Keywords: performance study; resilient city; public transportation; BRT lite

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A PERFORMANCE STUDY OF BUS RAPID TRANSIT LITE: TOWARD A RESILIENT SEMARANG CITY

Summary. BRT lite is the backbone of the public transport system in Semarang that potentially contributes to the city's resilient mobility. Although it has been a decade since the operation of BRT lite began, its performance has not led to a significant shift from the use of private vehicles to public transport. Therefore, this study aims to assess the performance of BRT lite service in supporting the concept of a resilient city. The assessment was performed by measuring city- and corridor-level performances using a scoring method against a set of standards of infrastructure and operational factors. At the city level, the performance only fulfilled 45.12% of the standard. At the corridor level, the best performance was shown by corridors I and IV, with 15% and 6%, respectively, over the average point percentage. BRT lite in Semarang has not yet been considered resilient as it still needs improvement on indicators that ensure accessibility, responsiveness to disruption, and inclusivity.

1. INTRODUCTION

Transportation is an important element upon which a city can build resilience in the face of urbanization, for three underlying reasons. First, transportation enables mobility for basic needs, such as commuting and earning a living [1]. The increasing mobility because of urbanization requires a reliable and effective transportation system to make it free from traffic congestion. Second, transport systems have much less adaptive capacity than other city systems [2]; hence, the disturbance in the transport system because of congestion and its potential pollution could influence the success of the city's efforts toward resilience building. Third, transportation is the fastest-growing contributor to global climate change [2]; thus, any alternative system and mode that offer emission reduction would have a positive impact on the city's resilience.

Related to the context of urban resilience, the concept of transport resilience has been broadened and can be interpreted in terms of a transport system being able to deliver a certain level of service. This service should be maintained during or even after the occurrence of a disruption event, such that functionality is recovered as soon as possible [3]. In addition, a resilient transportation system must also be reliable in terms of network connectivity and travel time, and economically, environmentally, and socially sustainable [1]. Resilience in the context of mobility should thus be a prerequisite for realizing a safe and sustainable mobility society [4].

As city traffic becomes more crowded with the development of Semarang, this places pressure on the transport system and leads to overcrowding and congestion. Without sufficient transport services and infrastructure, the growing number of private vehicles and commuters represents a traffic burden for the city, especially since public transport services in the city are in poor condition. Conventional forms of public transport such as *angkot* (para-transit) are mostly privately operated, and it is difficult for the operators to improve their fleet and service. Generally, Semarang has poor facilities for pedestrians, as pedestrian ways are unevenly distributed. In 2009, Semarang City government developed the Bus Rapid Transit (BRT) lite across Semarang in an effort to provide better public transportation, improve urban mobility, and reduce congestion and GHG emissions. The BRT system is considered a promising transit option for cities seeking to reduce their transportation-related GHG emissions through mode-shifting [5].

With the public transport and mobility issues that Semarang is facing, there is an urgent need to understand further whether its current BRT lite operation is contributing to the development of resilient Semarang. From the perspective of urban resilience, this paper thus aims to assess the performance of BRT Trans Semarang in delivering its service. This paper opens with a review of the current condition of the service and the issues that it faces. The results section then assesses both city- and corridor-level performances. Before concluding, the paper discusses how the results are connected to the concept of urban resilience.

Public transport performance, especially bus transport, has been widely discussed in the literature. Generally, previous research has used demand or supply approaches, or a combination of these, for their performance indicators. The demand approach usually involves passenger factors, such as demand performance and passenger attraction to the BRT [6]; alternative public transport from the user's viewpoint [7]; and customer satisfaction [8]. The supply approach measures bus service reliability at the route level and stop performance [9, 10] and the efficiency and effectiveness of public transport operational as well as technical performance [11, 12].

Studies specifically analyzing BRT lite performance in Semarang have usually focused on one or two corridors of services. The subjects measured have been the shelter service level [13, 14]; performance based on user satisfaction or experience [15, 16]; system effectiveness and efficiency [17, 18]; and a combination of subjective factors perceived by users, as well as system operational measures [19]. To complement the existing studies, this paper sheds further light on the infrastructure and operational factors accounting for the performance of the BRT lite service. Moreover, a more comprehensive analysis is presented by assessing all the corridors in operation in Semarang by early 2018. The paper also provides more perspective on the current practice of BRT lite provision in an urban area. Once a broader understanding of this is achieved, it may become an additional push factor for the future practice of resilient transportation development, especially when supported by the mobility pillar from City Resilience Strategy (CRS) of Semarang in 2016 [20].

2. MATERIALS AND METHOD

2.1. Materials

The research approach used is positivistic and causality. Positivistic approaches seek to record reality with measurable variables through a particular analytical system with an apparent size and effect. Causality is used to ascertain the relevance of the development of public transport in terms of the resilience concept. Data were mainly sourced from the BRT Trans Semarang user data set from surveys conducted in 2017 by Diponegoro University (UNDIP), the Institute for Global Environmental Strategies (IGES), and the Institute for Transportation and Development Policy (ITDP) Indonesia. The data collection process incorporated certain survey methods, as follows:

1. Speed Survey and Boarding-Alighting of BRT Trans Semarang: GPS tracking was used by surveyors who boarded the BRT fleet from start to end points. They recorded the number of boarding and alighting passengers at each station on weekdays during morning and afternoon peak hours in six BRT corridors.
2. Frequency and Occupancy Survey: The numbers of Trans Semarang BRT buses and passengers were calculated on weekdays during the morning and afternoon rush hours for two hours.

