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Spatial Analysis of Accessibility for Public Transportation, A Case Study in Jakarta, Bus Rapid Transit System (Transjakarta), Indonesia

[1,2]Apri Zulmi Hardi and [1]AbdulKader Ali Murad

[1]*Department of Urban and Regional Planning, Faculty of Architecture and Planning, King Abdulaziz University, Jeddah, Saudi Arabia*
[2]*Ministry of Agrarian Affairs and Spatial Planning/ National Land Agency, Jakarta 12014, Indonesia*

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Corresponding Author:
AbdulKader Ali Murad
Department of Urban and Regional Planning, Faculty of Architecture and Planning, King Abdulaziz University, Jeddah, Saudi Arabia
Email: Amurad@kau.edu.sa

Abstract: Integrating public transportation has become a prevalent aspect of urban expansion in developed and developing countries. There are numerous benefits associated with implementing public transportation systems within urban areas, which may serve as a viable solution to address various traffic-related issues. Nevertheless, certain nations that have adopted public transportation encounter accessibility issues affecting the efficiency of such services. The authors have conducted a case study on the public transportation system of Jakarta, explicitly focusing on the Bus Rapid Transit (BRT)/Transjakarta. The mode above of transportation is widely recognised as a prominent public transit system in Jakarta, frequently utilised by a significant portion of the populace to address. The authors applied spatial analysis techniques to evaluate the accessibility of public transportation in Jakarta. The assessment was conducted using the city concept of 5, 10, and 15 min and relied on open spatial data provided by the Jakarta Government. The results demonstrate that the accessibility evaluates the nearby BRT stations' roads and walkways on a standard scale. It revealed that just 41% of Jakarta's network could be used to access public transit (BRT), while over 58% of BRT stations are inaccessible or have a poor network connection. Furthermore, according to the analysis of accessibility overlaid by district (area/Ha), 33,37 Ha (51%) of Jakarta's total area is described as being inaccessible for BRT services, compared to 24% for the accessible region. At last, the authors conduct a K-means clustering analysis on the districts to identify clusters of accessible and inaccessible districts.

Keywords: Public Transportation, Bus Rapid Transit (BRT), 15 min City Concept, Accessibility Analysis, K-means Clustering Analysis

Introduction

In urban planning, public transportation is one of the leading amenities being enhanced by municipal governments worldwide. Sustainable transportation is a top concern in cities because it will be a supporting system that helps people's mobility in activities including the economy, society, culture, and politics (Muttaqin *et al.*, 2021; Nieuwenhuijsen, 2021; Żochowska *et al.*, 2022). Public transportation is described as broadly accessible regular passenger transportation offered along a predetermined route, route, or network at predetermined intervals (Domènech and Gutiérrez, 2017; Kaszczyszyn and Sypion-Dutkowska, 2019). In terms of directness, frequency, accessibility, dependability, affordability, speed, punctuality, regularity, accuracy of the information, comfort, level of crowding in the vehicle, cleaning, connections, environment, staff courtesy, safety, and security, public transportation must meet a number of requirements and passengers' expectations (Cheng and Chen, 2015; Tiznado-Aitken *et al.*, 2020; Wang and Chen, 2015).

Many cities worldwide are currently facing significant issues pertaining to public transportation (Hassan *et al.*, 2022; Kumar *et al.*, 2022). A salient concern pertains to the incongruity between the requisition for said services and their tangible accessibility, thereby engendering a disparity

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that results in a considerable number of users being either unattended or inadequately attended (Busco *et al*., 2023). The observed incongruity can be attributed, at least in part, to the escalating urban populace, which exerts additional strain on the pre-existing public transportation infrastructure that is frequently operating at or in close proximity to its maximum capacity (Klar *et al*., 2023; Weverka *et al*., 2023). Furthermore, the necessity for public transportation extends beyond mere quantity, encompassing the imperative of providing accessible, dependable, and cost-effective services, attributes which are not consistently fulfilled to a satisfactory degree (Klar *et al*., 2023).

As a result, a considerable number of individuals who depend on public transportation are confronted with a dilemma, as the presently accessible alternatives do not adequately fulfil their commuting requirements. (Chen *et al*., 2017; Żochowska *et al*., 2022). One of the public transport issues faced by cities and metropolitan cities is the accessibility of public transportation. Being able to plan an effective public transportation system in terms of accessibility, especially in urban regions around the world, is one of the key objectives for policymakers and regional planners (A'rachman *et al*., 2022). These problems are caused by not-integrated systems between the indicators of public transport, such as routes, stop points of public transport and accessible areas for demand. Therefore, the main goal of public transport is to reduce congestion, noise, and air pollution, as well as a lack of parking spots, which cannot be reached due to these problems (Żochowska *et al*., 2022).

Literature Review of Accessibility

A literature review was undertaken to identify accessibility-related concerns, with consideration given to temporal and spatial factors, to determine the methodology for assessing the accessibility of public transportation services. Access to transportation is the capacity to utilise transportation services and travel to specific locations, whereas accessibility to public transportation is the ease of access to public transportation facilities and the convenience of travelling to locations using that transportation (Bok and Kwon, 2016; Grengs, 2015; Kaszczyszyn and Sypion-Dutkowska, 2019). Moreover, the term access to transportation relates to an individual's capacity to utilise transportation services and arrive at specific destinations. Urban mobility is a crucial element that is influenced by various factors, including the accessibility of transportation services in a particular region, an individual's physical capacity to utilise these services (taking into account factors such as age, disability, etc.), and the cost-effectiveness of these services (Saif *et al*., 2019). Fundamentally, transportation accessibility pertains to the ability to effectively employ transportation facilities for the purpose of journeying from one destination to another while taking into account an individual's unique circumstances and the accessibility of transportation services (Vecchio *et al*., 2020). There are several techniques for measuring transit accessibility in the literature (Chen *et al*., 2017). Based on the paper, Żochowska *et al*. (2022) states that the measure of accessibility, the decision can be achieved through five distinct methods, as follows:

- Determined by infrastructure technology
- Determined by distance (Material, Temporal, Economic)
- Measured by the range of locations that can be reached at a certain time, with money or effort
- The opportunity for interaction between a traveller's starting location and a number of destinations
- Socioeconomic traits of each individual route user

The method specifies six characteristics of transit accessibility: Geographical, communicative, temporal, sociocultural, economic, and purpose (Żochowska *et al*., 2022). A transit system that exhibits high accessibility is characterised by its extensive geographic coverage, user-friendly navigational features, dependable and frequent service delivery, inclusivity and sensitivity towards sociocultural diversity, affordability, and versatility in accommodating diverse travel needs (Blanchard and Waddell, 2017; Chen, 2018).

