# Identification of e-Scooter Shared (ESS) Stations by using a GIS-based MCDM Approach

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**Abstract**
*The popularity of micromobility-shared systems has been rising in cities all over the world due to a number of advantages. Cities are increasingly looking for more environmentally friendly ways of transportation due to both traffic congestion and environmental concerns. The positioning of rental stations in respect to prospective congruent criteria is a crucial element in the effectiveness of micromobility-shared networks. Thus, it is crucial to use quantitative methodologies while conducting a site appropriateness analysis for micromobility-shared stations. With a focus on e-scooter shared (ESS) services, this study was conducted to assist the local authorities in identifying the factors and suitability of the ESS operating area. The area selected for this study was Shah Alam as the city council still allows this ESS to operate in some specific areas, especially in the city centre. This can indirectly help in the identification of the characteristics of the existing ESS operating area. The results of the study found a total of 35 existing ESS station locations in Shah Alam. Most of these ESSs are in recreation/park and tourism areas. Accordingly, some characteristics have been adopted from the study of according to suitability in Malaysia. A total of eight criteria have been identified and used, namely: proximity to sports centers/recreation/tourist/green area, proximity to shopping malls/business centers, proximity to educational institutions, proximity to residential, proximity to industries, proximity to bike lane/pathway, proximity to bus stop/bus station/train station; and population density. Besides. expert opinion has also been used in this study to obtain weighting information for each criterion. Results have recommended 9 new ESS locations for consideration by the local council.*

**Keywords:** E-scooter, GIS, MCDM, Multicriteria Decision Making, Suitability Analysis

## 1. Introduction

The use of micromobility devices, or MMDs, has improved recently and is now being observed to have been utilised as a means of transportation, as well as a first-mile-last-mile mode for mobility. Since they are a relatively new trend in urban transportation, electric scooters or e-scooter should be taken into account by city planners and policymakers while assembling a variety of transportation alternatives for their region [1]. Many cities throughout the world are embracing the idea of shared mobility due to its environmental advantages, such as a reduction in driving and automobile ownership as well as enhanced accessibility and connectivity [2]. Recently, there is notably an increase in the usage of shared micro-mobility tools including bicycles, e-bikes, and e-scooters [3]. National Priority Area 9 (BK9), or Safer Micro-mobility, is the focus of the Malaysian Road Safety Plan (PKJRM) 2022–2030. Establishing a management system and raising awareness of the use of micromobility, as well as developing the infrastructure for micromobility in suitable locations, are the two sub-areas under this BK9 [4].

Any vehicle intended to travel at or below 50 km/h and driven by an internal combustion engine, a combination of an internal combustion engine and human power, or by a combination of electrically powered mechanisms is referred to as a micro-mobility device (MMD) in Malaysia. The internal combustion engine and human power is regarded as a micro-mobility vehicle [5]. Most city inhabitants have already noticed the massive increase in shared bikes and scooters that have appeared throughout their area.

This is partially due to the frequent hurried, chaotic rollouts of shared micro-mobility services. Effective legislation and collaboration between organizations and users are needed.

Local governments utilising the e-scooter sharing (ESS) services network frequently choose the sites for service locations. Certain stations where the devices are locked are necessary for every ESS system. It is crucial to make choices on the initial locations and dimensions of stations as well as how to develop an existing system by adding stations or rearranging existing stations [6]. Yet, creating an effective ESS system with appropriate station placements is a difficult challenge. The relative station positions within the deployment network and their connections to tourist destinations, public transportation, and users must be considered in order to build a successful shared service network [7]. Consequently, a quantitative site appropriateness analysis for ESS services is essential. This study's objectives were to evaluate the ESS deployment services now available in Shah Alam, Selangor, and to find suitable station sites by comparing them to active stations. A geographic information system was combined with multiple multi-criteria decision-making strategies to resolve conflicting criteria (GIS). MCDA techniques are being employed frequently in similar previous research thus, this study implemented MCDA in GIS analysis to find the suitable locations as there are several criteria needed in the decision-making.

