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A SPATIAL ANALYSIS OF SUBSIDISED BUS ROUTE CATCHMENT FEASIBILITY IN AN URBAN AREA IN MALAYSIA

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Abstract

This paper focuses on subsidized bus services provided by a local authority in Malaysia to determine the route's feasibility. This case study explores the catchment area of the designated bus stops in its route, the distance between the bus stops, the passengers' boarding, and alighting points, and the level of service. A Global Positioning System (GPS) device was used for an onboard survey to identify the boarding and alighting points, and the service catchment area was explored with the Geospatial Information System (GIS) tool. Findings indicate that the service level lacks sufficient facilities, proper accessibility, comprehensive information, and signage at bus stops. Furthermore, relatively poor performing bus service in passengers loading and timely arrival during peak periods. Next, an analysis of forty-one (41) catchment areas revealed that only 37% of the bus stops are within a catchment area. Recommendations for bus services include timely and accurate information to ease users to plan their journey and providing comfortable bus stops.

Keywords: Public Bus Service; On-board Survey; Service Catchment; Level of Service (LOS)

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INTRODUCTION

Rapid urbanization in Malaysia has caused heavy traffic congestion (Norhisham et al., 2018). In cities without an effective transportation plan, demand and supply are out of balance (Givoni & Banister, 2010). Due to the importance of transportation to economic growth, a comprehensive and sustainable transportation system is essential (Brand et al., 2017). Globally, buses are the most prevalent, affordable, and accessible mode of transportation. When a broad geographic area is served, bus service planning is optimal (Taplin & Sun, 2020). Malaysia's capital, Kuala Lumpur, reorganized bus corridors according to primary routes in the city center through the implementation of the Bus Network Revamp (BNR) in 2015 (Norhisham et al., 2018). The BNR directs public transportation planning in all Malaysian states with the goal of enhancing the free public bus service to increase public transportation use, reduce private vehicle use, and reduce environmental pollution (Setiausaha Kerajaan Negeri Selangor, 2019).

Selangor, the most sustainable state in the country, intends to become a "Smart State" by 2025. (Smart Selangor, 2016) The Smart Selangor Initiative implements Internet of Things (IoT) solutions to enhance the quality of life of its citizens. This domain offers an IoT-based transportation solution and integrates big data and smart infrastructure in order to enhance the user experience (Smart Selangor Delivery Unit, 2016). Selangor Smart Bus provides free navigation for city buses (Setiausaha Kerajaan Negeri Selangor, 2019). Using the SITS application, passengers of Selangor Smart Bus can view bus routes and arrival times in order to avoid traffic (Fong et al., 2019).

Improving the catchment area and level of service are important factors to consider for enhancing the quality of bus services (LOS). The catchment area of a bus stop is the range of walkable passengers (Roy & Basu, 2019). A pedestrian shed analysis (ped-shed) depicts the areas covered by a 5-minute walk to a bus stop or a 10-minute walk to a train station (Salvo & Sabatini, 2005), or, a 400-800-metre buffer space between a bus stop and a train station that is accessible to pedestrians (El-Geneidy et al., 2014). The analysis determines the accessibility of an urban area by drawing a perfect circle around a designated point. Ped-sheds are asymmetrical in practice to accommodate actual walking distances (Daniel & Burns, 2018; Salvo & Sabatini, 2005). In the meantime, LOS has emerged as a useful metric for evaluating the quality of services (Das and Pandit, 2013).

RESEARCH BACKGROUND

Selangor Smart Bus's aims to provide efficient services and convenience. The Selangor Smart Bus SA02 Route (Hentian Pusat Bandar - Stesen Komuter Batu Tiga) in Shah Alam was chosen as a case study because of its service catchment area and route network feasibility for passengers have not been thoroughly determined. This study evaluates a route's efficiency and convenience. Spatial analysis was used to determine the distance between the designated bus route and bus stop (SA02 Route) based on passenger count, service level, boarding, and alighting locations, current planning, and service catchment.