Various analyses can be employed in the domain of public transportation to facilitate planning, decision-making, and evaluation processes (Blanchard and Waddell, 2017). Spatial analysis is a commonly employed technique among urban planners in the contemporary technological era (Di Marino *et al*., 2022; Hasan *et al*., 2023; Sun *et al*., 2016). The present article pertains to the subject of accessibility, which is deemed a pivotal component in augmenting the proportion of public transportation through the utilisation of spatial analysis within the framework of Geographic Information Systems (GIS) (Corazza and Favaretto, 2019; Domènech and Gutiérrez, 2017; Tubis *et al*., 2021).

This study centres on the analysis of proximity to public transportation and its coverage area. The methodology employed in this study is predicated on a segment of an exercise that pertains to bands of equidistant proximity from bus stop stations (Kaszczyszyn and Sypion-Dutkowska, 2019).

The study will concentrate on the analysis of accessibility related to the Bus Rapid Transit System (BRT), which is a mode of public transportation in Jakarta. The city of Jakarta, with a population of approximately 10 million (Martinez and Masron, 2020; Statistic Agency of DKI Jakarta, 2023), possesses a diverse array of transportation systems. As of September 2022, the city has achieved notable progress in establishing an integrated public transportation system, with a public transport service coverage of 86 per cent (Kusworo *et al*., 2022; Oktorini and Barus, 2022). The transportation infrastructure in Jakarta has primarily been designed to cater to the demands of private vehicles, resulting in a disparity between the requirements of public transportation and the utilisation of private vehicles (Sriratnasari *et al*., 2019).

Despite the city's endeavours to enhance the public transportation system, the initiatives have frequently failed to alleviate the issue of traffic congestion, as most individuals in Jakarta continue to favour private vehicles. The principal concern regarding the present public transportation system in Jakarta is that it was not originally conceived as a self-contained entity that could be seamlessly integrated with other modes of public transit, thereby restricting the range of accessibility alternatives accessible to the populace (A'rachman *et al*., 2022). The implementation of the system lacked adequate coordination and integration with other transportation modes, including trains, conventional buses, and angkot (public minivans). The absence of integration poses a significant challenge for commuters in terms of seamlessly transitioning between various transportation modes, thereby compelling them to depend on disjointed and frequently ineffective journeys to arrive at their intended destinations (Gaduh *et al*., 2022; Rahadianto *et al*., 2019). Spatial data analysis is employed to examine the population density in the urban areas of Jakarta and the range of urban functions accessible within a 5, 10, and 15 min walking distance (Kaszczyszyn and Sypion-Dutkowska, 2019) from bus stop stations.

In this case, the authors refer to the utilisation of spatial analysis within the context of boundary operation, network analysis, proximity analysis, and distance analysis, as facilitated by spatial software. GIS-based approaches are valuable instruments for assessing public transportation accessibility (Truden *et al*., 2022). The study will employ various indicators, including population, annual bus rapid transit passenger volume, bus routes and stops, as well as road networks.

Materials and Methods

This research focuses on a specific geographical location, namely the public transportation system in Jakarta, with a particular emphasis on the bus rapid transit system (BRT). The utilisation of GIS data, encompassing both vector and raster data, as well as GIS methodologies, is employed by the authors. The software employed in this study is ArcGIS Pro, utilising a version designated for student use.

Study Area

Public transportation has been operating in Jakarta for a number of years. This scheme is designed as a way to improve transportation in Jakarta. Previous attempts at improving transport in Jakarta have included traditional transit modes and trams. Various public transit methods are now being evaluated, along with some alternatives, in an effort to alleviate Jakarta's traffic congestion (Muttaqin *et al*., 2021). The Mass Rapid Transit (MRT), Light Rail Transit (LRT), Airport Railink, KAI Commuter (Local Train), Transjakarta (Bus Rapid Transit System), and Mikrotrans (shared taxi) are the six current public transportation options in Jakarta (A'rachman *et al*., 2022; Elida and Mukodim, 2015). Trans Jakarta was a public transportation system in Jakarta that was modelled after mass transit systems used in other cities across the world, including the US, China, Singapore, and Europe countries (Acton *et al*., 2022; Matubatuba and De Meyer-Heydenrych, 2022). Based on the policies of the transportation ministry of Jakarta, trans metro Jakarta was originally introduced in 2003 and has been in operation since. It is mass transportation, meaning that people may only board and exit the bus at specific stops (Muttaqin *et al*., 2021). This sort of public transportation is referred to as public transportation with set stops in this study. Trans Jakarta has 13 corridors and 1347 buses that travel around Jakarta. Figure 1 depicts the whole Trans Jakarta route. Coloured lines separate each corridor.

Data

The primary data utilised in this study is the vector map data (Table 1.), specifically associated with Jakarta's boundary, district population (Fig. 4), road networks (Fig. 3), bus rapid transit (BRT) stop points (Fig. 2), and BRT corridors (Fig. 1). These data sets were made accessible by the Jakarta government (Jakarta Government, 2020) via the following website: https://website-jakarta-satu-jakartagis.hub.arcgis.com/ This research includes additional data regarding the total number of passengers per corridor sourced from the Jakarta statistic agency (BPS).

