Allocating Of New Potential Bus Stop Location Using Analytical Hierarchy Process (AHP) technique

A A A Rahman*1,2, N A majid2, M H Ramlan1, M A Hakim3

1 Centre of Studies for Surveying Science and Geomatics, Faculty of Architecture, Planning and Surveying, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia
2 Institute for Environment & Development (LESTARI), Universiti Kebangsaan Malaysia (UKM), 43600 UKM Bangi, Selangor, Malaysia
3 Alam Flora Environmental Solutions Sdn. Bhd, Persiaran Kerjaya, Glenmarie Golf and Country Club, Seksyen U1, 40150 Shah Alam, Selangor

aziz121@uitm.edu.my

Abstract. Public bus service is an essential transport in major cities. This service makes it easier for passengers to move from one place to another place. The aim of this research is to allocate new potential bus stop locations in Shah Alam. The purpose is to use the AHP calculation method to find the average priorities weightage value of the criteria and sub criteria used in this research. The applying of GIS to process the data calculated from the AHP will identify which criteria is preferred over each other to locate new bus stop locations. The methodology in this research is divided into four phases which is preliminary work, data acquisition, data processing, and data analysis. Software used in this research for data processing is ArcGIS Pro. How strategic is the locations of the bus stop according to the population? The rising of urbanization has led to increasing in population density; hence the location, functionality, safety, and visual appearance of bus stop are crucial. Therefore, this research is focused on allocating of new potential bus stop locations that has been identified through the GIS geoprocessing tools.

1. Introduction
Public bus service is an essential transport in major cities. This service makes it easier for passengers to move from one place to another place, besides the fees is in low rate and also serve a better public transportation when many passengers are boarding, even some of bus companies offer free ride. The bus stop is the first point of contact between the passenger and the bus service. To improve the quality of bus services, bus stop is recognized as a crucial element. Bus stops should provide required facilities for safe boarding and alighting of passengers. Accessibility of a bus stop is a critical element in deciding the bus transport ridership. The locations of bus stop significantly influence bus transit system performance and customer satisfaction. The choice of locations is primarily related to the operational performance of the bus route and traffic but can also be influenced by the adjacent land uses and opportunities for easy transfer to crossing bus routes. Bus stop layout should enable safe and smooth flow of bus and passengers. A well-designed layout of bus stop can allow passengers to board and alight without the bus significantly impeding or delaying adjacent traffic [1]. Some issues relating to the existing bus stops location including two bus stops are maybe closely located in certain areas resulting
in depletion of resources. Sparsely built bus stops location forcing pedestrians to walk some distances to reach resulting in them taking other modes of transportation to reach their destinations [2]. Even some bus stops location is found not to be safe and hazardous posing danger to people and other vehicles, may also cause traffic congestion. Therefore, this research was conducted to locate new potential bus stops location in Shah Alam where the factors taken into account in the selection of the place are based on the location, functionality, safety, and visual appearance of bus stop which it is crucial to attracting and maintaining passengers in any location in the study area. Furthermore, this study aimed to identify the existing of hierarchy, operation systems and supply-demand gaps of bus provided, and also to provide an alternative to reduce the traffic congestion by making people choose buses as mode of transport. An analysis will be done through the collected data which will be attributed into a proper table to build a Geo-database of existing bus stops location. Finally, using Geographical Information System (GIS), the best route map will be generated based on the analyzed data from the Geo-database with the integration of tools from Analytic Hierarchy Process (AHP) based Multi Criteria Decision Analysis (MCDA) algorithm into a GIS package consists of layers of satellite-derived data and locally obtained data.

2. Methodology
This research consists of four main phases throughout its completion duration. Figure 1 shows the general research methodology flowchart for this study.

![Figure 1. General Research Methodology Flowchart](image-url)
2.1 Project Preparation
The study area was selected by considering the needs to have convenience located bus stop since most of the existing bus stops in the study area are certainly inconveniently located. Besides, the criteria that need to be highlighted and the suitable method that need to be use to perform this project is also done during this phase.

2.1.1 Study Area. Shah Alam is chosen as the study area for this research because it is a major city where public transportation is the main transport use by many residents. Since there are many high-level educational institutions in Shah Alam, the use of public bus services is greatly encouraged among the students and even for working people for the fare rate are considered cheap. As a basic necessity for public bus services, it is vital to fulfill the parameters design for bus stop locations such as distance from origin/destination point to the bus stop and the walking time, an ergonomic and weatherproof is a must for the physical conditions in order to give better satisfaction for users.

![Figure 2. Study area located at Seksyen U13 and Seksyen U12 Shah Alam](image)

2.1.2 Data Processing. This is the most crucial part in the research study as the data processing from acquired data is compulsory for the analysis purposes. The survey data collected will be analysed after accumulating primary and secondary data through Microsoft Office Excel for processing with the AHP method using the selected criteria together with the pairwise comparison, and plotting of GPS points using ArcGIS Pro.

2.1.3 Geoprocessing Tools in ArcGIS Pro. The first step in GIS based analysis is the data pre-processing that will be involving the digitizing of geographical spatial features followed by extracting features. The shapefile is the crucial data that need to be used functioning as digital vector storage that storing geographic location and associated attribute information. This research has used the shapefile of the Shah Alam district where the shapefile is downloaded online from the open-source database.
2.1.4 Plotting of GPS Points. For this research, the collected points of passengers’ access and egress points gather from the GPS will be imported into the GIS where the points will be plotted on the projected map (Bachok, Ponrahono, Osman, & Bohari, 2013). The collected points from the GPS would have to be back-up first into google drive where the files automatically stored into KML file format which is then imported into GIS. Figure 3 shows the interface of GPS apps (My Tracks).