3. Transfer Passenger Survey: On each Trans Semarang bus, records were kept of the total number of passengers alighting the bus and the number of alighting passengers who did not leave the bus stop to make a transfer to another corridor. The survey was conducted on weekdays during the morning and afternoon rush hours for two hours.

The data obtained from these surveys are part of a 2017–2018 study titled "Increasing Intermodality and Ridership of BRT Trans Semarang" by UNDIP, IGES, and ITDP, in support of Semarang City government's efforts to improve urban public transportation. In addition to these data, a compilation of updated BRT operational data from 2018 and 2019 was also used and gathered from the BLU Trans Semarang (the city government body responsible for the management of BRT Trans Semarang).

2.2. How service performance was assessed

The previous research has attempted to quantify BRT performance by defining and measuring contributing factors, but this does not rule out the possibility that the factors measured are similar or overlapping. From literature study, we found that the most comprehensively studied factors in the measurement of BRT performance can be grouped into three categories: elements, system performance, and the benefits of BRT, presented by the Department of Transportation, United States [21]. This paper focuses on the first two of these to measure the performance of BRT. The seven major elements of BRT (runway, station, vehicle, fare collection, intelligent transport system, service operation and plans, and branding elements) and the four elements of system performance (travel time, passenger safety and security, system capacity, and accessibility) are sub-components of performance, while indicators and standards were collected from theories and various studies. Figure 1 shows the indicators and standards of BRT Performance.

BRT performance is measured quantitatively using gap analysis by comparing the actual performance of the BRT system with the collected ideal standards; these were constructed from the maximum value applied in the measurement and assessment available in guidelines, regulations, and previous studies (see Table 1). To present a more thorough analysis, the assessment is divided into both city- and corridor-level performances.

1. **City-level performance:** Forty-seven indicators were used to measure performance at this level. Three scores were used to assess BRT performance: zero was assigned for indicators that did not meet the standard value; 0.5 was assigned when existing conditions only fulfilled some standards or the standard did not apply to the entire indicator; and 1 was assigned if the indicator fulfilled all standards. The scoring system is divided into three to illustrate whether the performance indicators work at the minimum, medium, or maximum level.
2. **Corridor-level performance:** This performance level only focused on those indicators that showed different performance values between corridors. The indicators used for this assessment were average speed, mileage of BRT per day, headway of BRT services, BRT travel time, passenger waiting time, vehicles with low emission, passenger load factor, ratio of bus occupancy, operation capacity, coverage of demand area, and BRT route length. Unlike the scoring for city-level performance, positive and negative correlations were used to compare service performance between corridors.

2.3. Current BRT lite service in Semarang

In early 2009, the Ministry of Transportation delivered 20 bus fleets to help Semarang City's government develop the BRT system. This new bus service was expected to provide better public transportation that is safe, comfortable, scheduled, and affordable. The BRT Trans Semarang is a lite BRT system. It now has 116 bus fleets in operation of two types: large, with a maximum capacity of 82 passengers, and medium, for up to 42 passengers. The large bus fleet operates only in Corridor I (see Fig. 2), which has a wide runway, and other corridors are served by the medium-sized bus fleet due to the narrow road conditions. BRT Semarang operates every day, from 05.30 until 18.30, using a flat fare collection system. The average speed of BRT lite in Semarang is 15.8 km/hour in Corridor 1.

