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Feeder Transportation Route Evaluation based on Origin-Destination Analysis and Land Function (Case Study of Trans Semarang Feeder 1A, Indonesia)

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Abstract

The Route modification for the Trans Semarang feeder line 1 resulted in the creation of feeder line 1A. To evaluate the effectiveness of this change in addressing critical community needs, an analysis was conducted. This study utilized passenger boarding and alighting data obtained through origin-destination surveys, combined with land use data from the Google Earth application. Findings revealed inconsistencies and fluctuations when comparing passenger movement patterns with land use values. The feeder transportation function was deemed effective, with the highest proportion of passengers (23.53%) boarding at the transit shelter. Conversely, the segment between Jalan Perkebunan and Desa Ngadirgo shelters exhibited the lowest passenger volume, attributed to long distances between shelters, extensive forested and plantation areas, and a one-way route. These factors suggest potential benefits of rerouting. Further research is recommended to comprehensively evaluate the broader implications of such modifications.

INTRODUCTION

Population growth drives an increase in mobility, consequently raising the demand for transportation. One solution to alleviate traffic congestion is through mass transportation [1]. However, the mere availability of mass transportation (such as buses) is not sufficient; several service considerations must be included to encourage passenger preference, such as travel time, access time, and cost [2]. This access time is further influenced by the surrounding infrastructure, including residential areas, offices, and educational facilities [3].

In Semarang City, the BRT system is implemented under the name Trans Semarang. The vision of Trans Semarang is to establish an independent, reliable, sustainable, professional, and affordable mass transportation network [4]. Prior research has examined the reach of Trans Semarang by considering all existing routes in relation to land use, population density, land availability, road networks, and the percentage of developed land within Semarang City [5]. Feeder lines serve as transportation modes that extend service to the city's periphery while maintaining operational efficiency and service quality. A case study of Trans Semarang feeder line 2 indicated that the effectiveness of the feeder is influenced by public preferences in mode choice [6]. The discontinuation of Urban Public Transportation (AUP) operating on the Cangkiran Terminal-Shelter Jrakah route has been shown to enhance the efficiency of Corridor IV of Trans Semarang. However, further research is needed to assess the efficiency of other public

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transportation options on the outskirts of Semarang City [7]. Recently, Trans Semarang implemented a route change, transitioning feeder route 1 to feeder route 1A. This modification aimed to improve community mobilization [8]. To ensure the continued effectiveness of Trans Semarang's reach, an evaluation of the new route's accuracy in serving locations with the highest demand is imperative.

METHODS

Passenger Origin-Destination Survey

The data required for this study consist of the number of passengers boarding and alighting Trans Semarang Feeder 1A buses. The method employed to analyze passenger movement is the passenger origin-destination survey method, conducted through direct observations recorded systematically. These direct surveys utilize a recording system developed using Microsoft Excel, featuring buttons to calculate the arrival and departure times of buses at each shelter, as well as the number of passengers boarding and alighting. Additional supporting data includes the location and distance of each shelter from the others. The survey results yield a map detailing the number of passengers boarding and alighting during each trip. The essential equipment for this survey is a laptop.