## 2. GIS-MCDM Approach in Micro-mobility

First-last-mile connection is still a persistent problem for Malaysians. The bicycle sharing system was introduced in Malaysia as an alternative mode in the year 2017. The service intends to help in reducing the number of private vehicles on the road as well as first-mile and last-mile solution. With the evolution of shared micro-mobility services, several companies started to enter Malaysia in 2018 [8]. The 12th Malaysia Plan already mentions micro mobility, and the government has put in place measures to promote its use as a first-last-mile connector [9]. According to traffic psychology specialist and travel behaviour analyst, micro-mobility should be a supporting mode and a viable option for sustainable transportation [10]. Beam has started operating in Shah Alam from April 2021 until August 2022, starting with 500 devices. This trial and pilot operation is a collaboration project between the city council of Shah Alam and several bicycle sharing companies. However, there are several issues and challenges identified during this period, among them operators' capability, infrastructure, and user behaviours, as well as regulation on implementation from the government [11].

However, according to the Ministry of Transportation, some micro-mobility vehicles, including e-scooter, cannot be driven on public road. The Road Traffic (Prohibition of Use of Certain Micro-mobility Vehicles) Rules 2021 had published this ban, which had been in force since December 17, 2021 [5]. This restriction is due to a number of issues including safety and management controls over its use. Nevertheless, several stakeholders are drafting regulations and laws to enable the operation of this micro-mobility vehicle to be implemented. MCDA is being employed frequently in research, both for traditional micro-mobility and e-micro-mobility. Their responsibility is to offer resources that will be utilised to rank and analyse possibilities for making decisions in the face of numerous, frequently incompatible criteria [12] and [13]. Based on the desired result, the best option among several possibilities is evaluated and chosen using computational approaches that incorporate a number of factors and order of preference. Based on the chosen criteria, their matching values, and specified weights, the application returns a ranking result [14]. Numerous multi-criteria decision-making techniques, including the Analytical Hierarchical Process (AHP), Analytical Network Process (ANP), Case-Based Reasoning (CBR), Data Envelopment Analysis (DEA), Fuzzy-AHP, Genetic Algorithm (GA), Mathematical Programming, Simple Multi-Attribute Rating Technique (SMART), and their hybrids, have been proposed for provider selection [13] [14] and [15]. Table 1 shows the comparison of each method with its purpose, advantages, and disadvantages.

## 3. Methodology

The methodology of this study is shown in Figure 1. It started with identifying criteria that influence the potential locations for ESS stations. Next, the data representing the criteria were collected in two (2) parts. First, the rating of the criteria was collected from experts by interviewing them. Second, the spatial data representing the criteria on ground was selected. Once the data had been collected, they were processed by calculating the weightage of the criteria based on the rating obtained from experts' choice by using AHP decision rules and the criterion map for each criterion was prepared by rasterization and reclassification.

**Table 1:** MCDM methods with it advantages and disadvantages

| Method | Description | Advantages | Disadvantages |
|---|---|---|---|
| AHP | Compared the importance of criteria, two at a time, through pairwise comparisons. | Can help you out with some of the most complex decisions – no bias in decision making. | A potentially large number of paired comparisons asked of decision-makers. |
| ANP | ANP is an effort to enhance AHP by using the human brain's examination of complex problems with non-hierarchical structures. | A decision problem is organised by the ANP as a network rather than by the AHP as a hierarchy with a goal, decision criteria, and options - Simplify complex problem. | Depend significantly on the expertise and their experiences.<br>Unwieldy model resulted from many elements. |
| CBR | A cognitive science and artificial intelligence paradigm that views memory as the primary foundation of reasoning. Case-based reasoners change by using stored "cases" describing comparable prior problem-solving episodes, they can adapt their answers to meet new needs. | Development is simpler because no information must be obtained in order to construct rules or procedures. | The CBR finds it difficult to manage a high caseload. CBR struggles mightily to address issues in the dynamic domain. |
| SMART | A thorough model of decision-makers to take both qualitative and quantitative factors into account - A group of alternatives is sorted into optimum selections. | Simple - Utilized for many different weight assignment methods – Less effort. | The process might not be practical. |