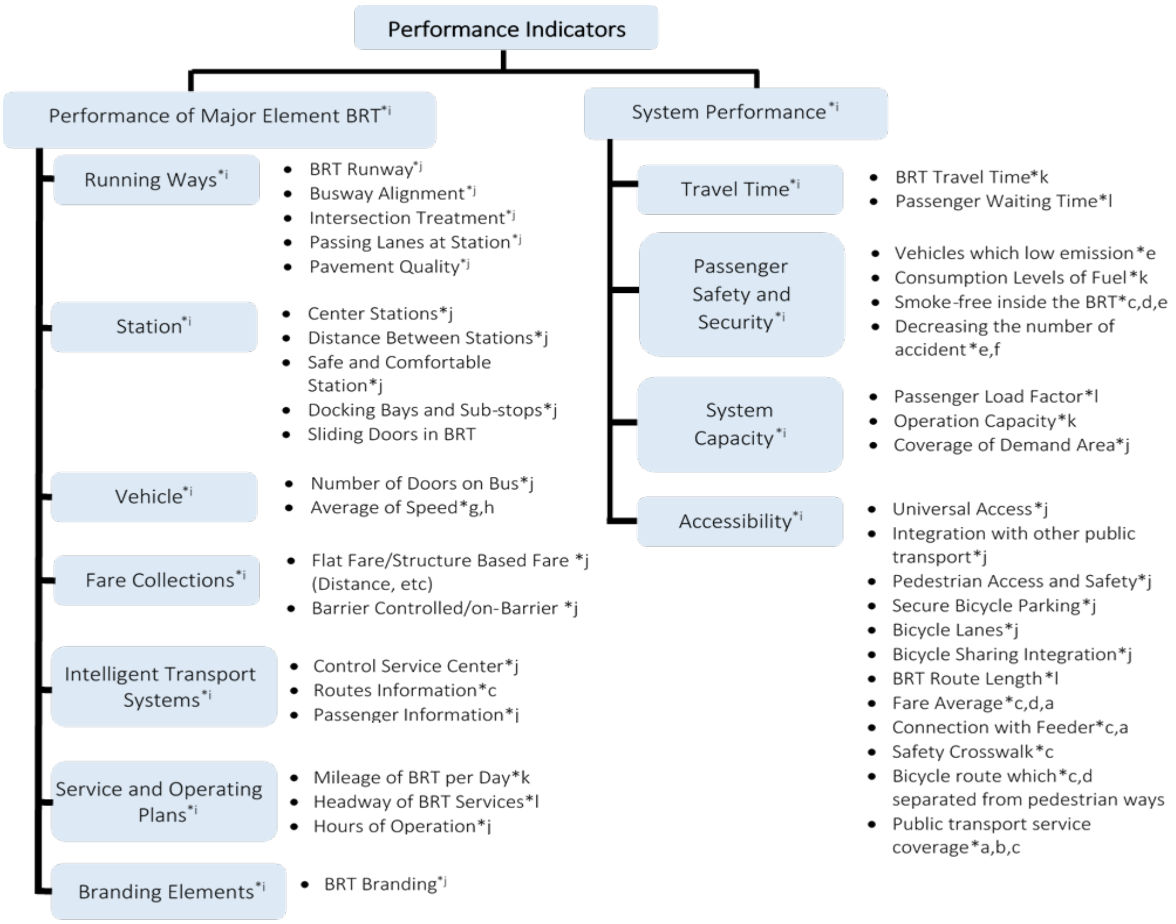

Fig. 1. Variables and Indicators of Performance Assessment

Table 1

Source of variables and indicators of performance assessment

a	Resilient Semarang (City Resilience Strategy - CRS) [20]
b	Regulation on Minimum Service Standards for the Transportation of People with Public Vehicles on the Route [22]
c	Global Age-friendly Cities: A Guide [23]
d	Indicators of a Child-Friendly City [24]
e	The Implementation of Healthy Districts/Cities [25]
f	Mayor Regulation on Smart City Master Plan of Semarang [26]
g	Analysis of Transport Performance Indicators [27]
h	Performance Measures for Iowa Transportation Systems [28]
i	Characteristics of Bus Rapid Transit for Decision-Making [21]
j	The BRT Standard [29]
k	Urban Transport by The World Bank [30]
l	Technical Guidelines for the Implementation of Public Passenger Transport in Urban Areas in Fixed and Regular Routes [31]
m	Creating Feeder Bus Lines for Transjakarta BRT [32]

Between 2009 and 2017, six corridors were built and they cover more than 113 km of corridor. According to data for 2016 from the Transportation Agency of Semarang City, there were 83 *angkot* (para-transit) and regular bus routes, aside from six existing routes for BRT Trans Semarang. Some *angkot* and regular bus services have overlapping routes with Trans Semarang. Although BRT offers a more comfortable ride and a more certain schedule, other public transport modes offer more flexibility and a longer service time. BRT may have a more affordable fare, but *angkot* can access a user's exact location. As BRT shelters are mostly located along the main roads, users usually need to walk longer or use other transport modes, such as *angkot* or a motorcycle, to reach them. In the end, overall spending on transport using BRT or *angkot* is more or less the same.