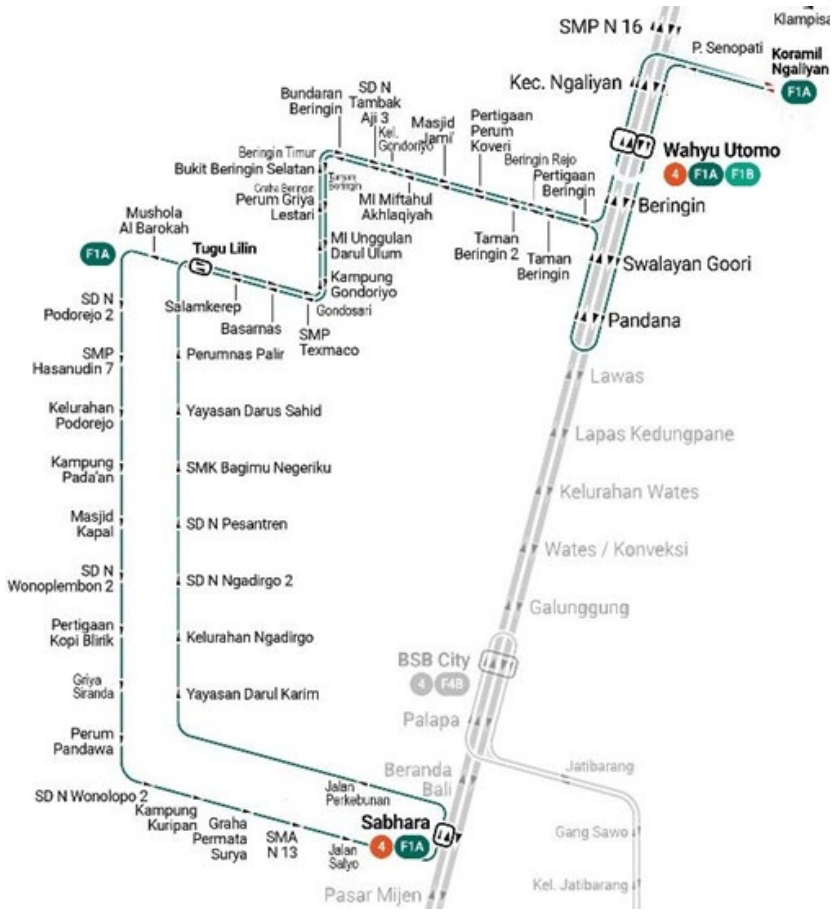

Figure 1. Trans Semarang Feeder *Route* 1A [9]

The sampling method employed was probability sampling using a systematic approach. Sampling was conducted during peak hours and extended over several days to ensure data consistency. The origin-destination survey was carried out over nine days (July 27th - August 4th, 2024), including four weekend days (Saturday and Sunday) and five weekdays (Monday - Friday). Each day was divided into three survey trip schedules: morning (05:30-07:30), afternoon (10:30-12:30), and evening (14:30-16:30). Consequently, the total survey data comprised 27 Trans Semarang Feeder 1A bus trips.

Land Use Function

In addition to passenger movement data, information on land use functions surrounding the Trans Semarang Feeder 1A route was collected. Land use functions were categorized based on the identified purpose of travel from previous

studies, including education, offices, commerce, healthcare facilities, tourist attractions, and social venues. Secondary land use data were obtained from the Google Earth application.

Land use functions were weighted based on their relative importance. The weight of each land use function was determined by multiplying the percentage of travel intent (derived from previous studies as shown in Figure 2) by the number of land use instances around each shelter. The weight of the land use function for each shelter ($Weight_i$) was calculated using Equation 1 [10]:

$$Weight_{(i)} = \sum_i (\%\, MP)\ x\ (Land\ Use) \quad (1)$$

Where:
i = Shelter
MP = The percentage of travel intent
$Land\ Use$ = Total land use around shelter i
$Weight_{(i)}$ = Weight of land use function in shelter i

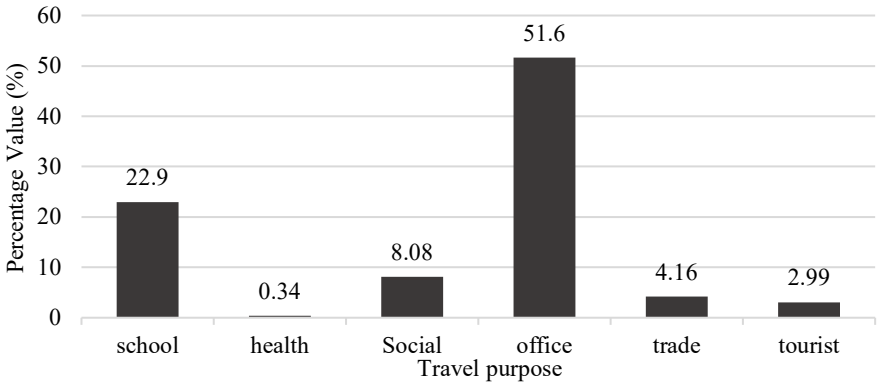

Figure 2. Travel Intent Percentage Graph [11-15]

RESULTS AND DISCUSSION

Based on the origin-destination survey, the number of passengers boarding and alighting at each shelter was obtained. These passenger movement data can then be compared with the calculated land use function value within a 300-meter radius of each shelter.