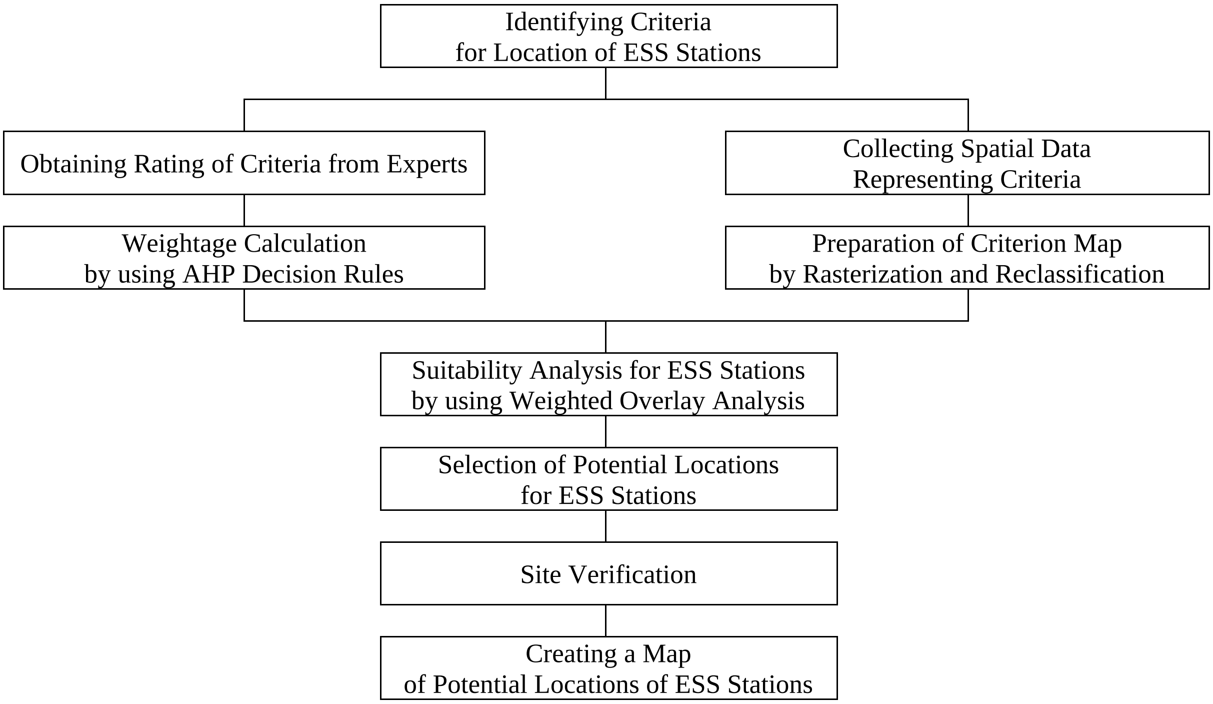


**Figure 1:** Flowchart of methodology


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Once both data were ready, the suitability analysis for ESS stations were modelled by using Weighted Overlay Analysis. The site verification was then conducted to review the potential location for ESS stations. Lastly, the map visualizing the potential locations of ESS stations was created.

*3.1 Data*

Data in this study consist of eight criteria to identify the suitable location for ESS stations. The criteria for choosing the location of ESS stations should take into consideration of Malaysia scenarios such as land use [16]. As a result, Table 2 lists the eight criteria for site selection that were determined for this study along with the rationale for their selection. Also, each criterion is given a code (ex.: C1, C2, C3, etc.). Criterion C1, C2, C3, C4, C5 was obtained from the land use data set provided by PLANMalaysia. Meanwhile, C6, C7 was obtained from the OpenStreetMap and C8 was obtained from the Department of the Statistics Malaysia (DOSM).

*3.2 Software Used*

ArcGIS 10.8 and Microsoft Excel 365 were the two main programmes used in this investigation. ArcGIS 10.8 was the main software used in this study. Using this software, the user can browse, edit, update, and analyse spatial data and attributes. Many ArcGIS tools and functionalities are utilised in this investigation. An example of how to extract the spatial criterion information from land use information and use it as the main programme to carry out the analysis to decide which places would be suitable for an ESS. The Spatial Analyst and the Geoprocessing Tools are the two main extensions used in this study.