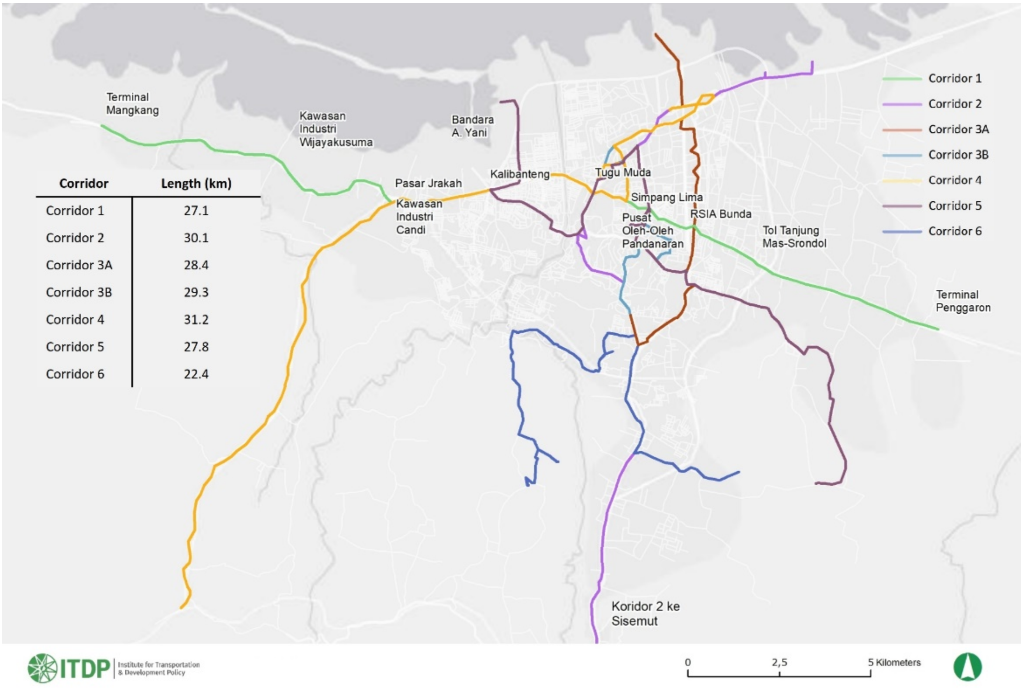

Fig. 2. BRT Lite Corridor Routes in Semarang

3. RESULTS AND DISCUSSION

Public transport service levels show how a service is performing according to certain standards and regulations in terms of supporting the mobility needs of its users. This research used variables and indicators, compiled from the literature, to measure the existing service performance of BRT lite in Semarang (see Table 1). Each indicator has a standard that explains how a BRT service should have been designed to deliver effective and efficient performance. In this study, BRT lite performance was assessed at the city and corridor levels.

3.1. BRT lite performance at the city level

The city-level assessment disclosed the existing service performance of BRT lite in detail and measured its shortcomings in comparison with an ideal BRT system (see Table 2). Of all 47 indicators used, the data on seven were unavailable. In terms of the elements in the assessment, the first performance variable (performance of major elements of BRT) was the physical infrastructure assessment of the whole BRT system, while the second (system performance) focused on how effectively the system mobilized passengers. Overall, the score of the physical infrastructure was higher than how it mobilizes passengers, although each variable had almost the same number of indicators. This suggests that the physical infrastructure performance of BRT lite is of critical concern for the government to improve this service.

At the sub-variable level, running way scored zero, even though five indicators were used to assess it. BRT lite in Semarang still has a mixed runway together with general traffic, and so a dedicated BRT lane arrangement is not available. For station assessment, the focus was on placement and design, which are important for infrastructure and system effectiveness. In this sub-variable, BRT lite only scored three, from seven indicators. Although the BRT lite's flat fare ensures affordability for all compared to a distance-based fare, and a flat fare is also more effective for commuting to the city center, fare collection is still manual, with no control gates or ticket machines. This potentially increases the possibility of fare evasion and ineffective fare collection. The fleet operations of BRT lite met the minimum average for commercial speed. However, the total mileage for each bus exceeds the ideal standard, and was recorded as being up to 272 km/day. Moreover, accuracy of travel time is very important because passengers need to be able to estimate time to destination, and travel time reliability can attract or retain passengers. Based on the passenger perspective, travel and waiting times on BRT lite in Semarang did meet the standard. Despite operating every day, its operational time is considered limited because it ends at around 18.30, meaning that passengers must switch to other transport modes. Often, passengers cannot reach their end point by BRT lite as the bus they need to transfer onto is no longer available once they reach the transit shelter.

Intelligent Transport Systems (ITS) technology needs to be integrated into the BRT lite system to increase operational effectiveness. The ITS sub-variable consisted of three indicators: control center services, route information, and up-to-date information. BRT lite in Semarang already has GPS on its bus fleets to provide updated positioning of the buses in operation, and the mobile app, "Trans Semarang", provides bus positioning and complete route information to users. This kind of information is vital for passengers, especially tourists, to access BRT services. BRT lite in Semarang has built brand identity by painting its buses in distinctive red and blue colors, and each bus has the logo "Trans Semarang", as well as city slogans, such as "Semarang Hebat" (Semarang is great). Bus shelters can easily be identified by their red color and elevated platform.

Safety, security, and the level of convenience were the main reasons why passengers chose BRT lite. The buses are smoke-free, prohibit food and drink, and are equipped with rubbish bins to ensure cleanliness. Passenger comfort is also supported by air-conditioning, and there are seating areas for male and female passengers. The majority of BRT lite buses have converters that enable the bus to switch from solar fuel to low-emission compressed natural gas (CNG). This means that by using BRT lite, urban travel is more environmentally friendly. The system capacity sub-variable reflects how many passengers the BRT lite system can mobilize. While vehicle operations met the standards, the loading factor was only 31% against the standard 70%, even though most corridors pass through the segments with the highest demand.

The accessibility sub-variable concerns the motorized and non-motorized transport facilities available for reaching a BRT shelter. The findings show that BRT lite in Semarang has provided enough pedestrian ways, especially in its city center segments, but there is still a lack of bike-friendly facilities and access. The non-motorized transport facilities are also not inclusive for people with disabilities, as many shelters lack pathways for wheelchairs or for the visually impaired. Overall, the city-level assessment shows that the BRT lite currently scores 18.5, or only 45.12% of the maximum score of the ideal standard. This implies that its performance in Semarang at the city level is far from ideal, and due to the current infrastructure, it cannot be recognized as a full BRT service.

3.2. Corridor-level BRT lite performance

BRT lite in Semarang City runs through multiple corridors and, although the standard service measure should be applied to the whole system, not every corridor delivers the same level of service. Using the same variable, indicator, and standard as the city-level performance assessment, the existing quality of each corridor will now be discussed. Of the 41 indicators supported with available data, 29 showed the same condition for all six corridors measured. Having the same condition suggests that for those 29 indicators, the performance of all corridors is at the same level. For the remaining indicators, different existing conditions were found in almost all corridors. Either a positive or a negative correlation is used to describe the performance of each corridor. Although corridors with a more positive correlation to the standard will be more highly ranked for their performance level, a higher rank is not necessarily closer to the ideal service. This is because the overall system assessment shows that the current condition still falls short of even 50% of the ideal BRT requirement. Table 3 shows the complete assessment for the corridor-level performance.

