Available online at
http://journal.uitm.edu.my/ojs/index.php/BEJ

e-ISSN: 2637-0395

Built Environment Journal 21(1) 2024, 76 – 85.

Built Environment Journal

Evaluating Bus Transit System for Efficient Last Mile Transportation in Universiti Teknologi MARA (UiTM) Shah Alam

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ARTICLE INFO

Article history:
Received 23 August 2023
Revised 28 September 2023
Accepted 5 October 2023
Online first
Published 1 January 2024

Keywords:
Bus transportation
Last mile
Optimisation
Space syntax
Universal design

DOI:
10.24191/bej.v21i1.475

ABSTRACT

As the leading example in sustainable transportation, universities should have an optimal and precedent system. Universiti Teknologi MARA (UiTM) campus provides bus transportation for students. However, with the vast coverage of the campus area, the bus stops should be distributed evenly. This research aims to evaluate the bus stop position to find the optimal last mile distance concerning the principle of Universal Design, precisely the aspect of low physical effort. This research uses the method of space syntax to analyse the spatial arrangement of urban environments, including transportation systems. It is based on the idea that the spatial structure of an environment affects its usability and accessibility and that the arrangement of elements can be optimised to improve accessibility and reduce physical effort. As a result, this research finds that UiTM's current bus stop distribution needs to be improved. It should have filled the demand for several spots, such as dormitories, sports centers, and faculties. Adding bus stops or bus volume is the appropriate solution to this finding, considering the growth of student numbers and the upcoming LRT station development. This research has proven a new depth perspective by combining topologic, angular, and metric logic. The findings of this research are beneficial in planning bus stops that carefully consider the universal design for all users wherever they live and work.

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https://doi.org/10.24191/bej.v21i1.475

INTRODUCTION

People commute daily from home to the workplace, school, university, etc. In Malaysia, the average commute distance of the employees is 17.4 km (Jaff & Hamsa, 2018). People need to use vehicles to perceive such distance. Private car or motor car is the most popular transportation mode in Malaysia. The count of registered cars has outnumbered the population of Malaysian citizens by 33.3 million and 32.6 million, respectively (Chan, 2022). The occupancy rate of cars in Malaysia is from 1.54 to 1.61 persons per vehicle (Mohd Shafie et al., 2008). So, most of the time, the car is only partially seated. It just has the driver; half the time, it has one (1) passenger. Those private vehicles have created many problems, such as traffic jams, gas emissions, parking space scarcity, etc. With its high popularity, getting rid of cars in Malaysian society has become a significant challenge.

In accordance with replacing cars as commuting vehicles, promoting public transportation is the solution. Public transportation is a mode of transit for passengers with a group travel system, a schedule, and an established destination (Chen et al., 2021). Many public transportation types exist, including buses, trains, high-speed trains, etc. The bus is the best alternative to replacing cars because they share the same infrastructure, such as roads. A bus is a good option for passengers with a fixed workplace, who travel during peak hours, students, adults with low income, and the elderly (Hensher, 2007). Throughout history, the bus has become an essential service for city transportation. Buses help ease traffic congestion, provide cost-efficient transport, and reduce carbon emissions.

A bus system in the universities shows that the university puts thought into supporting sustainable development (Mustaffa et al., 2022). As the place that prepares and generates top knowledgeable human resources for the world, universities should become the leading example in sustainable development (Amaral et al., 2015). In a recent study, teaching and research on the Sustainable Development Goals (SDGs) in many universities must catch up (Leal Filho et al., 2019). Improving and evaluating the bus transportation system is one of the realistic initiatives for the university in promoting sustainable transport.

Although buses help reshape the city into a low carbon, less congestion, etc., buses cannot provide last-mile travel. It means the bus cannot bring the passenger to the last destination. Passengers must walk about one mile from the bus stop to the last destination. Therefore, the distance is called the last mile (Gevaers et al., 2011). The last mile is the challenge of promoting buses as an alternative to cars. According to the sixth principle of universal design principles, a design (which in this case is the bus stop) should be a low physical effort (Smith & Preiser, 2011). This principle allows the passengers to efficiently and comfortably walk the last mile with minimal fatigue.