![Figure 3](image)

Figure 3. On-site GPR scanning process for underground data acquisition phrase

2.1.5 Plotting of GPS Points. In this research, the AHP method will be used to calculate a hierarchical structure of criteria used in deciding the new potential bus stop location.

3. Result And Analysis

The three main criteria used as being mentioned in research methodology are the land use pattern, road, and existing bus stop. The land use consisting of three sub criteria; residential, industrial, and commercial while the road is also consisting of three sub criteria; primary road, secondary road, and tertiary road, the existing bus stop is a standalone main criterion with no sub criteria. Figure 4 shows the hierarchical structure of the criteria and sub criteria used for this research.

![Figure 4](image)

Figure 4. The Hierarchical Structure of Criteria and Sub Criteria

Then the pairwise comparison from the AHP method will create a matrix where the relative importance of the problems will need to be weighted. The software tool will use the data to do a mathematical computation and assign relative weights to the criteria. Once the equation with weighted
criteria is complete, one can assess the options to choose the best solution for their needs [3]. Figure 5 below shows the value, definition, and explanation of the pairwise comparison.

| Intensity of importance | Definition | Explanation |
|-------------------------|------------|-------------|
| 1                       | Equal importance | Two activities contribute equally to the objective |
| 3                       | Moderate importance | Experience and judgement slightly favour one activity over another |
| 5                       | Essential importance | Experience and judgement strongly favour one activity over another |
| 7                       | Very strong importance | An activity is favoured very strongly over another; its dominance demonstrated in practice |
| 9                       | Extreme importance | The evidence favouring one activity over another is of the highest possible order of affirmation |
| 2, 4, 6, 8              | Intermediate values | When compromise is needed between two |

**Figure 5. The Pairwise Comparison Method [4]**

The AHP method is also being used to determine the location selection for the company. There are three locations which are A, B, and C from which the company can decide based on the following criteria of property value, distance from the suppliers, quality of labor pool, and labor cost [5]. Figure 6 shows the criteria with matrix of preferences.

**Figure 6. Criteria with matrix Preferences [5]**

The data collected from figure above is obtained from preferences of pairwise comparison. The A, B, and C are the sub criteria for the main criteria for the company to decide which location is the best. These value of the pairwise comparison can be solved using the formula shown in the figure below to calculate the criterion weightage for the three locations. From the weightage of the three locations, the priorities value for the criteria can be obtained and will be used to generate new appropriate location for the company’s new building plant using the geoprocessing tools in ArcGIS Pro, the Suitability Modeler. Figure 7 shows the formula to calculate criterion weightage.
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Figure 7. The Criterion Calculation Weighs Formula [6]

For example, at the property value criteria, the same step is used to every criterion too. The formula can simply be used by totaling the value of the column as figure 8 below, shows criteria with matrix preferences for property value.

Figure 8. Matrix Preferences for Property Value

Once the total value has been calculated, divide the value column by column as such figure below based on the matrix preferences value previously. Figure 9 shows the calculation for new matrix and figure 10 shows the new matrix for property value.

Figure 9. Calculation for New Matrix
From the new calculation property value as the figure above, the priorities value can be obtained by converting the fractions into decimals and then calculate the average for the three locations row by row as such. Figure 11 shows the calculation for priorities matrix and figure 12 shows the priorities matrix for property value.

The suitability modeler created the suitability model by determine and prepare the criteria data that has been calculated through the AHP method and automatically locate the points of location of bus stops. Figure 13 shows the new potential bus stops location together with the existing bus routes in Shah Alam. With the new bus stop locations created, the SMART SELANGOR can consider expanding its new bus routes that cover from the North region to South region alongside the Middle region of Shah Alam and everyone gets to use their services to travel with ease.
The land use criteria were used to find which pattern land of use is the most covering in the study area and the result shows residential is preferred over industrial and commercial. For the road criteria, the secondary road is preferred over the primary road and tertiary road as it shows the most transformed value. Results also show that different criteria preferences had quite different impacts on allocating of new potential bus stop locations. From the research, it is recommended that the bus stops must have safe access via sidewalks and appropriate street crossing locations. Where possible, pedestrian crossings should be accommodated behind the departing transit vehicle. According to the access management guidelines, driveways of 30 to 100 meter of an intersection are banned, since most bus stops are located at intersections depending on the intersection is signalized or non-signalized.

4. Conclusion
This research evaluated and combined the bus stop criteria of land use, road, and existing bus stop. Three sub criteria for land use, and road were considered respectively. The actively and retroactively enforce access management guidelines can spare passengers waiting in driveways for the bus. Last but not least, as the new potential bus stop locations are identified, the service provider can consider expanding its new bus routes with the purpose to make travelling easier for the residences of Shah Alam.
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Acknowledgments
The authors would like to thank the Centre of Studies for Surveying Science and Geomatics, Faculty of Architecture, Planning and Surveying, Universiti Teknologi MARA (UiTM) for their cooperation in completing this research. Thank you also to all of my colleagues and lectures who helped and contributed for data acquisition, images data processing and interpretation.