For the performance indicators of major BRT elements, none had an all-positive correlation in all corridors. Of the six corridors, only Corridor III fulfilled the required standard for the average speed indicator. Corridor V had the slowest average speed, and the other four corridors had an average speed ranging from 18 to 19 km/hour. With the average cycle being two per day for each corridor, Corridors I to IV had a mileage within the standard range of 230–260 km/day. These four corridors had a positive correlation to the mileage indicator, but the daily mileage of Corridors V and VI correlated negatively as they had 222.4 km/day and 224 km/day, respectively.

The final indicator used in this study of the performance of major BRT element is headway. This is a vital element in any identification of transport system performance, as it not only moderates service circulation to ensure availability but also indicates how much waiting time a user can expect during their journey. The assessment is divided into two time frames: ideal time and rush hour. All the corridors showed a consistent correlation for both time frames. The worst performance was in Corridor V, followed by Corridor III, and both corridors had a negative correlation. The other corridors correlated positively, with a better time for the ideal time, except for Corridor II, which performed better at rush hour.

Different conditions were found for the indicators under the system performance variable. This means that various levels of effectiveness in mobilizing passengers played a role in shaping the performance of BRT lite in Semarang. For the BRT travel time indicator, all six corridors performed within the standard time and therefore had a positive correlation. Data showed that for the passenger waiting time indicator, five corridors correlated positively, except for Corridor II, which had a waiting time of up to five minutes compared to the standard range. As of early 2019, the buses used for Corridors I, V, and VI had already switched to CNG fuel to produce lower emissions, and therefore, the three corridors had a positive correlation for the low-emission indicator, while the other three were negatively correlated. However, it is believed that all the BRT lite buses will gradually shift to CNG-fueled engines. In terms of the passenger load factor indicator, all the corridors performed under the standard. The ratio of bus occupancy had a negative correlation, except for Corridor I, which was positively correlated with a ratio of 72.12%. The number recorded for the passenger load factor and the ratio of bus occupancy indicators were significantly correlated to whether the existing routes already effectively capture and connect potential users. Since the majority are still, at the time of writing, far from the ideal standard, route evaluation could be considered to optimize service performance. The coverage of the demand area indicator is also related to route design. Of the six corridors, five had a positive correlation, except for Corridor VI. The highest demand segments in the standard were justified by whether the segments included a route that passes through the three main transit shelters with the largest number of passengers: Imam Bonjol Shelter, Balaikota (Cityhall) Shelter, and Simpang Lima Shelter. With Corridor VI, the route does not pass any of these shelters. Another indicator with an all-positive correlation result is operation capacity as most corridors have stand-by surplus buses that could be substituted for the on-the road buses in case of emergency.

Accessibility is an important deliverable for public transport services. To determine how many users are reached by a service, factors such as coverage area and bus route length can be considered. The route length in Corridor I scored more than the ideal standard, and hence, it had a negative correlation, but the other five corridors had a positive correlation. These results show that the performance of Corridor I is the best as it had a total of nine positive correlations from the 12 indicators. This was followed by Corridor IV with eight positive correlations. Corridors II, III, and VI all had seven positive correlations, while Corridor V had only six positive correlations from the indicator measurements.

3.3. Discussion

This assessment shows that the performance of BRT lite in Semarang showed better results for the variable of major BRT element performance than the system performance variable. However, although the former variable focused on infrastructure performance, the larger-scale assessment of system performance in this study has provided a better representation of the effectiveness and reliability of the BRT system.

The literature has also shown that assessing transportation performance at different levels with different elements can identify more problems in greater depth. For example, King and Shalaby (2016) examined 52 public transit networks in Toronto and found that disruption at one location affected the delay minutes of the whole system. In another example, the performance of an urban bus service was assessed for reliability, and the findings showed that the provision of an exclusive bus lane can effectively enhance bus service quality and improve reliability [9]. The best practical transportation services are seen in European cities, which generally operate a successful rapid transit network with an off-peak service seven days a week into the evening [34].

In this study in Semarang, the performance of BRT lite at the city level barely achieved half of the points it needed for its service delivery to be considered ideal. This also translated to its performance at the corridor level, as only two corridors exceeded the average point percentage that positively correlates to resilience building. Corridor I, followed by corridor IV, had the most indicators with positive correlations, showing just how vital their role is in the BRT lite system in Semarang. Indeed, the performance of these two corridors may be the key factor that will help improve the overall system become more reliable. In addition, the assessments at the two operational levels provide perspectives for working toward building a more advanced BRT in Semarang. The more advanced the BRT system, the more contribution it can make toward shaping the city's resilience mobility.

Semarang is at risk of the tidal floods and land subsidence that threaten the coastal area, and landslides, a lack of water, and flash flooding threaten the hilly areas [20]. These risks certainly affect the city's mobility as it hampers accessibility. Moreover, the increasing population due to urbanization also escalates population mobility. Under these circumstances, the effectiveness of the public transportation service requires improvement to accommodate travel needs, as well as to prevent a surge in the use of private vehicles. We referred to the qualities of a resilient mobility system developed by Arup [35] and 100 Resilient Cities [20] to find the resilience level of BRT lite in Semarang, based on performance at the city and corridor levels. Table 4 reviews the conditions at these levels through the lens of the resilience concept.