*3.2.1 Calculating the weightage of criteria.*

Various criteria were contrasted with one another. Using the question "Which is considered more important by the user, and how much more important is it with respect to satisfaction with the shared micro-mobility location?" and using a scale from 1 (equally important) to 9 for importance, C1. Proximity to Sports center/recreation/tourist/green area is compared with C3. Proximity to Education institution (very important). A pairwise comparison was created and distributed to the experts from varied backgrounds using a Google Form. Six experts in all, including academics, transport and safety engineers, and members of the bicycle or e-scooter communities, were chosen to help with this research as shown in Table 3. The experts' ratings on the criteria were then multiplied by the weightings. The AHP approach was employed to accomplish this purpose. The criteria were compared against one another. The numbers on the diagonal will always be one because they represent the results of an element being compared to itself. The vector ($a_{i1}$, $a_{i2}$, $a_{i3}$, $a_{in}$) for each i is the principal "eigenvector" method (EVM) or priority vector of a ($n_n$) reciprocal matrix, which is defined through pairwise assessments of the impacts of the m alternatives on the $i^{th}$ criterion.

**Table 2:** Shared micro-mobility (e-scooter/bicycle) station site selection

| Code | Criterion | Rationale |
|---|---|---|
| C1 | Proximity to Sports centres/recreation/tourist/green area | Enables user to sports centre, recreation area, tourist area and green areas for last-mile commutes or short-distance travel. |
| C2 | Proximity to shopping mall/Business centres | Enables user to shopping mall or business areas for last-mile commutes or short-distance travel. |
| C3 | Proximity to Education institution | Enables user to education institution such as school, universities, for last-mile commutes or short-distance travel. |
| C4 | Proximity to Residential | Enables user to residential areas for last-mile commutes or short-distance travel. |
| C5 | Proximity to Industries | Enables user to industries areas or workers for short-distance trips or first-last-mile commute. |
| C6 | Proximity to Bike Lane/Pathway | Enables user to mode shift from private vehicles and promote cycling/riding for commutes or long-distance travels. Increase the safety level. |
| C7 | Proximity to Bus stop/Bus station/Train station | Enables user to allow relocations between transport modes and promote cycling/riding for commutes or long-distance travels. |
| C8 | Population Density | Enables user to mode shift from private vehicles and promote cycling/riding for first-last-mile commutes, long-distance journeys, or both. |


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**Table 3:** Experts' background

| No | Gender | Age | Background | Experience |
|---|---|---|---|---|
| E1 | Female | 26 - 35 | Global institute for road safety | 11 – 15 years |
| E2 | Male | 36 – 45 | Local institute for road safety | 6 – 10 years |
| E3 | Male | 36 – 45 | Local Government Planning Department | 16 - 20 years |
| E4 | Female | 36 – 45 | Local institute for road safety | > 20 years |
| E5 | Female | 36 – 45 | Local university | 16 - 20 years |
| E6 | Male | 36 - 45 | Local institute for road safety | 11 – 15 years |

**Table 4:** Spatial data analysis list

| No. | Criterion | Data source | Technique to derive data |
|---|---|---|---|
| C1 | Proximity to Sports centres/recreation/tourist/green area | Shah Alam land use | Euclidean distance |
| C2 | Proximity to shopping mall/Business centres | Shah Alam land use | Euclidean distance |
| C3 | Proximity to Education institution | Shah Alam land use | Euclidean distance |
| C4 | Proximity to Residential | Shah Alam land use | Euclidean distance |
| C5 | Proximity to Industries | Shah Alam land use | Euclidean distance |
| C6 | Proximity to Bike Lane/Pathway | Bike lane/Pathway | Euclidean distance |
| C7 | Proximity to Bus stop/Bus station/Train station | Bus stop/Bus station | Euclidean distance |
| C8 | Population Density | Population | Density |

The method computes and combines each of the eigen vectors of the alternatives in order to produce the many final vectors of weight coefficients for the alternatives. The records of the final weight coefficients vector show the relative relevance (value) of each option in relation to the highest-level objectives of the hierarchy.