METHODOLOGY

The case study examines Selangor Smart Bus SA02 in Shah Alam, Malaysia (Figure 1). It covered Shah Alam's economic activities. The route connects neighborhoods, commercial districts, a train station, and an educational hub. he SA02 route was deemed a good reference for urban bus service providers.

Onboard Survey

Onboard the bus, a survey was conducted to observe the route and manually count passengers at each stop. Two pilot tests verified the data collection's reliability. Data were collected on three weekdays and one weekend day. Data collection was based on the bus's daily operating hours, as follows:

Morning Peak: 7.00 a.m. - 8.00 a.m.
Morning Off-Peak :10.00 a.m. - 11.00 a.m.
Afternoon :12.00 p.m. - 2.00 p.m.
Evening Peak :4.30 p.m. - 5.30 p.m.
Evening Off-Peak :7.30 p.m. - 8.30 p.m.

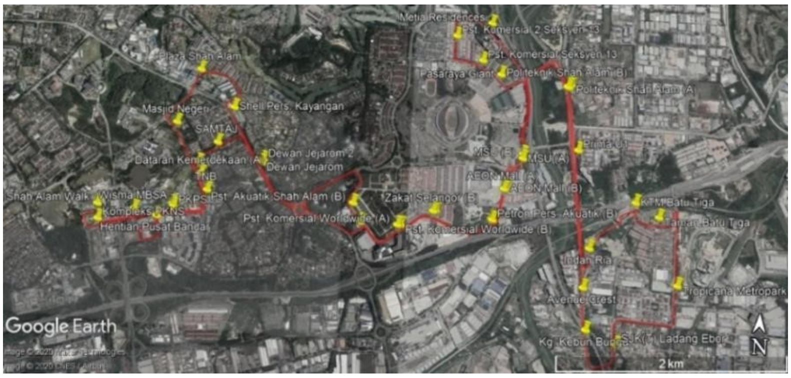

Figure 1. Selangor Smart Bus SA02 Route

The monthly number of passengers for the Selangor Smart Bus service SA02 Route in 2019 was obtained from Shah Alam City Council Urban Transportation Division. A further comparison was made between the peak and off-peak hours to observe the difference between the weekdays and weekends loadings.

GPS Points Recording

A mobile GPS device (Garmin GPSMAP® 64sx | Handheld GPS with Navigation Sensors) was used to record each passenger's boarding and alighting locations during the onboard survey. In addition to a pilot onboard survey, two pilot studies were conducted to calibrate the GPS device. Using the Google Maps service, the recorded GPS coordinates were validated by comparing them to the actual bus stop coordinates. A spatial analysis was utilized to determine the optimal boarding and alighting point coordinates for each stop.

Pedestrian Shed Analysis and GIS Spatial Analysis

A pedestrian shed analysis was conducted to evaluate passengers' walkability to the nearest bus stops and main stations at a buffer distance of 400 m and 800 m, respectively. A Geospatial Information System (GIS) spatial analysis was conducted using ArcGIS software to determine the service catchment area's type of land use surrounding the bus stops and study the pattern of pedestrians who can access the nearest bus stops or station.

Level of Service

Level of service (LOS) analysis validated the load factor, service frequency, service hour, and reliability. The collected data were rated from grade A to F according to the standards for LOS of bus services established from the Highway Capacity Manual (National Research Council, 2000)

Interview with Bus Service Planner

Three individuals from the Shah Alam City Council Urban Transportation Division bus service planners were interviewed about the bus service schedule, daily operation, passenger statistics, type of bus stop or station, and challenges they face providing a free bus service. Next, the Selangor Town and Country Planning Department an officer was also interviewed on the route's urban planning and GIS land use data was interviewed separately. All the interviews were conducted through an informal approach.