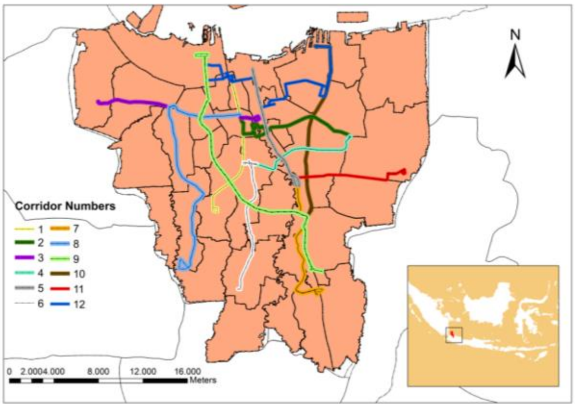

Fig. 1: Transjakarta (BRT) routes (Transjakarta, 2020)

The author gives below all the data in a spatial format (Figs. 1-4). The data for the Jakarta border comprises data for Jakarta by district and Jakarta by regency. The name of the district and its overall size are the following aspects/ attributes of this data. The total attribute population by the district is included in the population (people) statistics. The location and other details, including the station's name, the kinds of corridors, and the total number of passengers by the aisle, are shown in the statistics for BRT stations.

Table 1: List of data Gathered (Jakarta Government, 2020)

No.	Data	Description
1	Jakarta's boundary	The physical, administrative boundaries by district and regency
2	Population data	Population by district
3.	Bus Rapid Transit station (BRT)	Locations of the transit stations of BRT
4.	Bus routes/corridors	Routes of BRT in the corridor
5.	Passenger of BRT	Total passengers by corridors per year
6.	Network/roads	Street network with junctions, road network beginning and ending points

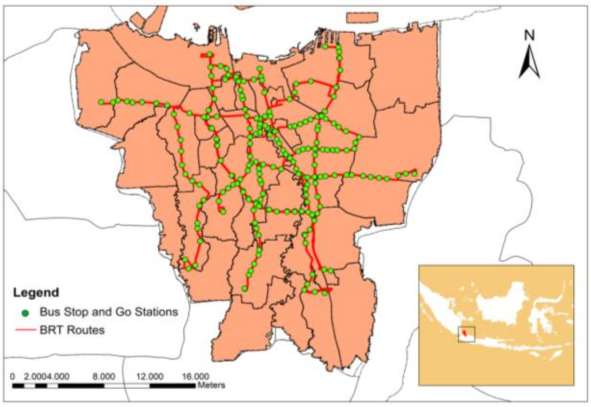

Fig. 2: Bus rapid stations and corridors (Jakarta Government, 2020)

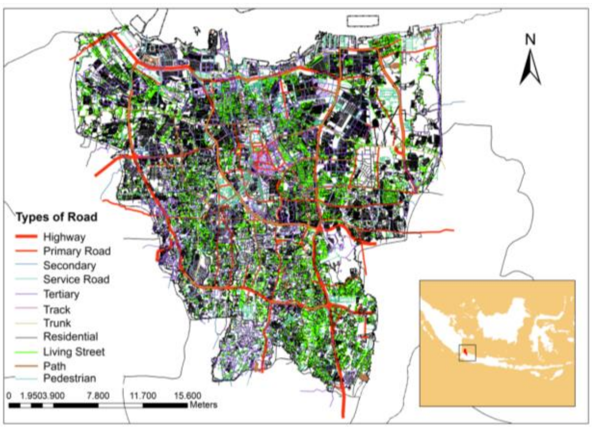

Fig. 3: Jakarta's network classification by types (Jakarta Government, 2020)

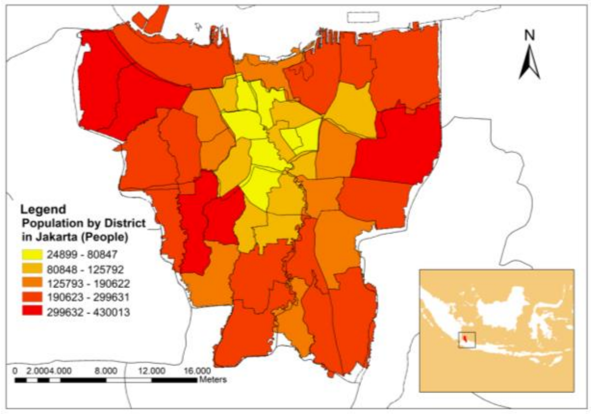

Fig. 4: Jakarta's Population (Jakarta Government, 2020)

In addition, Jakarta's boundary and population data are polygon data as a feature data type, while BRT is point data. Then the other data is line feature data presenting Networks/ roads in Jakarta. This data contains the attributes, such as the length of the streets, the types of roads, and the speeds of the road in Jakarta. This data is essential data for accessibility analysis. The other line data are bus routes, which present a road/corridor for BRT and have the names of corridors, the types of corridors, and passengers.

Methods

To evaluate the impact of bus rapid transit on station accessibility, the authors use the GIS method combining spatial analysis and network analysis (García-Palomares *et al*., 2018; Targa, 2003; Torinos-Aguado *et al*., 2022). By adding certain colours to each bound and visualising the data in the ArcGIS program, the accessibility level of bus stops may be determined. Based on research by (Chen, 2018; Kaszczyszyn and Sypion-Dutkowska, 2019; Tiran *et al*., 2022), a distance of 400 m was selected for this study as the separation between bus stop points for a range of accessibility, necessitating a 5-minute walk to the next public transportation stop (Table 2).