The highest volumes of passenger boarding and alighting were observed in transit areas, specifically at the Wahyu Utomo Shelter (3.074 passengers per trip), Sabhara Shelter (1.593 passengers per trip), and Tugu Lilin Shelter (0.907 passengers per trip). Cumulatively, passenger movements at these transit shelters amounted to 5.574 passengers per trip, representing 23.52% of the total passenger movements along the 1A feeder route. This aligns with the work of Anwar et al. (2024) [16], who highlight the importance of an integrated transportation network with transit areas within a system referred to as Transit-Oriented Development (TOD).

Furthermore, significant passenger activity was also noted in areas with educational land use (school), namely at the Jalan Salyo Shelter (1.463 passengers per trip), Koramil Shelter (1.111 passengers per trip), SMP Texmaco Shelter (1.407 passengers per trip), and SMP 16 Shelter (0.574 passengers per trip). Other shelters serving areas with educational institutions, albeit with slightly lower passenger volumes, include the MI Miftahul Akhlaqiyah Shelter (average of 0.815 passengers per trip), SMK Bagimu Negeriku Shelter (average of 0.741 passengers per trip), and Tugu AMD Shelter (average of 0.611 passengers per trip).

Based on the total of 640 passengers recorded across 27 trips across all shelters, the average passenger volume was 23.7 passengers per trip. A substantial decrease in passenger numbers (66.59%) was observed during weekend compared to weekdays. Weekday trips (15 trips) recorded a total of 505 passengers, yielding an average of 33.67 passengers per trip. In contrast, a survey of 12 weekend trips showed a total of 135 passengers, resulting in an average of 11.25 passengers per trip

Figure 3 illustrates the most significant changes in passenger numbers on weekends. Specifically, Shelter SMP 16, Jalan Salyo, and SMP Texmaco experienced the largest decrease in passengers during weekends. These shelters are

located in areas adjacent to schools, supporting the earlier finding that school proximity influences passenger numbers. Conversely, the Masjid Kapal shelter, an area characterized by tourism land use, showed an increase in passengers on weekends.