RESULTS AND DISCUSSION

Bus Stop and Interchange within SA02 Route

There are 41 distinct bus stops or stations along the SA02 Smart Bus Route. Twenty-one (21) pole bus stops, seventeen (17) bus stops, two (2) major stations, and one (1) ghost bus stop are all present on the route (Figure 2). The Shah Alam City Council defines a phantom bus stop as a designated stop that has no facilities or signage. Shelter and bus route information are available at the main station and standard bus stops. The remaining 21 pole bus stops are signposts without shelter. S Standard and main bus stops are lit and powered by electricity. A bus driver might pass by people at a bus stop that isn't well lit at night because the pole and phantom bus stops rely on nearby street lighting. Passengers frequently need to cross the street to stop a bus when waiting at a pole or makeshift bus stop, which is dangerous. Pole stops are located at stops 1, 2, 13, 29, and 33, while stop 16 is unprotected and unlit. The SA02 route also makes it possible to travel quickly within and outside of Shah Alam, where 18 interchange routes are run by various bus companies, and 34% of the SA02's 41 bus stops are interchanges. Kuala Lumpur, Petaling Jaya, Klang, Subang Jaya, Cyberjaya, and Kuala Langat are all accessible from Shah Alam via its six routes. The number of passengers at stops O, 13, 17, 24, and 33 increases as a result of this integration with the SA02 interchange routes.

Figure 2. Example of Bus Stop. (a) Main Bus Station; (b) Bus Stop; (c) Pole Bus Stop.

The Selangor Intelligent Transport System (SITS) application was developed by the Smart Selangor Delivery Unit (SSDU) to aid in trip planning. It displays the anticipated arrival time at each bus stop. SITS do not fully integrate bus stops because bus operators and application developers are from separate organizations (Appendix, Table 8). For instance, the application does not display Shah Alam Walk, Dewan Jejarom 2, MSU (A), MSU (B), Dewan Jejarom, or Dataran Kemerdekaan. Without these bus stops in SITS, passengers are unable to determine if a bus stops at a specific stop, as the driver may not see the route signage. In the application, some of the bus stops have different names. The ambiguity, inconsistency, or deficiency of information regarding bus routes can discourage individuals from using public transportation. For the SITS application to be able to provide information, both bus operators and application developers should improve bus route planning, including frequent updates on GPS location in the database (Fong et al., 2019), which would enhance the user experience. Some of the existing features, such as displaying the license plate number of the approaching bus and its current location on the map, are effectively integrated.

Bus Stop Coordinate Comparison Analysis

This study discusses GPS coordinates from an onboard survey that validated passengers' boarding and alighting points. Validating GPS points helped researchers study the SA02 Bus Route's catchment area. SA02 covers 27.7 km and 4.33 km^2. Geospatial data validation used GPS-based comparison analysis. Each test's most precise GPS coordinates were compared to a geospatial resource. Optimal coordinates were chosen based on the trip variation. If the sampling site is at the equator, a second of longitude equals 30.87 m of latitude. Longitude and latitude range differences are 0 to 0.5 seconds and 0 to 0.6 seconds, respectively. This result represents a distance difference of fewer than 20 m caused by actual road traffic. Because there was no stopping at these bus stops, the GPS coordinates for stops 12, 15, and 17 were automatically selected from their geospatial resources. Bus stops O and 23 were not chosen from the onboard survey because they arrive and depart from different locations in the main station. This discovery validates the bus stop's location, easing future transportation planning and upgrading.