BRT lite in Semarang lacks robustness as buses are often delayed when disruptive events occur, such as flooding. These affect the bus headway and time schedule because the bus and its lane are not designed to pass over the flood water. The existing BRT lite system also lacks redundancy, as indicated by how the bus lane is not separated from other traffic that prevents the bus from reaching its maximum speed while also being affected by disturbances from outside the BRT system itself. The BRT lite system in Semarang has no emergency plan to provide alternative routes when flooding and traffic accidents occur, reflecting the inflexibility of the BRT lite system. The unavailable connectivity with other public transport leaves passengers with no alternative modes during emergency, whereas if disruption occurs, integrated transport enables traffic demand to be shared or transferred from one mode to another [36].

Technology allows urban transport operators to respond quickly to disruption and channel information to travelers via various means of communication [37]. However, the ITS technology installed in the BRT lite system is not equipped with fast-response communication to provide users access to a rescue or alternative plan for emergency. Most BRT lite shelters cannot be easily reached by walking from a residential area; some passengers have to ride a motorcycle or *ojek* (motorcycle taxis) to reach the nearest shelter. The limited access is more apparent for disabled users, where a lack of inclusiveness is also reflected. BRT shelters are not equipped with a proper wheelchair lane and buses do not provide enough space for a wheelchair. The system also has no audio-visual facilities for the deaf and visually impaired.

Table 2

Assessment of city-level performance of BRT lite in Semarang

	Sub-Variable	Indicator	Standard	Existing Condition	Score	Max. Score
PERFORMANCE OF MAJOR ELEMENTS OF BRT*i	Running Way*i	BRT Runway*j	Physically Dedicated Runway *j	Non-Dedicated Runway, mixed traffic	0	1
		Busway Alignment*j	Two-way Alignment Busway *j	One Way Alignment	0	1
		Intersection Treatment*j	Turns Prohibited across Busway *j	None	0	1
		Passing Lanes at Station*j	Dedicated Passing Lanes *j	None	0	1
		Pavement Quality*j	Pavement designed for 30-year life over entire corridor *j	No-Data	-	-
	Stations*i	Stations Set Back from Intersections*j	75% of stations on corridor are set back at least 40 m from intersections, or meet at least one of the above exemptions *j	< 75% of stations in corridor are set back at least 26 m from intersections	0.5	1
		Centre Stations*j	>80% of stations in a corridor have centre platforms serving both directions of service *j	None	0	1
		Distance Between Stations*j	Average spacing between stations 0.3–0.8 kilometers *j	Yes	1	1
		Safe and Comfortable Station*j	Stations have all four elements (wide, weather protected, safe, attractive) *j	Weather Protected	0.5	1
		Docking Bays and Sub Stops*j	At least two sub stops or docking bays at the highest-demand stations *j	Yes	0	1
		Sliding Doors in BRT Stations*j	All stations have sliding doors *j	No	0	1
		Platform Level Boarding*j	Buses are platform level, having 4 cm (1 ½ inches) or less of a vertical gap *j	Yes	1	1
	Vehicles*i	Number of Doors on Bus*j	Buses have at least three doors (for articulated buses) or two wide doors (for non-articulated buses) on the station side. System allows boarding at all doors *j	No	0	1
		Average Speed *g,h	Minimum average commercial speed 20 km/hour and above *j	24.35	1	1
	Fare Collection*i	Flat Fare/Structure-Based Fare (Distance, etc)*j	Flat fare (for a developing country) *j	Flat Fare	1	1
		Barrier /Non-Barrier Controlled*j	Barrier controlled *j	Non-Barrier Controlled	0	1
	Intelligent Transport Systems*i	Control Centre Services*j	Full-service control centre with all three services (automatic dispatch, automatic vehicle location, active bus control) *j	Automatic Vehicle Location	0.5	1
		Route Information *c	Information is correct and updated in real time *c	Yes	1	1
		Passenger Information*j	Functioning real-time and up-to-date static passenger information corridor-wide*j	No	0	1
	Service Operation and Plans*i	Mileage of BRT per Day*k	230–260 km/day *k	272	0	1
		Headway of BRT Services*l	Headway ideal = 5–10 minutes *l	Average headway of BRT Semarang is 4.8 minutes during the day and 6.8 minutes during afternoon	1	1
			Headway peak hour = 2–5 minutes *l			
		Hours of Operation*j	Every day, both late-night and weekend service *j	Everyday, 05:30 – 18:30	0.5	1
	Branding Elements*i	BRT Branding*j	All buses, routes, and stations in a corridor follow a single unifying brand for the entire BRT system *j	Only the buses	1	1
Total Score of Performance of Major Elements of BRT					**9**	**22**
SYSTEM PERFORMANCE*i	Travel Time*i	BRT Travel Time *k	<180 minutes *k	79 minutes	1	1
		Passenger Waiting Time *l	5–10 minutes *l	5–10 minutes	1	1
	Passenger Safety and Security*i	Low Emission Vehicles *e	Emission requirement fulfilled *e (e.g. using low-emission fuel)	CNG fuelled	1	1
		Fuel Consumption *k	3.6–3 km/litres (large-sized double deck fleet) *l	No Data	-	-
			3 km/litres (medium-sized fleet) *l	No Data	-	-
		Smoke-free BRT *c,d,e	Smoke-free inside the BRT *c, d, e	Yes	1	1
		Decreasing the Number of Accidents *e, f	Decreasing the number of accidents up to 100% *e, f	No Data	-	-
	System Capacity*i	Passenger Load Factor *l	Minimum 70% *l	31%	0	1
		Ratio of Bus Occupancy per Hour	Minimum of 70% of seat ratio	45.61%	0	1
		Operation Capacity *k	Comparison of the number of operating vehicles with the number of existing vehicles = 80–90% *k	93%	1	1
		Coverage of Demand Area*j	Corridor includes highest demand segment *j	Yes	1	1
	Accessibility*i	Universal Access*j	Full accessibility provided (physical and audio visual) *j	Non-standard wheelchair lane	0.5	1
		Integration with Other Public Transport*j	Integration of both physical design and fare payment (MRT, LRT, Metro) *j	None	0	1
		Pedestrian Access and Safety*j	Good, safe pedestrian access at every station and many improvements along corridor *j	Yes	1	1
		Secure Bicycle Parking*j	Secure bicycle parking at least in higher-demand stations and standard bicycle racks elsewhere *j	None	0	1
		Bicycle Lanes*j	Bicycle lanes on or parallel to entire corridor *j	None	0	1
		Bicycle-Sharing Integration*j	Bicycle-sharing at minimum of 50% of stations on corridor *j	None	0	1
		BRT Route Length*l	Route lengths a maximum of 32 km *i	133 km of service route	1	1
		Fare Average *c, d, a	Public transportation costs are affordable for ≤100% of the community *c, d, a	Affordable	1	1
		Connection with Feeder *c, a	Feeder connects residential area to corridors *m	No-Feeder	0	1
		Pedestrian Crossing *c	100% wheelchair crossing points (wheelchair accessible and elderly) *c	None	0	1
		Separate Bicycle Route from Pedestrian Paths *c, d	100% separate bicycle lanes from the pavement *c, d	None	0	1
		Public Transport Service Coverage *a, b, c	100% of urban areas are served by public transportation routes *a, b, c	No Data	-	-
Total Score of System Performance					**9.5**	**19**
Total					**18.5**	**41**
Percentage (%)					**45.12**	