Table 2: Classification of accessible public transportation locations (Kaszczyszyn and Sypion-Dutkowska, 2019)

Time (min)	Distance to bus station (m)	Colour	Level of accessibility
<5	<400		Accessible
5-10	400-800		Moderate
10-15	800-1200		Poor
>15	>1200		Inaccessible

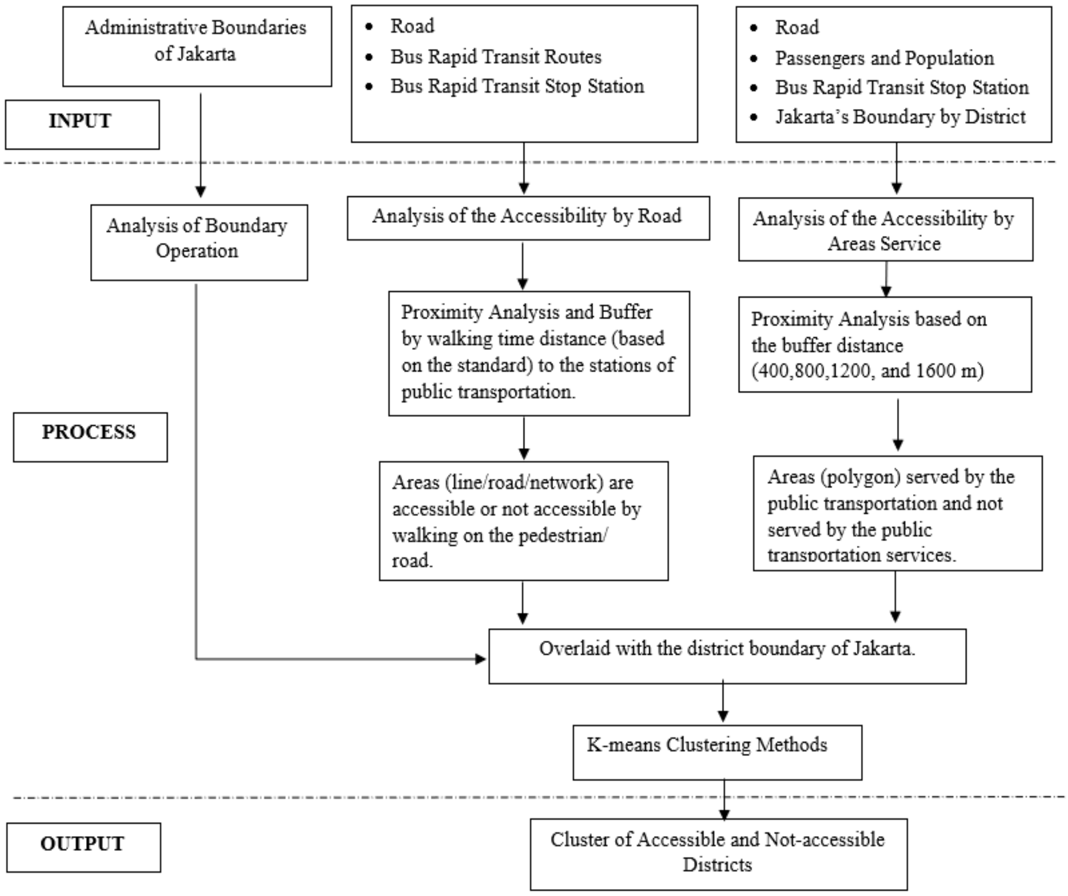

Fig. 5: Methods diagram of spatial analysis of accessibility for public transportation Transjakarta (BRT)

A different methodology employed in this study was proximity analysis, which shows where the itineraries of different fleets of vehicles overlap. Based on the separation of layers in a geographical study, proximity analysis (Acton *et al*., 2022; Muttaqin *et al*., 2021) To establish the relationship characteristic between identification for each portion, Geographic Information Systems (GIS) software would employ a buffering technique, such as generating supporting layers around layers within a specific distance (Groß *et al*., 2009; Sun *et al*., 2016) As a result, proximity analysis used location intelligence and mapping software to determine distances (for example, the distance from a hospital to a residential neighbourhood and the distance from a filling station to a highway).

Based on the diagram above (Fig. 5) presents the data and its attributes used in this research. There are various analyses, feature manipulation and selection, classification analysis, analysis of boundary operation, proximity analysis for accessibility and overlay analysis. Boundary analysis is a base step for spatial data; it contains some tool analyses such as extract, overlay, etc. Then, network distance analysis will be used to assess the people's accessibility to reach the bus station within a four-time classification, 0-5 min (accessible), 5-10 min (moderate), 10-15 min (poor accessibility), and >15 min is inaccessible. Besides, the accessibility map based on served service will describe a coverage area using the distance analysis and proximity analysis (buffer) based on standard (Table 2), <400 m (accessible), 400-800 m (adequate), 800-1200 m (poor), and >1200 m (not accessible).

The diagram approach in Fig. 5 is a general flow analysis procedure in this research. The figure below shows this study's spatial data model in ArcGIS connected to data, map usage, feature kinds, source, and analysis. Overall, the author indicates six primary data for this accessibility research, which are connected to the technique diagram above (Fig. 5) and the data model below (Fig. 6).