*3.2.2 Euclidean distance analysis*

The term "distance measurement" refers to estimating the Euclidean (straight line) distances between objects. The points of a layer can be compared to the points of other layers or to the closest line or point in another layer. In both cases, distance measurements are taken in a field. The distance between each cell and the closest source is determined using EUCLIDEAN DISTANCE tools. The population data set is the only one that does not require EUCLIDEAN DISTANCE analysis, as shown in Table 4, because population is unaffected by distance. This analysis make it possible to determine the nearest distance from each data layer. There are numerous normalizing techniques that can be used to normalize the decision matrix. The vector normalization technique used in this study is expressed as follows:

$$\frac{(X - X_{min})}{(X_{max} - X_{min})}$$

Equation 1

Where:
$X$ is a collection of observable values found in $X$
$X_{min}$ is the minimum values in $X$
$X_{max}$ is the maximum values in $X$

*3.2.3 Reclassification*

In order to determine the proper location, this step involves reclassifying the criterion normalization layer with the relevant class. Each normalizing data layer was thereafter divided into nine classes.

*3.2.4 Random sampling*

Even after applying many filters depending on criteria, there are still overlapping position options within a 250-meter radius, therefore this study used Excel to do a RANDOM SAMPLING analysis in order to identify one of the best locations.

*3.2.5 Site verification*

This is the study's final procedure. The verification process demonstrates that the analysis complies with all performance requirements specified in the system performance specification, functional and allocated baseline, and its intended functions. This is done to verify or calibrate the results of the analysis that has been done. Based on the chosen location, this step is carried out by making a site visit.

## 4. Result and Analysis

The experts from the diverse backgrounds fill out an individual pairwise comparison matrix using the AHP scales of 1 to 9. According to the scale, a score of 1 denotes that two things are of equal importance. Three indicates that the criterion in the column has a lesser value than the criterion in the row. The other numbers, 3, 5, 7, and 9 all signify strong relevance, proved prominence over the other, and absolute significance in the same way.

### *4.1 Weightage of Criteria for Site-Selection of ESS Stations*

As shown in Table 5, the public transport station overweight's other dimensions. The closest public transport services such as bus stop, bus station, or railway station is C7, which has the highest priority value overall (28.5%) in the site selection criteria group for ESS deployment. The outcome also discloses research demonstrating a favorable correlation between the quantity of public transportation and usage rates [17] [18] and [19]. ESS may be crucial for sustainable urban mobility. Additional important criteria include C6, closeness to a bike lane or walkway (19.2%), in order of weight. Previous study also demonstrated the requirement for a separate route for these vehicles to ensure user safety lends support to this [20]. They are also prepared to travel farther when riding on bikeways [21]. The criteria C4, proximity to residential (18.9%), C8, population density (13.3%), C3, proximity to educational institution (8.4%), C1, proximity to sports facilities/recreation/tourist/green area (5.6%), C2, proximity to shopping mall/business centres (3.6%), and C4, proximity to industries (2.5%), all had the lowest significance values. This suggests that they expect the use of e-scooters to be concentrated in urban areas with high employment rates and cycling infrastructure [22]. It is preferred if the AHP Consistency Ratio (CR) is less than 10% (0.1), but this cut-off value is only a rule of thumb. Depending on the particulars of the project, smaller numbers are generally preferred than higher ones, while values beyond 0.1 may occasionally be acceptable. As a result, this study's CR value, which is 2.4%, or 0.024, is deemed to be acceptable.

Figure 2 displays the criterion map for each criterion with their normalized values. The criterion map was derived from spatial dataset obtained from various agencies. As mentioned in Table 4, different spatial analysis methods were used to derive the dataset. For C1 – C7, Euclidean distance was used to derive the dataset as the criteria need to be represented as a proximity. For C6, the dataset was derived by using density analysis. The process derives the dataset in a raster format. Then, the reclassification was conducted to reclassify the values in the dataset. The classification is needed to ensure the uniformity in the class values for each of the criterion map. With these, the criterion map for each of the criteria was derived and ready to be used for the site suitability analysis by using Weighted Overlay Analysis. In this stage, the weightage for each criterion was assigned to their respective criterion map. Then, suitability index model was generated to determine the suitability for ESS stations.