Universiti Teknologi MARA (UiTM) provides buses for their students. The bus system has seven (7) different routes served by twenty-six (26) buses in total. The UiTM Shah Alam area has eight (8) active bus stops distributed approximately 1.6 km square. The problem with bus transportation is that the current bus stop distribution needs to comply with the sixth principle of universal design. Most users need to walk extra, while some are lucky to have the destination near the bus stop. To venture about the bus stop distribution issue, the current development of LRT has planned one (1) station next to UiTM. The station is near the UiTM's Dewan Agung Tuanku Cancellor (DATC). The LRT station is expected to be operational on 1 July 2024 (UiTM Shah Alam LRT Station | Mrt.Com.My, n.d.). The current bus route should be evaluated to respond to this future development. This study hypothesises that an additional bus station should exist in that area.

Motivated by those issues, this research is trying to answer the question, "How efficient is current bus stop distribution in UiTM Shah Alam?" This research aims include collecting data on bus stop distribution, modeling the area of UiTM Shah Alam, and creating a map by space syntax analysis and synthesis of the analysis. The expected significant contribution of this research is to evaluate the future development of a

https://doi.org/10.24191/bej.v21i1.475

bus stop distribution plan in UiTM Shah Alam. This research can bring several implications for society, such as improving the bus transportation system in UiTM Shah Alam, raising the demand for buses and public infrastructure, and minimising car users, space for car parking, and carbon emission to achieve sustainable transportation.

LITERATURE REVIEW

Universal Design is an approach to designing products, environments, and services that are inclusive and accessible to everyone, regardless of their abilities or disabilities (Imrie, 2012). One of the fundamental principles of Universal Design is low physical effort (the sixth principle), which means designing products and environments that are easy and comfortable to use, focusing on reducing physical strain and fatigue. This principle can be applied to designing bus stops and planning bus stop distances (Bidin et al., 2018). Bus stops are an essential part of public transportation, and it is vital to ensure they are accessible and usable for everyone. By incorporating the principle of low physical effort into the design of bus stops and planning bus stop distance, public transportation can become more inclusive and accessible for people with various abilities.

In terms of designing bus stops, it is essential to consider the physical effort required to use the stop. This includes designing stops that are easy to reach, with adequate space for approaching and using the stop. This can be achieved by placing the stops in inaccessible locations, with clear and well-lit paths leading to the stop, and providing adequate space for people to wait comfortably. Additionally, it is crucial to ensure that stops are easy to navigate, with clear signage and information displays that are easily visible and readable. When it comes to the planning of bus stop distance, it is essential to take into account the physical effort required to travel between stops. This means ensuring that stops are spaced far enough apart that people can easily walk between them but close enough together that it is convenient for people to use the bus. Additionally, it is crucial to consider the terrain and accessibility of the route between stops and to ensure that the route is easy to navigate for people with a variety of abilities (Christopherson, 2022).

In summary, the principle of low physical effort is a crucial aspect of Universal Design, and it is essential to consider this principle when designing bus stops and planning bus stop distance. By designing bus stops that are accessible and usable for everyone and planning bus stop distances to reduce physical effort, public transportation can become more inclusive and accessible, allowing people with a variety of abilities to participate fully in everyday life. Reducing physical effort makes people more likely to use public transportation, even if they walk a longer distance between stops. This can lead to increased public transportation usage, which can help reduce congestion and air pollution and promote sustainable transportation practices.

METHODOLOGY

This research uses a quantitative method to measure and evaluate UiTM's bus distribution area coverage. Evaluation of bus stops is conducted by using the space syntax method. Space syntax is a method to analyse how humans use space by social logic (Hillier & Hanson, 1984). One of the features of space syntax is distance measurement. This method can help measure the distance of a bus stop to any destination in UiTM Shah Alam. This method can spot which area is the most inaccessible.