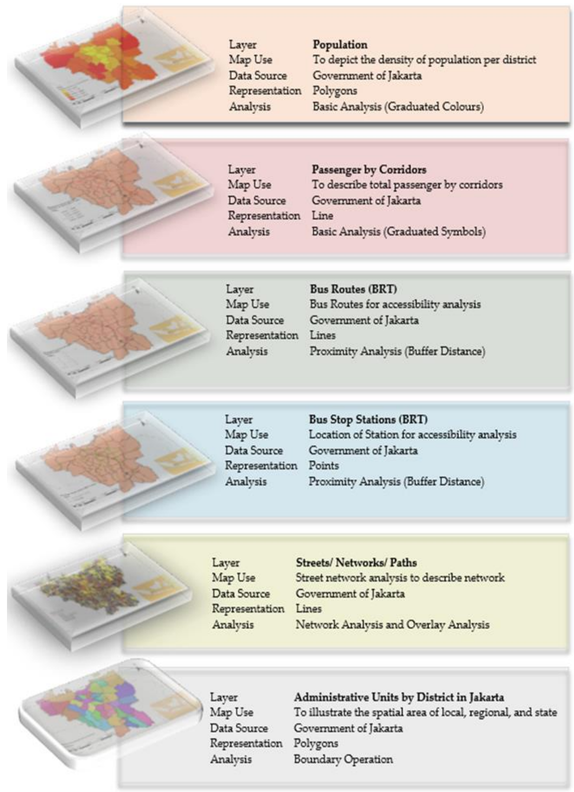

Fig. 6: Data model for ArcGIS of public transportation accessibility of BRT in Jakarta

K-means Clustering Analysis

The authors conducted an analysis of the area served and not served by BRT services based on ArcGIS-calculated geometry data. The purpose of this study was to examine the clustering of districts into accessible or inaccessible categories. The utilisation of K-means clustering analysis by the authors involves the exploration of patterns within a given data set through the process of grouping observations into distinct clusters (Sinaga and Yang, 2020). This approach aims to identify a superior classification scheme in which the entities or data points belonging to each cluster exhibit a high degree of similarity (homogeneity). Nevertheless, the groups show dissimilarity from one another, indicating heterogeneity (Novianti *et al*., 2017).

The K-means cluster analysis method aims to divide a set of multivariate data containing n individuals into K distinct clusters, with each individual being assigned exclusively to a specific cluster (Sinaga and Yang, 2020). K-means cluster analysis is an iterative process that operates as a complicated partitioning algorithm. Initially, the data is partitioned. The means of each group are computed, and subsequently, the data is re-partitioned by assigning each datum to its closest cluster position of means (Novianti *et al*., 2017). At its most basic level, this procedure comprises three distinct phases (Likas *et al*., 2003). The object of this analysis (Kodinariya and Makwana, 2013).

$$W(S,C) = \sum_{k=1}^{K} \sum_{i \in Sk} \| y_i - c_k \|^2$$

Let S denote a K cluster partition of the set of entities represented by vectors y_i ($i \in I$) in an M dimensional feature space. This partition comprises non-empty and non-overlapping clusters Sk, each of which is characterised by a centroid c_k (k=1, 2,…K). The present analysis employs data about the district wise area (in hectares) that has been overlaid with buffer distance results of the BRT accessibility analysis.

Results

The analyses were conducted utilising the ArcGIS tool software, generating two primary sections, as outlined below.

Accessibility Analysis by Road/Network System

The main data for this analysis are road, bus routes and bus stations. This analysis indicates which line of road networks is accessible by walking within 5 min and which is not accessible by more than 15 min. The road instruments were colouring based on proximity to the closest public transportation stop. The distance of 400 m, similar to a 5 min walk, was coded green; the distance of 800 m, corresponding to a 10 min walk, was coloured yellow; the distance of 1200 m, equivalent to a 15 min walk, was coloured orange; and the distance of 1600 m, equivalent to a 20 min walk, was coloured red.

The author obtains the results of accessibility analysis based on networks, roads, and pathways after doing an accessibility study in ArcGIS utilising proximity technique and distance analysis. The accessibility map above (Fig. 7) shows the routes and networks that can go to the bus station in less than 5, 10, 15 min, and more than 15 min. The route that can be reached by bus (231 BRT stops) in 5 min is shown in green, indicating that it is a very accessible road (231 BRT stations). The networks and pathways that are shown in yellow can be reached in 5-10 min. On the other hand, the orange roads show that it is difficult to get to the 231-bus station by foot in 10-15 min, while the red roads show that it is impossible to get to the bus station by foot in more than 15 min.

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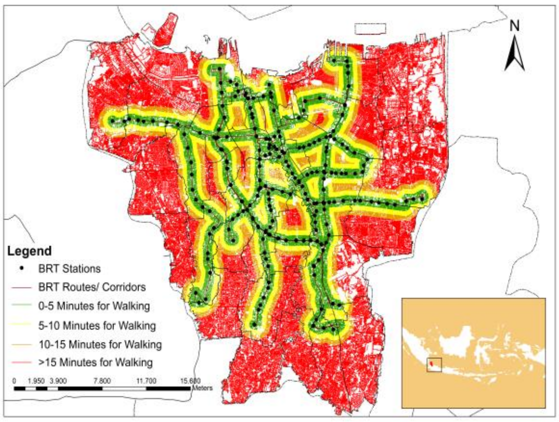

Fig. 7: Accessibility map of public transportation BRT in Jakarta

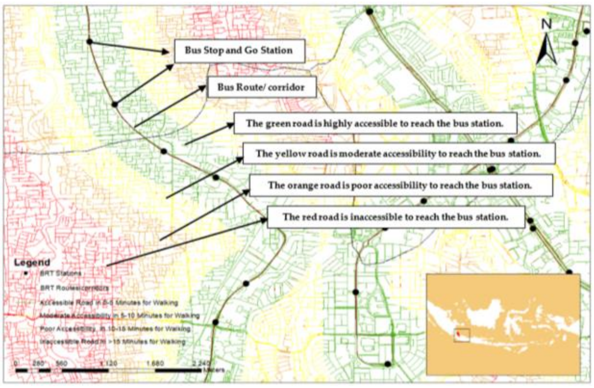

Fig. 8: Map detail of public transportation accessibility of BRT in Jakarta

Table 3: Result of the total length of road accessibility to public transportation (BRT) per total road in Jakarta

Time (min)	Distance to bus station (m)	Col.	Level of accessibility	Length (Km)	(%)
< 5	<400		Accessible	3,914	25.0
5-10	400-800		Moderate	2,614	16.5
10-15	800-1200		Poor	1,987	12.5
>15	>1200		Inaccessible	7,307	46.0

The overall accessibility result of Jakarta is shown in Fig. 7-8 depicts a small-scale map detail that represents the state of the roads, bus stations, and bus routes in four different colours: Green, yellow, orange, and red. Based on the result of road access by walking time to the public transportation (BRT), we calculate the length for each classification using calculated geometry in ArcGIS. Before that, the author performed the essential analyses, such as clip, intersect, erase, and dissolve, by overlaying the road with the buffer distance of BRT stations and routes. Also, the table and pie chart will show how long each category is.