Table 3

Assessment of corridor-level performance of BRT lite in Semarang

Variable	Sub-Variable	Indicator	Standard	Unit	Corridor Condition					
					I	II	III	IV	V	VI
Performance of Major Element of BRT *i	Vehicles *i	Average Speed *g, h	Min. average commercial speed 20 km/hour plus *j	km/hour	18.94	18.19	40.82	19.06	16.40	18.81
				**	(-)	(-)	(+)	(-)	(-)	(-)
	Service and Operating Plans *i	Mileage of BRT per Day *k	230–260 km/day *k	km/day	232.0	240.8	233.6	245.6	222.4	224.0
				**	(+)	(+)	(+)	(+)	(-)	(-)
		Headway of BRT Services *l	Headway ideal = 5–10 minutes *l	Minutes	3.5	4.3	**6.7**	3.5	**15**	5
				**	(+)	(+)	(-)	(+)	(-)	(+)
			Headway peak hour = 2–5 minutes *l	Minutes	4.6	2.5	**7.5**	4.6	**10**	4
				**	(+)	(+)	(-)	(+)	(-)	(+)
System Performance *i	Travel Time *i	BRT Travel Time *k	< 180 minutes *k	Minutes	91.5	92	40	89.5	89.5	69.5
				**	(+)	(+)	(+)	(+)	(+)	(+)
		Passenger Waiting Time *l	5–10 minutes *l	Minutes	5-10	**10-15**	5-10	5-10	5-10	5
				**	(+)	(-)	(+)	(+)	(+)	(+)
	Passenger Safety and Security *i	Low Emission Vehicles *e	Emission Requirement Fulfilled *e (e.g. using low-emission fuel)	-	CNG fuelled	No	No	No	CNG fuelled	CNG fuelled
				**	(+)	(-)	(-)	(-)	(+)	(+)
	System Capacity *i	Passenger Load Factor *l	Minimum 70% *l	Percent	41%	31%	53%	42%	44%	13%
				**	(-)	(-)	(-)	(-)	(-)	(-)
		Ratio of Bus Occupancy per Hour	Minimum of 70% of seat ratio	Percent	72.12%	44.55%	22.27%	35%	28.64%	25.45%
				**	(+)	(-)	(-)	(-)	(-)	(-)
		Operation Capacity *k	Comparison of no. of operating vehicles with no. of existing vehicles = 80–90% *k	Percent	88%	88%	88%	92%	100%	100%
				**	(+)	(+)	(+)	(+)	(+)	(+)
		Coverage of Demand Area *j	Corridor includes highest demand segment (passing through three main transit shelters) *j	-	Yes	Yes	Yes	Yes	Yes	No
				**	(+)	(+)	(+)	(+)	(+)	(-)
	Accessibility *i	BRT Route Length *l	Route lengths maximum of 32 km *i	km	37.1	30.1	28.85	31.2	27.8	22.4
				**	(-)	(+)	(+)	(+)	(+)	(+)
				(+) Points	9	7	7	8	6	7
* See Table 1 for complete reference ** Correlation				Point Percentage	75%	58%	58%	67%	50%	58%

In general, the BRT lite system in Semarang still uses a business-as-usual scenario in delivering its service. It still hasn't accommodated the most needs of its users and hasn't had reliable system that help handle aftershocks from disruptive situations. Despite how the services compared to the ideal resilience perspectives (see Table 4), BRT lite in Semarang has the potential to lead toward resilient transport. Theoretically, the performance could be improved by improving related indicators for each resilience perspective. This is also supported by the fact that in its decade of operation, the BRT lite system has been developing to accommodate more passengers as shown by the increasing number of its annual users.