In detail, this research will be conducted in two (2) phases according to the objectives (see Figure 1). The first phase is data collection of the bus stop distribution, bus stop route, and bus volume. The second phase is creating the map of bus stop efficiency by analysing space syntax, manual mapping of bus movement, and overlaying all the maps for evaluation. The space syntax analysis is conducted to map bus stop depth in UiTM. That map shows how long the distance from the bus stop to the surrounding area in

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UiTM. The map is in colored graphics. For example, a colored area is identified as far from the bus stop. The data and map will be used to evaluate the efficiency of bus stop distribution. The consideration variable has two (2) more additions: the LRT station location and the principle of low physical effort. The output of this research will be evaluating bus stop distribution in UiTM Shah Alam.

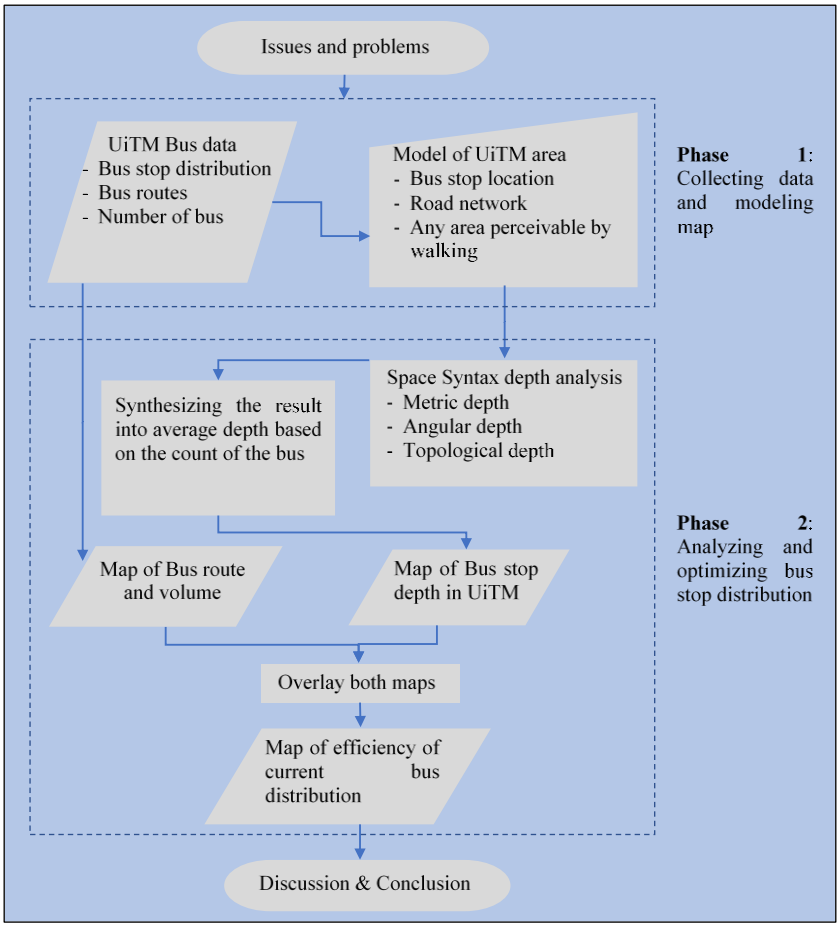

Fig. 1. Flow chart of research process

Source: Authors, 2023

RESULTS AND DISCUSSION

Data and Model of UiTM Bus Stops

This section refers to phase 1 of the research process: collecting data and modeling a map. Universiti Teknologi MARA Shah Alam's campus provides seven routes: A, B, C, C2, D, E, and G (see Table 1). The campus bus has nine (9) bus stops in the university area (see Table 2). By counting how many active buses are on each route and which route will stop at which bus stop, this research provides information on the bus volume (see Table 2). This volume is also a factor determining how easy the access to this bus stop is. As the volume is more prominent, it is easier to access.

