highly Suitable
12	Kedamaian	-5.407	105.275	Highly Suitable
13	Tanjung Karang Pusat	-5.421	105.253	Highly Suitable
14	Tanjung Karang Pusat	-5.422	105.247	Highly Suitable
15	Tanjung Karang Pusat	-5.414	105.247	Highly Suitable
16	Kedaton	-5.383	105.259	Highly Suitable
17	Kedaton	-5.386	105.268	Highly Suitable
18	Kedaton	-5.381	105.270	Highly Suitable
19	Kemiling	-5.381	105.221	Highly Suitable
20	Kemiling	-5.398	105.204	Highly Suitable
21	Sukabumi	-5.415	105.381	Highly Suitable
22	Sukabumi	-5.432	105.342	Highly Suitable
23	Enggal	-5.423	105.271	Highly Suitable
24	Bumi Waras	-5.445	105.294	Highly Suitable
25	Panjang	-5.493	105.326	Highly Suitable
26	Panjang	-5.452	105.314	Highly Suitable
27	Panjang	-5.449	105.304	Highly Suitable

No	*District*	*Latitude (°)*	*Longitude (°)*	*Classification*
28	Panjang	-5.453	105.312	Suitable
29	Teluk Betung Utara	-5.436	105.264	Highly Suitable
30	Teluk Betung Utara	-5.444	105.266	Highly Suitable
31	Teluk Betung Utara	-5.432	105.254	Highly Suitable
32	Teluk Betung Timur	-5.465	105.245	Highly Suitable
33	Way Halim	-5.391	105.279	Highly Suitable

Based on the table above, the map of suitability for fuel stations in the city of Bandar Lampung can be seen in Fig. 9.

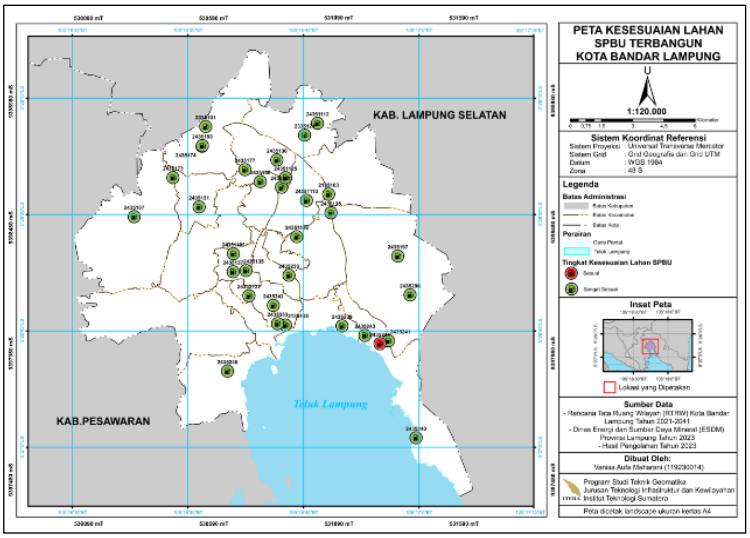

Fig. 9. The map of the suitability of fuel stations in Bandar Lampung

After obtaining the classification of the land suitability level, field validation can be conducted, referring to the parameters of fuel stations suitability level and Pertamina's criteria for fuel station's locations. Field validation is conducted within Panjang District for one of the fuel stations classified at the suitable level.

Based on the results of field validation, one of the coordinates of the fuel station location do not match the actual location. The fuel station with the code 2435244 should be located in the Bumi Waras District, with latitude -5.435° and longitude 105.285°. Based on the actual coordinates, this fuel station should be classified as very suitable because it meets all the parameters and criteria for fuel station's locations set by Pertamina. Additionally, the districts that do not have a distribution of fuel station have land that is less suitable according to the parameters used, such as being on local roads and having limited residential areas.

IV. Conclusion

Fuel stations suitability analysis in Bandar Lampung using geographic information system can be drawn several conclusions:

1. Based on the data processing results, there are only 33 fuel stations distributed in 17 out of 20 districts in Bandar Lampung City, namely Bumi Waras, Enggal, Kedamaian, Kedaton, Kemiling, Labuhan Ratu, Langkapura, Panjang, Rajabasa, Sukabumi, Tanjung Senang, Tanjung Karang Pusat, Teluk Betung Selatan, Teluk Betung Timur, Teluk Betung Utara, and Way Halim. Meanwhile, 3 districts do not have a distribution of fuel stations, namely Tanjung Karang Barat, Tanjung Karang Timur, and Teluk Betung Barat.
2. The parameters used in analyzing the suitability level of fuel station in Bandar Lampung consist of four parameters, namely road function, distance between built gas stations, distance from gas stations to residential areas, and susceptibility to landslide disasters.

3. The suitability level of fuel station land refers to the four parameters used in this study, divided into three categories: highly suitable, suitable, and less suitable. The results of the analysis of the suitability level of fuel station land in Bandar Lampung are that 32 gas stations are classified as highly suitable, and 1 gas station is classified as suitable.

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