### *4.2 Potential Locations for Deployment for ESS Stations Area*

The suitability computation entails multiplying the weight of each criterion by the value of each map pixel. The south-west and west regions are best suitable for ESS station villages, according to the results. In contrast, rates are lowest in the northeast. shows that the position of the ESS station is not appropriate for the area. Also, the outcome demonstrates that 15% of the area is a VERY SUITABLE area for the deployment of ESS stations. While 20% and 44%, respectively, are suitable and very suitable locations. Just 6% of the research region fell into the NOT SUITABLE - EXTREMELY NOT SUITABLE category, according to the report.

**Table 5:** Criteria weights value based on AHP analysis

| | Criterion | Weight (%) |
|---|---|---|
| C1 | Proximity to Sports centres/recreation/tourist/green area | 5.60 |
| C2 | Proximity to shopping mall/Business centres | 3.60 |
| C3 | Proximity to Education institution | 8.40 |
| C4 | Proximity to Residential | 18.90 |
| C5 | Proximity to Industries | 2.50 |
| C6 | Proximity to Bike Lane/Pathway | 19.20 |
| C7 | Proximity to Bus stop/Bus station/Train station | 28.50 |
| C8 | Population Density | 13.30 |
| | Sum | 100.00 |

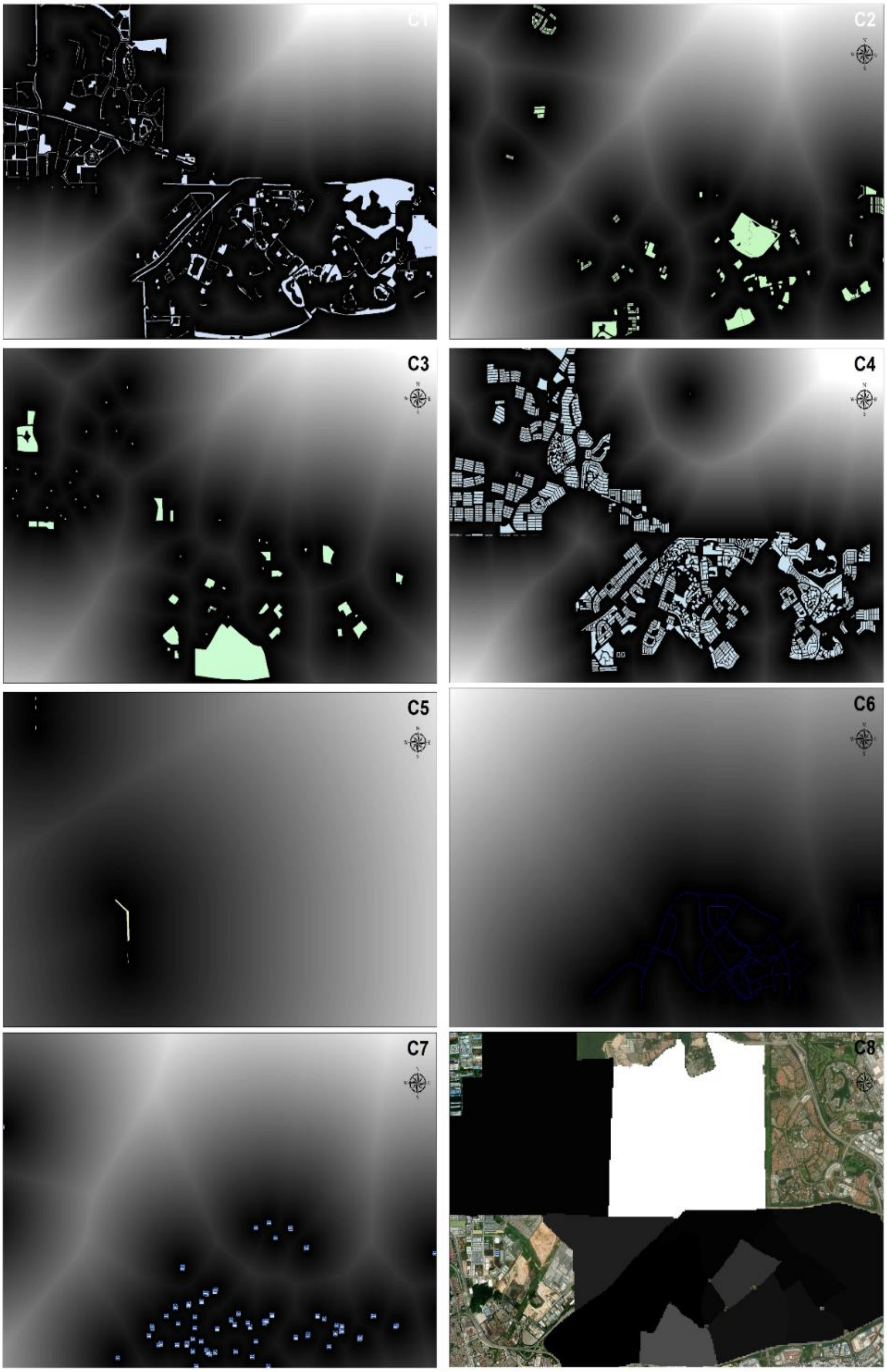


**Figure 2:** Criterion maps


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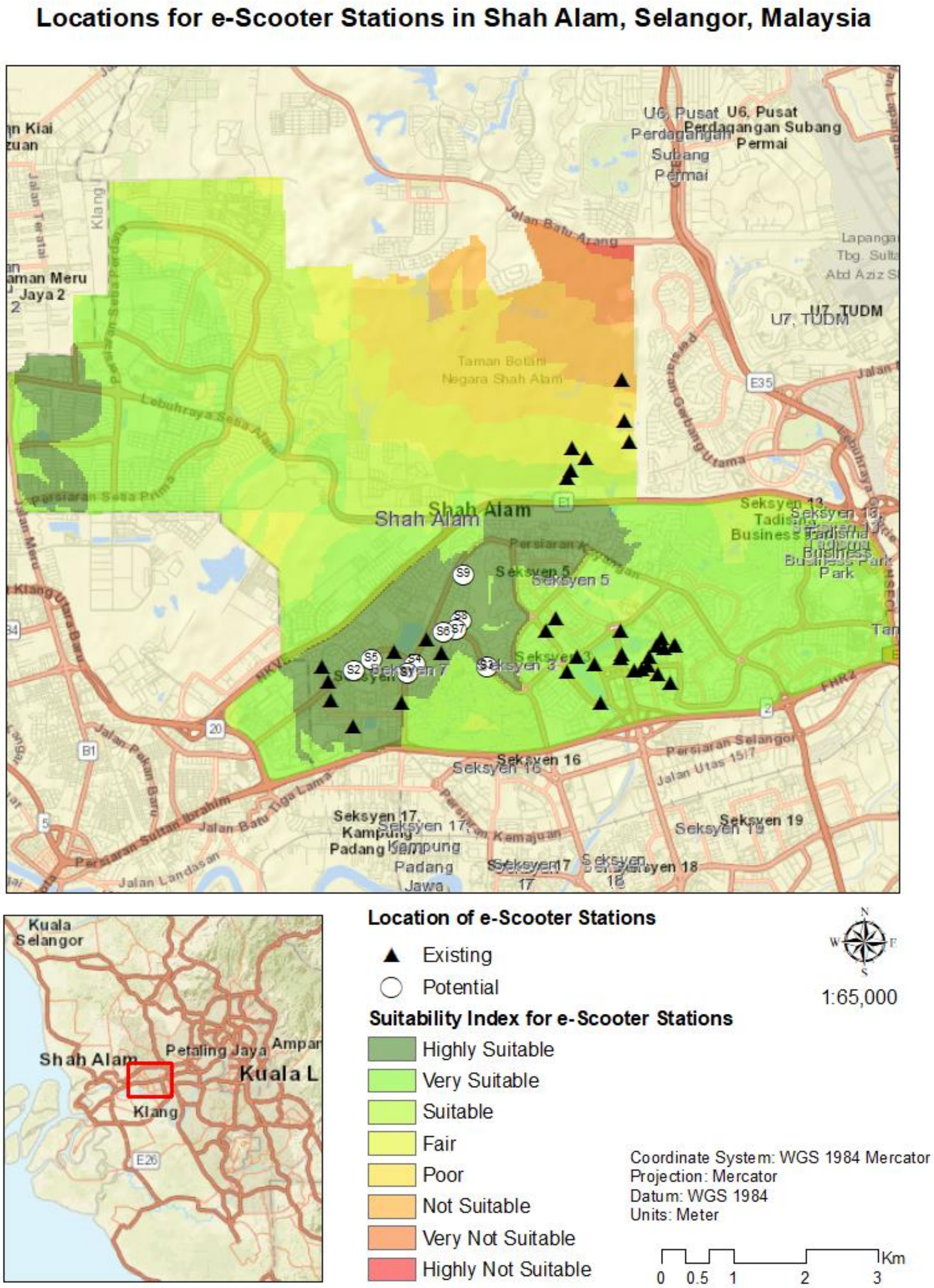