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Table 1. UiTM's bus routes

No	Bus route	Number of active buses on weekdays	Number of active buses on weekend and holiday
1	A	3	3
2	B	3	3
3	C	6	3
4	C2	3	3
5	D	4	3
6	E	3	3
7	G	4	4

Source: Authors, 2023

Table 2. UiTM's bus stops name and their data

No.	Bus stop	Bus routes	Total volume of bus on weekdays	Total volume of bus on weekend
1	Hentian Mawar (DC)	B, C, C2, D, E, G	28	22
2	Hentian Pusat Kesihatan	B, C, C2, D, E, G	28	22
3	Hentian Anggerik	B, C, C2, D, E, G	28	22
4	Padang Kawad	A, B, D	6	6
5	Hentian Perindu	C, C2, E, G	13	10
6	Hentian Seroja	B, C, C2, D, E, G	28	22
7	Hentian FSKM (Fakulti Sains Komputer Dan Matematik)	B, C, C2, D, E, G	28	22
8	Hentian FKPM (Mascom)	B, C, C2, D, E, G	28	22
9	Hentian Budi Siswa	A	3	3
	Grand Total of bus		190	151

Source: Authors, 2023

UiTM bus routes have four (4) types of characteristics based on their destination. The research categorises the characters by four (4) colors (see Figure 2). The colors green and purple serve the transportation inside the university area only. Bus route A only server short bus route. It is only from the bus stop Padang Kawad to the bus stop Hentian Budisiswa. Bus routes B and G (colored purple) serve the main ring route of UiTM. The only difference is route B to Bus stop Perindu, while route G to Bus stop Padang Kawad. The colors red and blue serve the transportation to the inside and outside of the university. Bus routes C and C2 (colored red) go outside by the back gate of UiTM. Bus routes D and E (colored blue) are going out by the main gate of UiTM. Nearby UiTM, there is also the future and ongoing construction of the LRT station. Currently, there has yet to be a route transportation to that station.

The map model must be imported to DepthmapX Space Syntax Software to run space syntax analysis. The model of the UiTM boundary of the area perceivable by walking is created using AutoCAD software. The boundary is also combined with the road network. The output of this process is the CAD drawing map.