Table 1. Comparison of Passenger Origin-Destination with Land Use Weight

	Shelter	Land Use (Radius 300 m)						Number of Passengers			
		school	health	Social	office	trade	tourist	value	origin	destination	Average per trip
		22.90%	0.34%	8.08%	51.60%	4.16%	2.99%				
1	Koramil Ngaliyan	5	1	1	3	1	2	2.88	42	18	1.111
2	Senopati/SMP 16	4	1	1	3		2	2.61	0	31	0.574
3	Kec. Ngaliyan	6	2	1	3	1	2	3.11	2	0	0.037
4	Wahyu Utomo	1	2	1		2		0.4	63	103	3.074
5	Beringin / Damri L.	1	2	1		2		0.4	0	8	0.148
6	Swalayan Goori/RS	1	1	1	1	2		0.91	2	4	0.111
7	Pandana	1	1	1				0.31	9	0	0.167
8	Jl. Beringin	1	2	1		2		0.4	3	0	0.056
9	Pertigaan Beringin	1	1	1		1		0.36	0	0	0.000
10	Taman Beringin 1			1	2			1.11	5	1	0.111
11	Beringin Rejo			1	2			1.11	0	0	0.000
12	Taman Beringin 2		1	1	2			1.12	2	1	0.056
13	Pertigaan Perum K.	2	1	1	1			1.06	7	7	0.259
14	Masjid Jami'	3	1	1	2			1.8	7	6	0.241
15	MI Miftahul A.	3	1	1	2			1.8	21	23	0.815
16	Kel. Gondoriyo	4	1	1	1			1.52	3	3	0.111
17	SD N Tambak A. 3	2	1	1	1			1.06	1	0	0.019
18	Bundaran Beringin	1	2	1	2			1.35	16	26	0.778
19	Bukit Beringin T.		1	1	2			1.12	16	12	0.519
20	Bukit Beringin S.	1	1	1	1			0.83	6	8	0.259
21	T. Bukit Beringin	1		1	1			0.83	0	12	0.222
22	Perum Graha B.	1		1	2			1.34	14	7	0.389
23	Perum Griya L.	1		1	2			1.34	2	5	0.130
24	MI Unggulan D. U.	1		1	2			1.34	2	5	0.130
25	Kp Gondoriyo	1		1				0.31	5	10	0.278
26	Gondosari	3	1	1				0.77	19	13	0.593
27	SMP Texmaco	2		1				0.54	68	8	1.407
28	Basarnas				1			0.52	0	0	0.000
29	Salamkerep			1				0.08	3	12	0.278
30	Tugu Lilin							0	21	28	0.907
31	Gapura Kaliancar		1	1				0.08	1	2	0.056
32	Mushola Al B.	1	2	1				0.32	1	16	0.315
33	SD N Podorejo 2	1	2	1				0.32	15	4	0.352
34	SMP Hasanuddin 7	2		1	1			1.05	17	0	0.315
35	Kp Podorejo	2		1	1			1.05	5	2	0.130
36	Jl. Kiyai Padak	2		1				0.54	0	7	0.130
37	Masjid jami K. P.	1		1				0.31	2	14	0.296
38	Makam Kiyai P.	1		1				0.31	0	8	0.148
39	Masjid Kapal						1	0.03	12	3	0.278
40	SD Wono 2	2		1				0.54	16	1	0.315
41	Pertigaan Kopi B.	2		1				0.54	7	1	0.148
42	Griya Siranda			1				0.08	22	10	0.593
43	Perum Pandawa	1		1				0.31	1	2	0.056
44	Tugu AMD	3		1				0.77	14	19	0.611
45	SD N Wonolopo 2	3	1	1				0.77	8	10	0.333
46	Kp Kuripan	1	1	1				0.31	20	15	0.648
47	OASIS		1	1				0.08	1	1	0.037
48	Graha Permata S.			1			2	0.14	13	5	0.333
49	SMA N 13	2	1	1			2	0.6	11	6	0.315
50	Jalan Salyo	3	2	1	1	1	1	1.36	37	42	1.463
51	Sabhara	2	1	1	1	1	1	1.13	33	53	1.593
52	Jalan Perkebunan		1	1			1	0.11	2	0	0.037
53	Yayasan Darul K.	1		1				0.31	0	6	0.111
54	Jl. Bima	2	2	1	1			1.06	1	3	0.074
55	Kel. Ngadirgo	1	2	1	1			0.83	0	3	0.056
56	SD N Ngadirgo 2	2	1	1				0.54	6	7	0.241
57	SD N Pesantren	1	2	1	2			1.35	13	4	0.315
58	SMK Bagimu N.	1	1	1	1			0.83	28	12	0.741
59	Yayasan Darus S.			1				0.08	3	10	0.241
60	Perumnas Palir	1		1				0.31	9	16	0.463
61	Palir Sejahtera U.			1				0.08	3	7	0.185
	Total								640	640	23.700

Table 2. Comparison of Passenger Survey Numbers on Weekdays and Weekends

	Number of Passengers	Number of survey trips	Average Passengers per trip
weekdays	505	15	33.67
weekend	135	12	11.25
Total	640	27	23.70

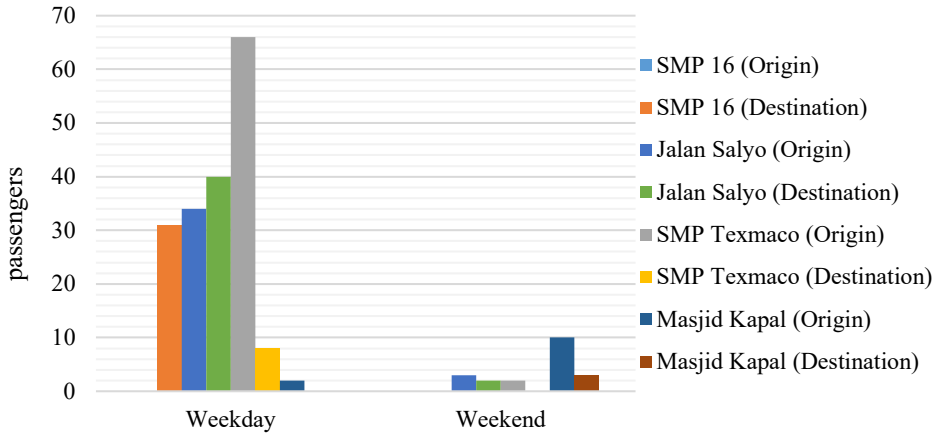

Figure 3. Changes in the Number of Passengers at Several Shelters

The office area is not a significant contributor to the increase in the number of passengers using Trans Semarang Feeder 1A, unlike the trend in travel intentions in Indonesia as shown in Figure 2. A similar finding was reported in another study conducted in Semarang City by Ismiyati (2017) [17]. The study revealed that residents living on the outskirts of the city tend to prefer private transportation for commuting to urban areas, citing reasons such as comfort, efficiency, and punctuality