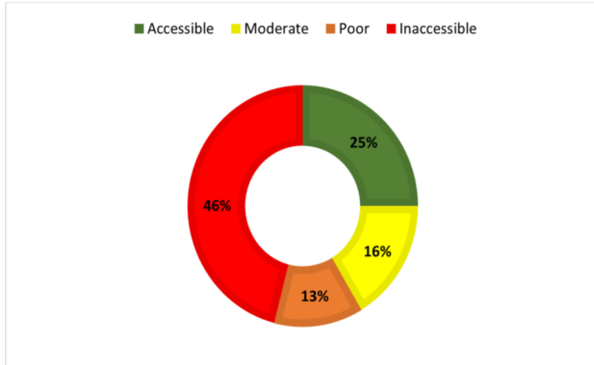

Fig. 9: The pie chart of road access level to bus station (public transportation) in Jakarta

According to the calculated geometry analysis result in Table 3., inaccessible roads and the poor category account for reaching public transportation are the largest percentage and proportion of Jakarta's total road length (7,307 km and 1,987 km, or 58.5%), while the percentages of high and moderately accessible roads that are used for reaching public transportation (BRT) are only 25% and 16.5%, respectively. Generally, this suggests that most of Jakarta's roads are too difficult (inaccessible) to be reached by walking via public transit (BRT).

A total of 15822 km of roads and trails were examined; of them, 3914 km (or 25%) were rated as being very accessible to bus stop stations, while 2614 km (16%) were rated as being moderately accessible. 1987 km (13%) of streets and walkways had poor accessibility, while 7307 km (46%) of those were classed as having inadequate bus access. In addition, this data indicates that road or path access to the BRT station was dominated by inaccessible paths (Fig. 9).

Accessibility Analysis Based on District Areas

A polygon of coverage area served by the public bus transportation or not coverage will be analysed by accessibility analysis with proximity and distance analysis. The ranges of coverage area by public transportation are from 0 until >1200 m (based on the people experience research), which is classified into an accessible area (served area) and not accessible area (not-served area) to BRT services. Then, it was overlaid with the district boundary and population aiming to evaluate the district that was not reached by public transportation of BRT.

The picture (Fig. 10) illustrates in spatial that the public transportation of BRT is not entirely reaching all areas of Jakarta for serving. It was shown by the red area that is not served by BRT was dominated by than accessible area. To clarify, the author calculates in spatial analysis the percentage of the served area and not served area per district.

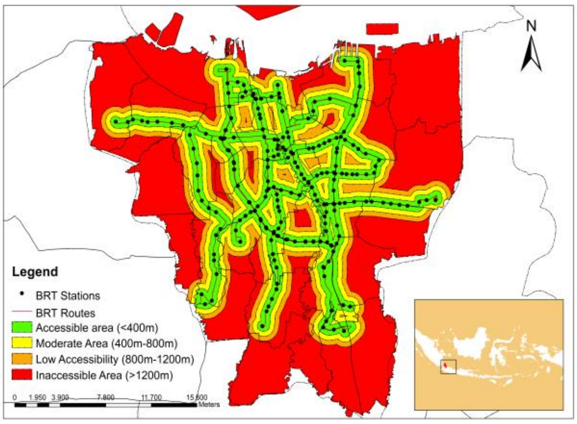

Fig. 10: Service areas for BRT (public transportation) in Jakarta

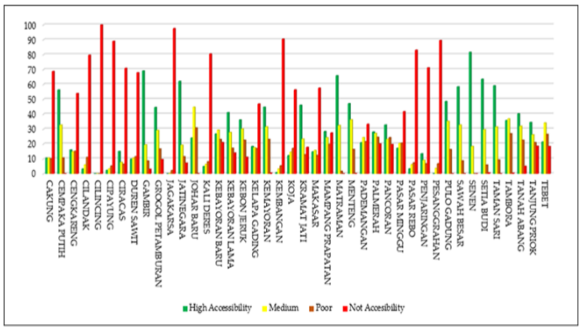

Fig. 11: The districts (42) served and not served by BRT public transportation in Jakarta

The author presents the calculated data from calculate geometry analysis in the ArcGIS tool, which results in the area (Ha) covered by BRT services. For instance, the Senen district has 355 Ha of the highest accessible area for BRT services from the total area of Senen, 435 Ha (81,61%), and it is followed by Gambir and Setia Budi districts, around 70 and 64%, respectively, while 0% (0 Ha) and 0.07% (1 Ha) of the accessible area by Jagakarsa district, Cilincing and Pesanggrahan district mean not-served area, respectively, to bus station BRT.

According to proximity and distance research, there are 42 districts in Jakarta, and the BRT is one kind of public transit that hasn't yet reached every one of them. According to the results shown in Figs. 11-12, several areas are primarily unserviced by BRT systems. These areas include Cilincing, Jagakarsa, Kembangan, Cipayung, Pesanggrahan, Pasar Rebo, Kalideres, Cakung, etc. These districts are 100 to 50% outside of the BRT service region (Ha). Nevertheless, more than 50% of BRT services are currently provided in the following locations: Senen, Sawah Besar, Gambir, Matraman, Setia Budi, Jatinegara, Taman Sari, and Cempaka Putih. Less than 50% of the territory is covered by BRT services in the other districts.