https://doi.org/10.24191/bej.v21i1.475

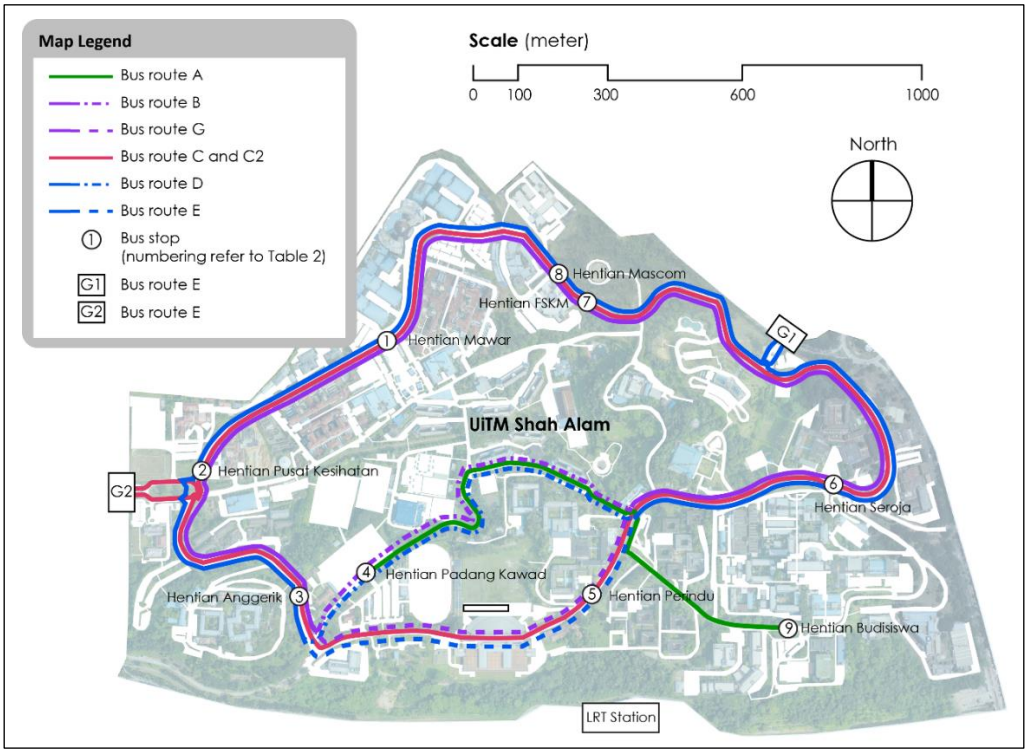

Fig. 2. UiTM Shah Alam bus route map

Source: Authors, 2023

Space Syntax Analysis

This section refers to phase 2 of the research process: "Analysing and optimising bus stop distribution". This study evaluates the bus stop distribution using space syntax spatial analysis techniques. Specifically, this study uses the visibility graph, where the maps are represented by colored graphics of dots that contain a mathematical value. The dots use a grid of 0.6 meters by assuming human shoulder width (Panero & Zelnik, 1979).

This analysis has three (3) depth logic: topological, angular, and metric (Xia, 2013). These three (3) logics help measure the bus stop's depth to the surrounding area. The first topological logic is how depth is counted by how many turns it takes to proceed to a destination (Dao & Thill, 2022). People tend to choose the route with the fewest turns. Too many turns can tire people because the brain needs to focus on orientating and wayfinding while turning. The second logic, angular, counts the angle of each turn from the starting point to the destination (Xia, 2013). Like we are using vehicles such as bicycles, it is more relaxed and smoother to ride on the track with a straight route and less curvy. Like walking, turning while walking uses significant physical effort, especially for people with disabilities. The third logic, metric, is common sense, where force times distance equals energy. It means more distance requires more energy. Metric logic measures how long the distance is by the length of the tract regardless of the turn count or turning angle. Most enthusiastic walkers are more considerate of the length. This kind of walker is the one who always seeking shortcuts.

The bus stop depth analysis process involves analysing the depth of each bus stop. Figure 3 shows the topological analysis per bus stop. In contrast, other logic is only presented in the average form in Figure 4.

https://doi.org/10.24191/bej.v21i1.475

Using equations 1, 2, and 3, the author synthesizes the average depth for each logic. The average equation is simple, not as simple as adding and dividing the total bus stops. Before adding the value, the value of each bus stop must be multiplied by the bus volume. The volume is obtained from Table 2, column four (4), which contains weekday bus volume. Each depth logic is counted on the same conditions.