Pedestrian Shed Analysis and GIS Spatial Analysis

Based on bus service providers' ridership statistics for the SA02 route, more than 610,000 passengers were recorded in 2019, or 50,000 per month (Figure 3). The bus company confirmed this number in all their records. This route's constant ridership requires a study of bus stop catchment areas to ensure efficiency. Figure 4 shows each bus stop's catchment area, which is 400-m except for stops O and 23, which are 800 m as main stations. When the 400-m circles overlapped, they were combined. These combinations show that passengers at the intersection of two catchment but-stop walk between bus stops within the circled walkability range. When a passenger's destination is just one bus stop away, the circle shows whether they can walk there instead of waiting 20 minutes for the next bus. Red circles represent the catchment area for Hentian Pusat Bandar (bus stop O) to KTM Batu Tiga (bus stop 23), while blue circles represent the return direction. Red lines go from bus stop O to 23 and blue from 23 to O. Following are some key findings from Pedestrian Shed Analysis, GIS Spatial Analysis and observation during the on-board survey:

- Bus stop O has one of the most prominent locations in Shah Alam's city center. The stop spans bus stops 1 to 6, which overlaps a second catchment area from bus stop 36 to the origin bus station (bus stop O). Because it was a parking lot, bus stop 1 was hard to reach. Shah Alam's origin station is the main bus hub.
- The area around bus stops 1, 2, 3, 4, 38, 39, and 40 is dominated by commercial and government offices. The same street has ten bus stops, from 11 to 15 and 30 to 34. All of these bus stops are within the next stop's catchment area, so a passenger must walk about five minutes.

- Bus stops 11, 12, 33, and 34 serve the commercial area along the street, while stops 13 and 32 are interchange stops. Bus stops 14 and 31 are near a shopping center.
- At bus stop 31, food stalls cause evening rush-hour traffic congestion. Bus stops should have a 3-meter buffer zone to avoid traffic conflicts (Salvo & Sabatini, 2005). University students use stops 15 and 30. No passengers were seen boarding the SA02 Smart Bus from phantom stop 15.
- Bus stops 10 to 12 and 33 to 35 serve residential areas, but residents cannot access them. When designing a bus stop, the catchment area radius should be based on the walking distance route, not a straight-line radius, as this reduces the neighborhood catchment area (Azmi et al., 2012)
- Bus stop 16 is strategically located because it serves low-income neighborhoods with residents who walk to amenities. In this dense, low-income community, bus stop 16 is served twice per round trip (Azmi et al., 2012).
- A highway separates bus stops 22 through 28. The origin station route of KTM Batu Tiga terminates at bus stop 22, between a condominium and an industrial area (bus stop 23). The rail station is a five-minute walk from bus stop 23, so passengers can walk. The last catchment area comprises stops 26 through 28. The 26th bus stop faces a primary school. Despite their proximity, bus stops 27 and 26 are not accessible on foot due to a major road. Bus stop 28 is located in a condo-and-business district and the SA02 serves numerous commuters daily.

The gap between bus stops ranges from 220 to 700 meters to 800 to 1,800 meters. To simulate the actual scenario, actual bus distance was used instead of displacement. 74% of the gap distance between bus stops on the SA02 route fell between 220 m and 700 m, with half of it falling within the catchment area of 400 m; this indicates that 37% of bus stops on the SA02 route are designated as being within walking distance. Eleven non-designated bus stops were surveyed during the onboard survey (Table 2). The points are known as intermediate drop-off points (IT), with the exception of IT1 and IT10, the majority of which are insignificant due to their proximity to a designated bus stop or the low number of passengers alighting from the point. IT1 is a safer bus stop for the SA02 route because it is located on a side road before exiting the main road and is closer to commercial and residential areas. In contrast, IT10 was a dangerous place for a bus to stop because it was located immediately after a traffic light, which posed a high potential for an accident. Mostly residential. Both the previous and subsequent bus stops from IT10 are appropriately labeled to serve the entire residential area. Therefore, there should be an instruction prohibiting bus drivers from stopping at locations where it is unsafe for passengers to exit the bus, such as IT10. Thus, to encourage the use of public transport, safer and more convenient pedestrian access to interchanges and main hubs must be provided (Aziz and Mohamad, 2020).