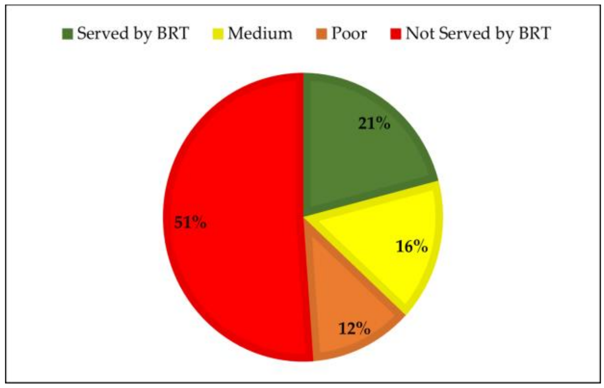

Fig. 12: The Pie Chart of Percentage Areas served and not served by BRT Public Transportation in Jakarta

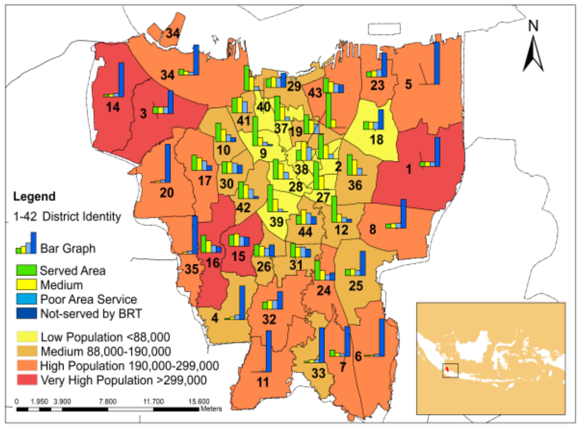

Fig. 13: The Map Graph of Population Data (people) overlaid with the percentage of Accessibility Area of BRT

The total area of Jakarta is 65,092. As shown by the pie chart (Fig. 12), the accessibility of BRT services overlaid with area/district reveals that the majority of areas in Jakarta are not accessible to BRT Station, with 51% and poor accessibility being 12% and only 21% and 16% of area Jakarta that are accessible to reach public transportation services, respectively.

The above-mentioned result (Fig. 13) demonstrates that there are districts with very high and high populations that are not covered by BRT transit or are inaccessible areas >1200 m, such as Cilincing (5), Cakung (1), Kalideres (14), Cengkareng (3), Jagakarsa (11), Kembangan (20), Pesanggrahan (35), etc. In contrast, areas with the highest access for accessing the BRT public transit, such as Senen district (38), Gambir (9), Sawah Besar (37), and Setia Budi (39), have a low population.

K-Means Clustering Result

The datasets utilised in this analysis consist of overlaid data obtained from a map that is accessible, which includes information on districts (42) measured in hectares completed by SPSS.

The ultimate cluster centres are determined by calculating the average for each variable within each respective final cluster. The ultimate cluster centres are indicative of the attributes of the standard case within each cluster. Based on Table 4. shows that there are 4 clusters (k = 4):

- Cluster 1 consists of inaccessible districts with a maximum value of 1.325
- Cluster 2 consists of accessible districts with a positive value of 0.059
- Cluster 3 indicates moderate districts of accessibility with a maximum value of 2.043
- Cluster 4 consists of districts that have poor accessibility to BRT stops and go with a maximum value of 1.079

Table 5 shows the result of the clusters of K-means analysis that districts categorised under clusters 1 and 4 exhibit poor accessibility to inaccessible accessibility to BRT stations. Clusters 2 and 3 refer to the regions that are readily reachable via Bus Rapid Transit (BRT) stations in accordance with the distance-based service criterion.

Table 4: Result of final cluster centers K=4

Zscore /K	1	2	3	4
Zscore (Accessible)	-1.29186	.05997	1.90926	.15984
Zscore (Medium)	-1.13951	-.26878	2.04322	.73194
Zscore (Poor)	-.54472	-.52221	1.40213	1.07951
Zscore (Inaccessible)	1.32574	-.63037	-.55772	.54029

Table 5: Cluster membership K = 4

No	District	Cluster	Distance
1	Cakung	4	1.777
2	Cempaka Pu	2	.761
3	Cengkareng	4	.645
4	Cilandak	1	.983
5	Cilincing	1	2.203
6	Cipayung	1	.407
7	Ciracas	2	1.193
8	Duren Sawi	4	1.161
9	Gambir	2	1.063
10	Grogol Pet	2	1.138
11	Jagakarsa	1	.777
12	Jatinegara	2	1.446
13	Johar Baru	2	1.499
14	Kali Deres	1	1.317
15	Kebayoran	4	1.089
16	Kebayoran	3	.376
17	Kebon Jeru	3	.533
18	Kelapa Gad	4	.875
19	Kemayoran	2	.418
20	Kembangan	1	.183
21	Koja	2	1.200
22	Kramat Jat	2	1.480
23	Makasar	4	.498
24	Mampang Pr	2	.578
25	Matraman	2	.984
26	Menteng	2	.313
27	Pademangan	4	1.121
28	Palmerah	2	.754
29	Pancoran	2	.787
30	Pasar Ming	4	1.273
31	Pasar Rebo	1	1.112
32	Penjaringa	4	1.757
33	Pesanggrah	1	.985
34	Pulo Gadun	3	.984
35	Sawah Besa	2	.583
36	Senen	2	1.305
37	Setia Budi	2	1.305
38	Taman Sari	2	.840
39	Tambora	2	.686
40	Tanah Aban	2	1.216
41	Tanjung Pr	3	.994
42	Tebet	2	1.419