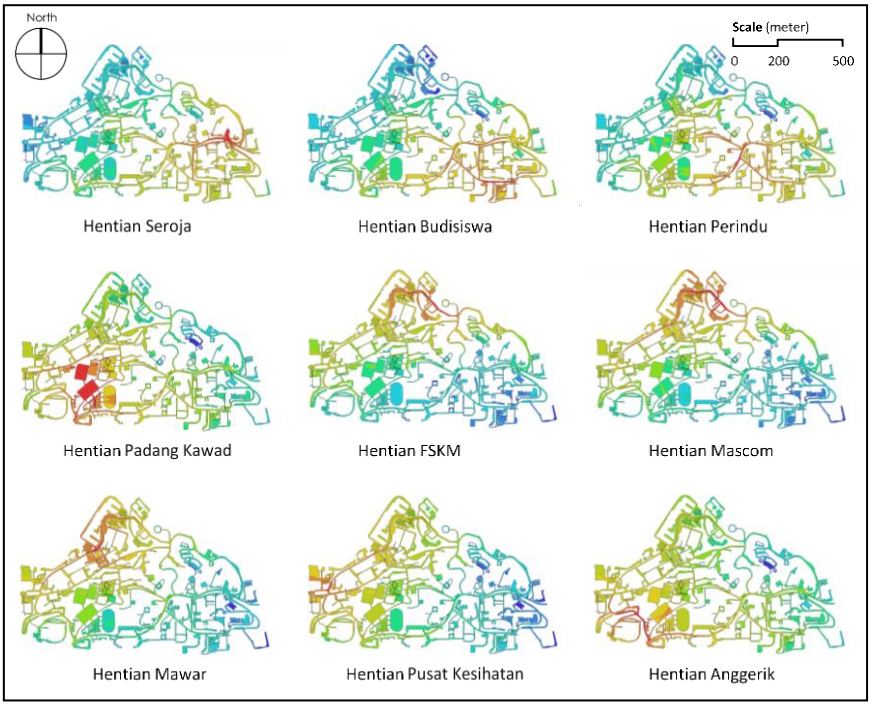

Fig. 3. Topological depth counting from each bus stop

Source: Authors, 2023

As the results, the analysis shows several spots in UiTM Shah Alam have not been properly served by the bus stop (see the black circles in Figure 4). The depth analysis shows that area one (1), near the main gate (G1), especially the Canseleri Tuanku Syed Sirajuddin UiTM building, is far from the nearest bus stop. It does not mention the terrain and altitude. Walking to Canseleri Tuanku Syed Sirajuddin UiTM must comply with the low physical effort principle. Another spot, spot number two (2), is the swimming pool and bowling sports facility. The sports facilities are located in the middle but seem isolated due to their access from the bus stop. Spot number three (3) is located on UiTM Koperasi Berhad. This spot is near bus stop Seroja, but the track is curvy and has a rough contour.

Spot four is the Faculty of Art and Design, the main library, and the area around the bus stop of Budisiswa. Even though the bus stops inside the radius, this spot is measured as the deepest corner space of UiTM. It is because the volume of the bus stop is deficient, only two buses. Spot five (5) is the student dormitory, while spot six (6) is the sports center. Both spots have a high demand for commuting students but are far from the bus stops.

$$\text{Avg. Top.} = \frac{(\text{Top. bs A} \times \sum \text{V bus in bs. A}) + \ldots + (\text{Top. bs G} \times \sum \text{V bus in bs. G})}{\text{Grand volume of bus}}$$

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Equation 1: Average of topological depth from all bus stop considering the bus volume that stop in the bus stop.

$$\text{Avg. Ang.} = \frac{(\text{Ang. bs A} \times \sum \text{V bus in bs. A}) + \ \ldots \ + (\text{Ang. bs G} \times \sum \text{V bus in bs. G})}{\text{Grand volume of bus}}$$

Equation 2: Average of angular depth from all bus stop considering the bus volume that stop in the bus stop.

$$\text{Avg. Met.} = \frac{(\text{Met. bs A} \times \sum \text{V bus in bs. A}) + \ \ldots \ + (\text{Met. bs G} \times \sum \text{V bus in bs. G})}{\text{Grand volume of bus}}$$

Equation 3: Average of metric depth from all bus stop considering the bus volume that stop in the bus stop.

$$\text{Avg. Bus stop depth}_{\,i} = \frac{\text{met. depth}_i\% + \text{ang. depth}_i\% + \ \text{top. depth}_i\%}{3}$$

Equation 4: Average of all depth parameter.