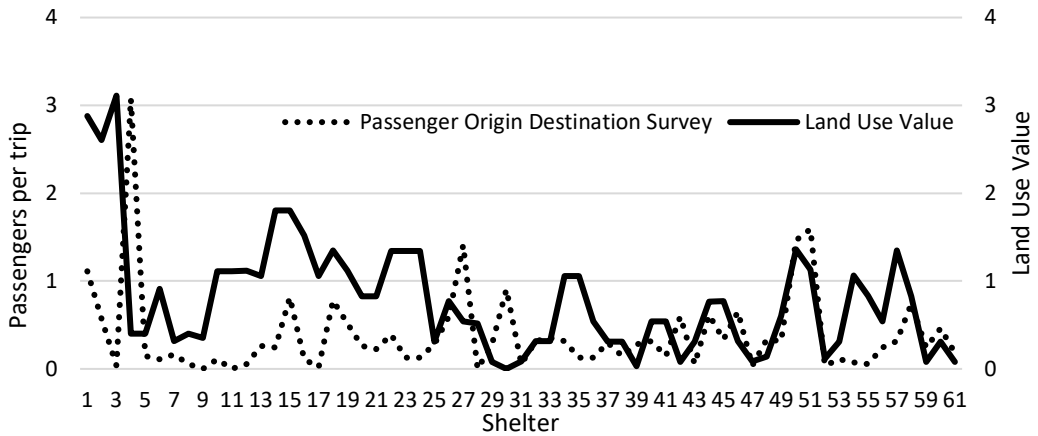

Figure 4. Comparison Graph of Passenger Origin-Destination with Land Use Weight

A comparison between the origin-destination survey data and the land use function value, as depicted in Figure 4, reveals fluctuating values with no apparent significant correlation. For instance, Shelters 3 and 4 exhibit contrasting trends. Shelter 3 (Kec. Ngaliyan Shelter), despite having a high land use function weight of 3.11, recorded a low passenger movement of 0.04 passengers per trip. Conversely, Shelter 4 (Wahyu Utomo Shelter), with a low land use function weight of 0.4, demonstrated high passenger movement at 3.07 passengers per trip. However, in certain instances, such as Shelter 1 (Koramil Ngaliyan Shelter), both the land use function weight and passenger movement were relatively high.

Analysis of Figure 4 indicates that the lowest passenger boarding and alighting numbers were concentrated between the 8th and 12th shelters, spanning the area from the Beringin Shelter to the Taman Beringin 2 Shelter. This segment lacks prominent educational facilities (school), which the origin-destination analysis identified as a frequent travel purpose. However, further analysis yielded several considerations regarding the significance of this area. The shelters in this segment are in proximity, with a total distance of 775 meters across the five shelters. The total passenger count for this area was 12 passengers across the 27 survey trips. Notably, this area provides close access (within 500 meters) to Corridor 4 of the Trans Semarang system. Furthermore, this segment is crucial for connecting route 1A to subsequent areas via Jalan Beringin Raya. Connecting routes between zones are essential in transportation, aligning

with Bruton [1], explanation of this as a key function of highway network and alternative public transport development.

Theoretically, it is known that a shelter as a supporting transportation infrastructure with a high land use function value will provide high passenger movement [18-20]. However, Shelter 3, Ngaliyan District with a high land use function weight, recorded low passenger movement. This phenomenon is estimated to occur due to the development of digitalization, according to the results of Afdhila's research [21] and Fajri & Sumabrata [22], that public transportation users have decreased because passengers prefer online motorcycle taxis which are much more effective [21,22]. On the other hand, areas with small land use functions showed high passenger movement. This is estimated by the large number of student passengers who need cheap transportation [23]. However, these two analyses need to be studied further for Shelter 3 (Kec. Ngaliyan Shelter) and Shelter 4 (Wahyu Utomo Shelter). This is because not only costs and time efficiency, but also comfort, travel time, shelter accessibility, and other factors affect public transportation usage [24].