Table 6: Clusters of district accessibility

Accessible (Cluster 2)	Moderate (Cluster 3)	Poor (Cluster 4)	Inaccessible (Cluster 1)
1. Cempaka Putih	22. Kebayoran Lama	26. Cakung	34. Cilandak
2. Ciracas	23. Kebon Jeruk	27. Cengkareng	35. Cilincing
3. Gambir	24. Pulo Gadung	28. Duren Sawit	36. Cipayung
4. Grogol Petamburan	25. Tanjung Periok	29. Kebayoran Baru	37. Jagakarsa
5. Jatinegara		30. Makasar	38. Kali Deres
6. Johar Baru		31. Pademangan	39. Kembangan
7. Kemayoran		32. Pasar Minggu	40. Pasar Rebo
8. Koja		33. Penjaringan	41. Penjaringan
9. Kramatjati			42. Pesanggrahan
10. Mampang Prapatan			
11. Matraman			
12. Menteng			
13. Palmerah			
14. Pancoran			
15. Sawah Besar			
16. Senen			
17. Setia Budi			
18. Taman Sari			
19. Tambora			
20. Tanah Abang			
21. Tebet			

Out of the 42 districts in Jakarta (Table 6), 25 districts are within walking distance of less than 10 min to reach BRT stations and accessible services within a distance of fewer than 800 meters. Conversely, there exist 17 districts that are not easily accessible in terms of reaching BRT stops and go.

Table 7: Annova table

	Cluster error					
	Mean square	df	Mean square	df	F	Sig.
Zscore (Accessible)	9.413	3	.336	38	28.026	.000
Zscore (Medium)	11.142	3	.199	38	55.899	.000
Zscore (Poor)	8.817	3	.383	38	23.032	.000
Zscore (Inaccessible)	8.759	3	.387	38	22.606	.000

Presented Table 7 is a displaying the results of the ANOVA analysis, indicating the presence or absence of statistically significant group clustering. The obtained statistical significance level of the test is 0.000, indicating a p-value of .000, which falls below the conventional alpha level of 0.05. Consequently, there exists a statistically significant relationship among all cluster variables.

Discussion

In addition to the spatial studies of accessibility analysis based on travel time (road) and area distance depicted in Figs. 7, 9 and 10, it is worthwhile to evaluate the magnitude of the mismatch between public transportation, accessibility, and prospective transport demand by population.

An accessibility analysis using the walking time buffer distance reveals that the majority of Jakarta's total road length (7,307 km, or 58.5%) is made up of inaccessible roads and the poor category, while the percentages of high and moderately accessible roads that are used to access public transportation (BRT) are only 25% and 16.5%, respectively. This generally implies that the majority of Jakarta's roadways are too challenging (inaccessible) to be accessed by foot for public transportation (BRT). Overall, these results mean that many roads/ networks are inaccessible for walking to the BRT station because people need more time >15 mins to walk to the nearest station. Moreover, the authors overlay the BRT stations (231) and routes (12) with the Jakarta border region. It also reveals that, of Jakarta's total area of 65,092 Ha, the majority of places/districts are not accessible to BRT Stations, with 51% and poor accessibility being 12%, and just 21% and 16% of Jakarta's area are accessible to public transportation services, respectively. In addition, it was supported by the accessibility analysis overlaid with the population that describes the highest population mentioned above, and the type of land use is residential is not served by the BRT services within 1200 m, about 58%. It means that many potential demands for increasing the passenger of BRT by population density.

To sum up, the authors construct an overlay to compare the accessibility of the BRT region with the K-means clustering of the districts (42 districts), as shown in Table 6. Due to this, some individuals may prefer using their automobiles to go to their destinations or activities than using public transportation of BRT. BRT accessibility can be improved by integrating all modes of public transportation or evaluating, adding, and revising the bus station to meet the new demand for public transportation accessible.

Conclusion

The approach for evaluating the accessibility analysis of BRT in Jakarta that takes into account spatial analysis features is presented in the paper. The method's comparison of the evaluation of public transportation's accessibility with the evaluation of the prospective demand for transportation among the population and passengers is a key component. Based on the findings and discussions, this study may serve as an evaluation tool for the Jakarta government as it plans and improves public transportation, particularly the BRT system, in areas with a high potential for passengers and population (Table 6). For instance, Cilincing, Cakung, Kalideres, Cengkareng, Jagakarsa, Kembangan, and Pesanggrahan may have a high population and limited accessibility to the BRT system as public transportation, which might be potential demand for BRT passengers, and depending on the potential access (0-10 min by walking time), the Jakarta Government can strengthen and improve the accessibility via road/network access or improve the BRT stations close to demand access. If public transportation is planned and implemented effectively and efficiently, it may help to alleviate Jakarta's traffic issues.

Making public transportation more appealing to people would help reduce the number of automobiles on the road and ease Jakarta's traffic issues. This may be done by increasing residents' access to and the cost of public transportation. Given the time and distance required to walk to the closest stop, the comparison between the circular buffer technique and the spatial analysis method reveals the former to more correctly reflect the real distance to the public transportation stations. The technique might be applied to make it easier to identify troublesome locations that have limited access to public transportation. It gauges the distance travelled by the walker by measuring the distance between the lines.

The drawback of this strategy is that the kind of network layers are lacking. However, the authors will study more to improve the accuracy of this analysis. Analyses must also be performed for the upcoming study's accuracy and validity, including the use of transport models, other methods for estimating accessibility analysis of public transportation, questionnaire surveys, and careful examination of the supply between different traffic zones.

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Author's Contributions

Apri Zulmi Hardi: Formal analysis, data analysis, written original drafted preparation, visualization.

AbdulKader Ali Murad: Methodology, validation, designed the research planned and organized the study, written reviewed and edited.

Ethics

The writers confirm that the work in this publication is original and unpublished. There are no ethical concerns because the paper has been read and authorised by all authors.

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