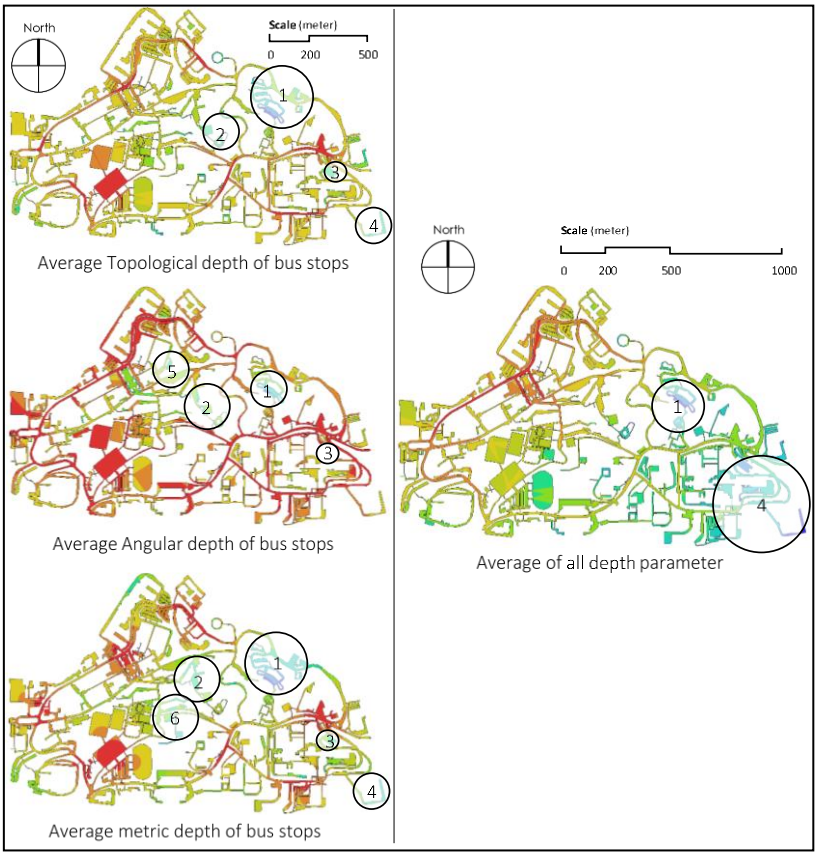

Fig. 4. Synthesising depth parameter of bus stops

Source: Authors, 2023

https://doi.org/10.24191/bej.v21i1.475

In summary, the bus stop distribution in UiTM needs to be increased. There is a critical demand for students commuting to various destinations such as dormitories, sports centers, and faculties. This analysis recommends adding more bus stop to the center of UiTM near spot number five (5) and number six (6). This analysis also suggests adding more bus routes to bus stop Budisiswa to carry out the demand to that area where essential places like the main library and several faculty are nearby.

Besides the bus stops future planning, this research found a theoretical finding about how depth is perceived. While Xia (2013) sees three (3) of the logic of depth separately, this research has proven a new depth perspective by combining and averaging those three logics: topologic, angular, and metric. These three logics should stand as one to get a comprehensive evaluation for last mile distance. Using Equation 4, this research can highlight areas that need higher physical effort to perceive. This finding is beneficial in planning bus stops that consider the universal design for all users wherever they live and work.

CONCLUSION

The excessive use of cars in Malaysia has given an awareness to society to shift toward sustainable transportation. Buses, with their flexibility of movement, have become a suitable car alternative. The challenge of bus transportation is that the user must walk a long distance from the bus top to the last destination, the last mile. According to the universal design principles, the bus stop location should accommodate a short distance of walking to the destination. Motivated by the issues, this research evaluates the current bus stop distribution in UiTM Shah Alam. Through the evaluation, this research aims to improve UiTM's bus service. The implication of the result can bring a new pace for development toward low carbon transportation and minimize car users, space for car parking, and carbon emission.

ACKNOWLEDGEMENT

None.

AUTHORS' CONTRIBUTIONS

All authors involved in carried out the research, wrote and revised the article, conceptualised the central research idea and provided the theoretical framework, review and approved the article submission.

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