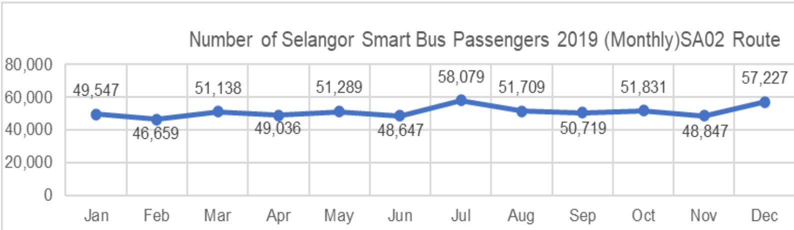

Figure 3. The number of Selangor Smart Bus SA02 Route Passengers in 2019 (Monthly)

Table 2. Gap Distance of Each Bus Stop to the Subsequent Bus Stop (Based on Distance Travelled by Bus).

Bus Stop	Gap Distance (m)	Bus Stop	Gap Distance (m)	Bus Stop	Gap Distance (m)
O to 1	650	14 to 15	400	28 to 29	1,800
1 to 2	300	15 to 16	1,000	29 to 16	900
2 to 3	400	16 to 17	220	16 to 30	1,600
3 to 4	350	17 to 18	450	30 to 31	400
4 to 5	550	18 to 19	600	31 to 32	290
5 to 6	550	19 to 20	1,200	32 to 33	550
6 to 7	650	20 to 21	650	33 to 34	350
7 to 8	800	21 to 22	1,100	34 to 35	600
8 to 9	550	22 to 23	650	35 to 36	1,700
9 to 10	1,200	23 to 24	350	36 to 37	600
10 to 11	450	24 to 25	1,000	37 to 38	300
11 to 12	350	25 to 26	1,100	38 to 39	300
12 to 13	550	26 to 27	550	39 to 40	400
13 to 14	300	27 to 28	350	40 to O	700