Table 4

Conditions of BRT lite in Semarang from the resilience perspective

Definition	**Conditions of BRT Lite in Semarang**		**Related Indicators**
	City Level	**Corridor Level**	
Robustness			
Strength of the system to withstand disruption without lost function [36]	Lack of robustness due to the fact that fleets are often delayed when disruptive events occur	The area serviced by Corridor II is prone to flooding, meaning departures are often delayed	• BRT Runway • Busway Alignment • Safe and Comfortable Station • Headway of BRT Service • Hours of Operation • BRT Travel Time • Passanger Waiting Time
Redundancy			
Spare capacity purposefully created to accommodate disruption due to extreme pressures	BRT lane not specifically designed with an adequate height to prevent floods entering the lane	Corridor II (Terboyo area) is prone to flooding but has still not been equipped with a designated emergency plan or infrastructure.	• BRT Runway • Busway Alignment
Flexibility			
The ability to adopt alternative strategies in response to a disruptive event	Trans Semarang has no alternative routes to avoid flooding and landslide, and can only accommodate the alternative route for incidental events that happen to block part of a route	Corridor II (Terboyo area) is prone to flooding but has still not been equipped with a designated emergency plan or infrastructure.	• BRT Runway • Busway Alignment • Intersection Treatment • Pedestrian Access and Safety • Universal Access • Integration with Other Public Transport • BRT Route Length • Connection with Feeder • Public Transport Service Coverage
Responsiveness			
The ability of the system to respond quickly due to shock and stresses	Trans Semarang is not yet equipped with fast-response communication technologies which could immediately help users to access a rescue/alternative plan when shocks and stresses happen		• Control Center Services • Route Information • Passenger Information
Integration			
The ability of the system to work together to achieve greater ends	Trans Semarang System is not connected to other public transport modes		• Pedestrian Access and Safety • Universal Access • Integration with Other Public Transport • Bicycle Lanes • Bicycle-sharing Integration • Connection with Feeder • Safety Crosswalk • Public Transport Service Coverage
Inclusiveness			
Inclusive processes emphasize the need for board consultation to create a sense of shared ownership or joint vision to build resiliency	The infrastructure of BRT Semarang has already considered wheelchair users' needs but in practice its systems often do not work	Shelters in the corridor sections outside of the city centre are generally ill equipped with disability friendly infrastructure	• Pedestrian Access and Safety • Universal Access • Safety Crosswalk

4. CONCLUSIONS

BRT lite in Semarang is clearly the backbone of public transport in Semarang City, but to increase the mobility of city residents, and especially their usage of the BRT lite service, all the supporting conditions need to be enabled and managed to meet the demand. To date, the service has been unable to provide an effective and efficient service due to various factors. The study found that the most obvious are the condition and the availability of supporting infrastructure, limited-service coverage, and the lack of integration with other public transport modes. The existing BRT system requires most users to rely on other transport modes to reach BRT shelters, and this means that they spend more money on travel. The shelters also do not properly accommodate users with a disability.

The need to transfer between buses of different corridors within the BRT corridor system also adds to travel time, which is clearly a disadvantage for those using the BRT compared to a motorcycle or other private vehicle. Moreover, the speed of Trans Semarang is still relatively low and traffic congestion slows the bus further. The service performance of BRT Trans Semarang only reaches approximately 45% of the ideal standard at the city level, while for the corridor level, the performance is in the range of 50–75% for its positive correlation to resilience building. Corridor I performed the best among the six corridors assessed, and was 15% better than the average, while Corridor IV was 6% over the average. The performance of these two corridors could be the starting point for working on building a more advanced BRT system in Semarang.

In the context of transport resilience, the BRT lite service has yet to comply with the six resilience indicators. The current infrastructure and operational factors are not designed to handle disruptive events such as flooding and traffic-related shocks and stresses. There is absence of access for alternative and emergency plans for users as the system still uses a business-as-usual scenario. It results in Semarang's BRT lite system unable to reach its full potential in providing a resilient service for its users. However, with the ever-growing number of people relying for their mobility on BRT lite, the performance could be enhanced by improving the delivery of indicators affecting the six resilience perspectives.

Acknowledgements

This paper is part of the "Performance Study of BRT Trans Semarang: Towards a Resilient Semarang" funded by the Engineering Faculty of Diponegoro University. The data collection process was only possible with the cooperation of and help from the Institute for Global Environmental Strategies (IGES), the Institute for Transportation and Development Policy (ITDP) Indonesia, and Semarang Transport Agency, as collaborators in support of the Semarang City government during the study titled "Increasing Intermodality and Ridership of BRT Trans Semarang" in 2017-2018.

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Received 12.05.2020; accepted in revised form 09.09.2021