**Figure 3:** ESS Locations in Shah Alam

This suggests that the city centre of Shah Alam is a good location for ESS operations. There are no rules for determining the ideal separation between ESS services. According to [16], 250m is the estimated distance that people will walk to reach the ESS station (2018). As a result, the appropriate spots that were more than 250 metres from the present station and not in an area with EXTREMELY SUITABLE conditions were excluded. This characteristic is also taken into account because public transportation has a higher weight. Out 50 of the 53 CANDIDATE LOCATION points were found in extremely acceptable locations, and of these, 19 were deemed UNSUITABLE because they were situated within

250 meters of an ESS station. A total of 31 alternative ESS services sites were found using this approach. Due to big numbers, study eventually picked the location based on the 3 primary criteria: adjacent to public transport and residential area; provided with bike lane/pathway; 250 meters or less from each station. In certain cases, the same area has many locations. To make decisions, this study employs RANDOM SAMPLING analysis in Excel. The results suggest 19 potential sites for an ESS station. The verification process must next be carried out to confirm that the chosen site is appropriate for additional ESS stations. A total of 19 location choices have been verified in the field. As a result, a total of 10 locations were identified as unsuitable for the proposed new ESS site. Among the rejection factors for other locations are as follows: Gated and guarded residential area. Therefore, riders cannot access the station; Unsuitable bike lane/pathway conditions. The surfaces condition that are hazard to ride; Slope terrain. This can pose a danger to the user. Users can crash if they fail to control the device and speed; No connectivity. No public transport, any place of interest such as shop or mall and disconnect route.

The local authority should take into consideration nine new location proposals that are acceptable for ESS station placements as S1, S2, and S3 (Figure 3). Most of the new ESS installations are found in suburban areas. In addition to having bike lanes or pathways, all locations also have area that can be used as station sites. In addition to site suitability, user safety is taken into account during the survey to make sure that the location choice is not only cozy, convenient, but also secure.

According to the findings of the observation, S2, S3, and S5 are situated close to the bus stop. The position is very close to the Shah Alam hospital, according to the results of the survey in S1. For S2, however, it is discovered to be close to homes, businesses, and schools. S3 is close to both apartments and terraced homes. Also, the position is not far from university’s main entrance. The intersection that connects housing with the main road is not far from S4. The position of S5 is one of the comparatively decent stations since it connects bus stops, residential, and business sector. Students, who are also the intended user group, will be drawn to S6's location at a university’s entrance. The S7, S8, and S9 stations are situated in densely populated neighborhoods and quarters. Also, the location's suitability enables for the creation of a dockless station, which will reduce the operator's and the local authority's preparatory expenses.

## 5. Conclusion

This study used AHP analysis integrated with the GIS to achieve the objectives. The main steps of study approach are displayed in the flow-chart shown in Section 2. This study highlighted eight (8) criteria that can be utilised in finding the ESS locations. The criteria were weighed, and their weightage used in weighted overlay analysis to determine the suitability of sites for the ESS. Based on the suitability index found, nineteen (19) locations were selected as potential locations for ESS stations. Due to the system's advantages, ESS services have become more widely used and implemented in recent years. Cities have been able to easily incorporate the technology due to its accessibility and environmental friendliness. The ESS are a useful technique for reducing the traffic congestion and pollution. This programme could serve as attractions for commuting. Utilizing ESS services, people can travel and explore new areas. Additionally, cities that make use of these systems discover that the networks for ESS improve their current intercity transit systems. As was previously indicated, the environmental advantages of the ESS are its most significant contributions.

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