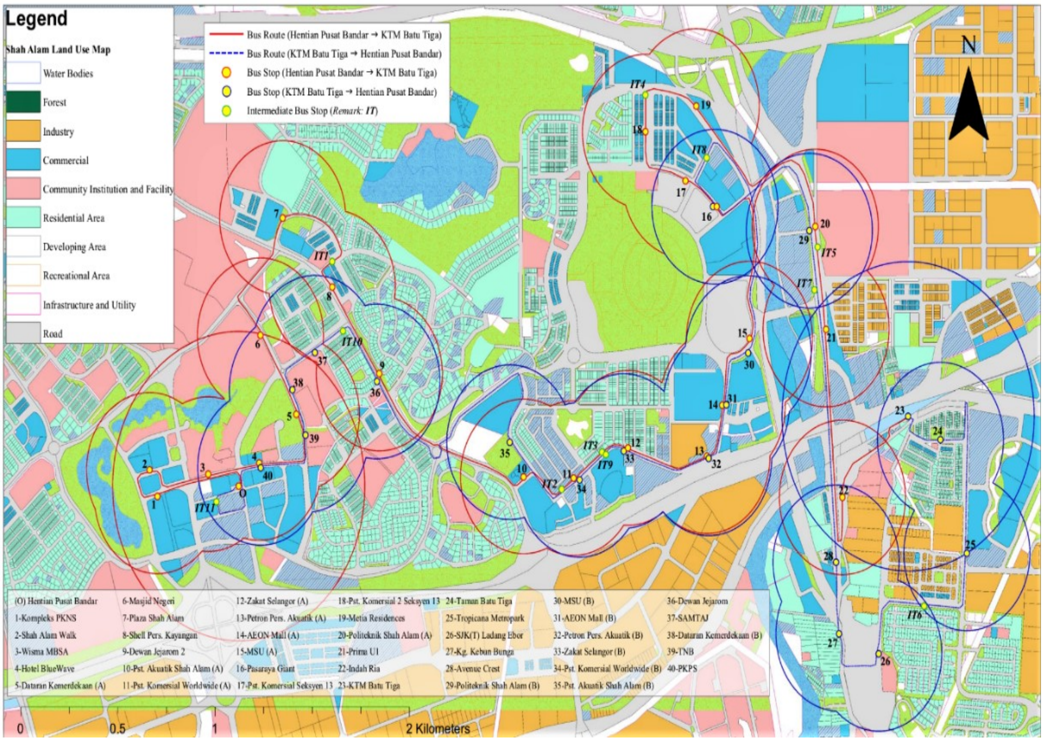

Figure 4. Catchment Area of SA02 Bus Route from Each Bus Stop

Table 3. Passengers Loading LOS Thresholds Grade for SA02 Route

Time Period	Level of Service (LOS)			
	Test 1 (Monday)	Test 2 (Friday)	Test 3 (Wednesday)	Test 4 (Saturday)
Morning Peak	D	C	E	B
Morning Off-Peak	B	C	C	A
Afternoon	B	C	B	B
Evening Peak	F	F	F	C
Evening Off-Peak	A	A	C	C

Table 4. Hour of Service LOS for SA02 Route

	Scheduled First Trip	Scheduled Last Trip	LOS
Weekdays	6.00 am	10.00 pm	B
Weekends	6.00 am	10.00 pm	B

Table 5. Duration of each Trip in SA02 Route at Different Period of Time

Time Period	Duration (minutes)				
	Weekdays				Weekend
	Test 1 Monday	Test 2 Friday	Test 3 Wednesday	*Average*	Test 4 Saturday
Morning Peak	97	79	109	*95.0*	93
Morning Off-Peak	80	73	76	*76.3*	76
Afternoon	92	75	77	*81.3*	102
Evening Peak	98	151	127	*125.3*	84
Evening Off-Peak	84	67	71	*74.0*	70

Table 6. On-Time Performance (OTP) LOS for Weekdays and Weekend for SA02 Route

Time Period	Weekdays			Weekend		
	On-Time Percentage (%)		LOS	On-Time Percentage (%)		LOS
	OTP	100 - |OTP|		OTP	100 - |OTP|	
Morning Peak	18.75	81.25	E	16.25	83.75	E
Morning Off-Peak	-4.63	95.37	B	-5.00	95.00	B
Afternoon	1.63	98.37	A	27.50	72.50	F
Evening Peak	56.63	43.37	F	5.00	95.00	B
Evening Off-Peak	-7.50	92.50	C	-12.50	87.50	D

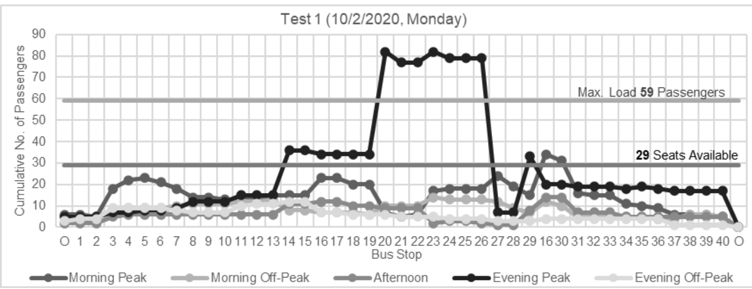

Figure 5. Cumulative Number of Passengers Loading for Test 1 (10/2/2020, Monday)

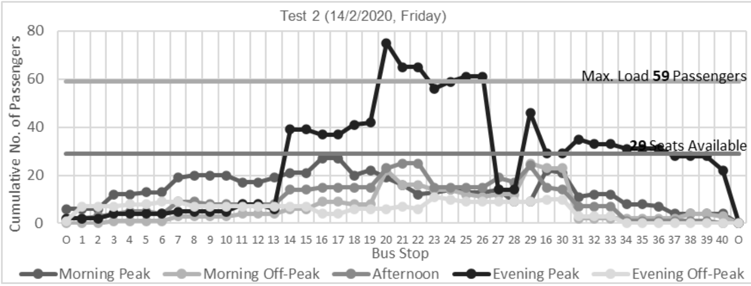

Figure 6. Cumulative Number of Passengers Loading for Test 2 (14/2/2020, Friday)

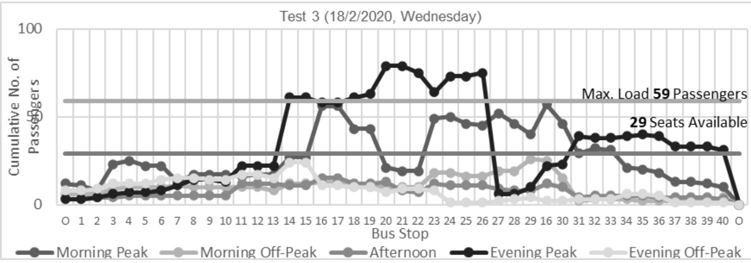

Figure 7. Cumulative Number of Passengers Loading for Test 3 (18/2/2020, Wednesday)

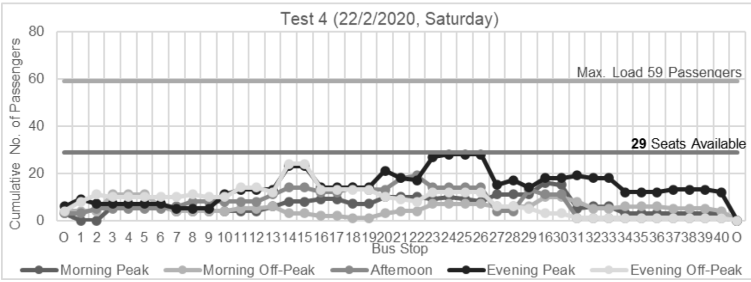

Figure 8. Cumulative Number of Passengers Loading for Test 4 (22/2/2020, Saturday).

Level of Service (LOS)

Daily, six buses travel this route. In the United Kingdom, the Alexander Dennis Enviro200 is one of five low-emission bus models (LowCVP). Each bus has 29 seats for a total of 30 passengers. The onboard survey collected information from numerous passengers at various times (Figures 5, 6, 7, and 8). The bus's 59-passenger capacity was exceeded by more than 1.5 times during evening rush hour (LOS F) (Figure 5-7 and Table 3). The maximum passenger capacity was 82. During morning rush hour, passengers boarded a fully seated bus (LOS C) or stood comfortably (LOS D and LOS E) without reaching the maximum passenger load. During the week, levels above the threshold were recorded (LOS D). Every weekend, passengers are able to find seats, so LOS is sufficient. Despite a service frequency of every 20 minutes, bus frequency varied between LOS B and LOS

C. However, in practice, passenger wait times varied between 20 and 40 minutes. During data collection, this held true both weekdays and weekends. This route has LOS B throughout the entire week because it operates more than 17 hours per day (Table 4). Table 5 displays the duration of each trip based on the dependability of the service. Comparing weekday and weekend trip durations (Table 6), weekday and weekend round-trips differed significantly, particularly during afternoon and evening peak periods. The evening rush hour (LOS F) on weekdays was the busiest, while the weekend afternoon was the busiest (LOS F). Other time periods vary slightly. Only off-peak trips were completed in 80 minutes; all others exceeded the acceptable range by between 4 and 71 minutes. Service providers and local governments should therefore increase the frequency of bus departures and arrivals in order to improve the LOS (Shukri et al., 2020).

CONCLUSION

The catchment area of the SA02 bus route was analyzed to determine the optimal GPS coordinate for each bus stop. This study used the 400-800 m catchment area as a guideline, but it is not fixed because distances vary from location to location and over time. Upon analyzing the SA02 bus route's catchment area, numerous demand-supply gaps were uncovered. Some bus stops exceeded their passenger capacity, while others were poorly integrated. The SA02 bus route's LOS is inconsistent in terms of passenger load and punctuality. Therefore, recommendations include adopting an application that provides timely and accurate information to help users plan their journey, providing a comfortable bus stop to improve user comfort and safety, and planning the location of bus stops by considering the surrounding land use are all practical actions. The findings of the study will determine the future of public transportation in this region.

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REFERENCES

Advani, M., & Tiwari, G. (2006). Review of capacity improvement strategies for bus transit service. *Indian Journal of Transport Management, 30*(4), 363-391.

Azmi, D. I., & analyzingKarim, H. A. (2012). A comparative study of walking behaviour to community facilities in low-cost and medium-cost housing. *Procedia-Social and Behavioral Sciences, 35*, 619-628.

Aziz, A., & Mohamad, J. (2020). Public transport planning: Local bus service integration and improvements in Penang, Malaysia. *Planning Malaysia, 18*.

Brand, J., Hoogendoorn, S., Van Oort, N., & Schalkwijk, B. (2017, June). Modelling multimodal transit networks integration of bus networks with walking and cycling. In 2017 5th *IEEE international conference on models and Technologies for Intelligent Transportation Systems* (MT-ITS) (pp. 750-755). IEEE.

Daniel, P., & Burns, L. (2018). How steep is that street?: Mapping 'real'pedestrian catchments by adding elevation to street networks. *Radical Statistics*, (121), 26-48.

Das, S., & Pandit, D. (2015). Determination of level-of-service scale values for quantitative bus transit service attributes based on user perception. *Transportmetrica A: Transport Science, 11*(1), 1-21.

El-Geneidy, A., Grimsrud, M., Wasfi, R., Tétreault, P., & Surprenant-Legault, J. (2014). New evidence on walking distances to transit stops: Identifying redundancies and gaps using variable service areas. *Transportation, 41*(1), 193–210.

Fong, S. L., Chin, D. W. Y., Abbas, R. A., Jamal, A., & Ahmed, F. Y. (2019, June). Smart city bus application with QR code: a review. In 2019 *IEEE International Conference on Automatic Control and Intelligent Systems* (I2CACIS) (pp. 34-39). IEEE.

Givoni, M., & Banister, D. (2010). The need for integration in transport policy and practice. In Integrated transport (pp. 17-28). Routledge.

Norhisham, S., Ismail, A., Sidek, L. M., Borhan, M. N., Zaini, N., & Yen, A. T. G. (2018, April). Assessing Bus Performance Rating in Kajang, Selangor. In *IOP Conference Series: Earth and Environmental Science* (Vol. 140, No. 1, p. 012076). IOP Publishing.

Roy, S., & Basu, D. (2019). Ranking Urban Catchment Areas according to Service Condition of Walk Environment. *Journal of Transportation Engineering*, Part A: Systems, 145(4), 04019005. https://doi.org/10.1061/jtepbs.0000225

Salvo, G., & Sabatini, S. (2005). A GIS approach to evaluate bus stop accessibility. In Proceedings.

Setiausaha Kerajaan Negeri Selangor. (2019). Setiausaha Kerajaan Negeri Selangor. (2019), Perkhidmatan Bas Selangor Percuma. https://www.selangor.gov.my/index.php/pages/view/1181

Shukri, N. S. M., Ponrahono, Z., Sunoto, Y. N., & Ghazali, W. N. W. W. (2020). Evaluation of Level of Service (LOS) on routes of smart bus in Kajang, Selangor. *PLANNING MALAYSIA, 18.*

Smart Selangor Delivery Unit. (2016). Smart Selangor Delivery Unit. (2016). Smart Selangor Executive.

Taplin, J. H. E., & Sun, Y. (2020). Optimising bus stop locations for walking access: Stops-first design of a feeder route to enhance a residential plan. *Environment and Planning B: Urban Analytics and City Science, 47*(7), 1237–1259.

National Research Council. (2000). Transportation Research Board., 2000 Highway Capacity Manual. Washington, DC.

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