The next area exhibiting low passenger numbers is situated between the 52nd and 55th shelters, specifically from the Jalan Perkebunan Shelter to the Kelurahan Ngadirgo Shelter. This segment recorded low passenger boarding and alighting rates, ranging from 0.04 to 0.11 passengers per trip. This area is characterized by significant distances between shelters, totaling 2,373 meters across the four shelters. The total number of passengers in this area was only 15 across the 27 survey trips. This region also presents relatively few land use functions and a lower population density. As illustrated in Figure 5, this area is predominantly marked in green, indicating forests or plantations. Additionally, this segment operates on a one-way route, suggesting its potential for route diversion.

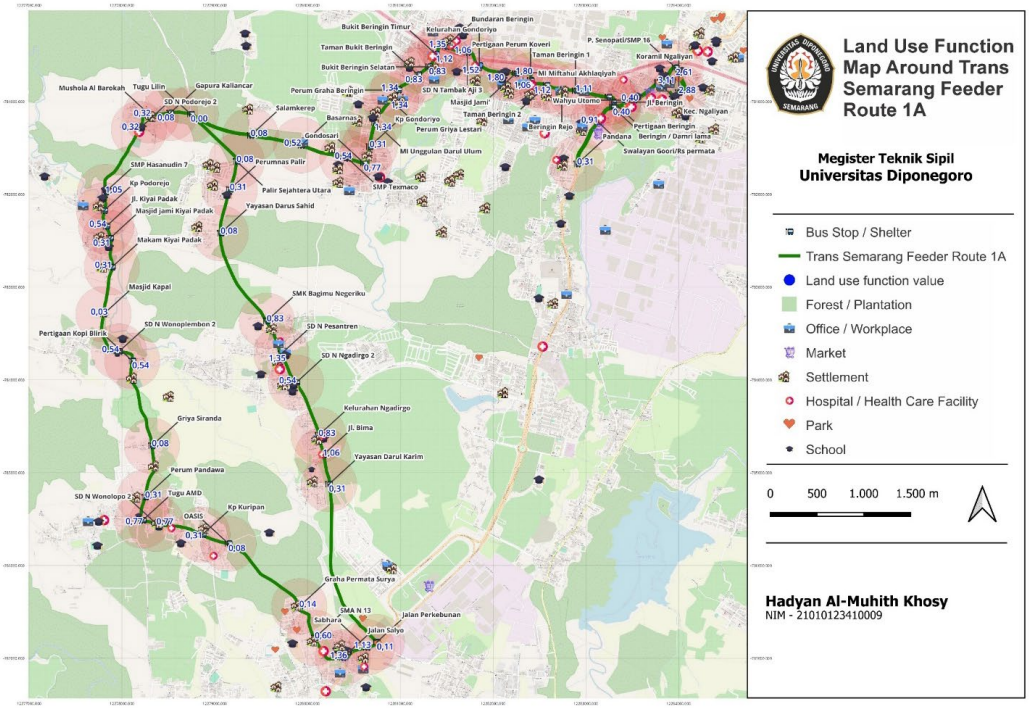

Figure 5 . Land Use Function Map around Trans Semarang Feeder Route 1A

CONCLUSIONS

Based on the survey of origin-destination and land function weight, the comparison between origin-destination and land function weight values appears inconsistent and fluctuates. This indicates that passenger movement is not significantly influenced by land function, particularly office areas, which contribute heavily to land function weight based on travel intentions in Indonesia. However, workers tend to favor private transportation for their commute.

The origin-destination survey revealed an average passenger movement of 23.7 passengers per trip. A substantial decrease of 66.59% in average passenger numbers was observed on the weekend (11.25 passengers per trip) compared to weekdays (33.67 passengers per trip). The largest decline was observed in the education sector, characterized by fewer trips to school on weekends. The feeder function of Trans Semarang feeder 1A has been fulfilled, with the highest passenger movement recorded at the transit shelters: Wahyu Utomo (3.07 passengers per

trip), Sabhara (1.59 passengers per trip), and Tugu Lilin (0.91 passengers per trip). Passenger movement at these transit shelters constitutes 23.53% of the total passenger movement on the 1A feeder route.

The route evaluation identified the segment encompassing the Jalan Perkebunan Shelter, Yayasan Darul Karim Shelter, Jl. Bima Shelter, and Kelurahan Ngadirgo Shelter as having the lowest passenger numbers. This area contributed to only 15 passengers across 27 survey trips, with a total route distance of 2,373 meters across these four shelters. Analysis of land use functions in this area indicates a low population density, with most of the land being forests and plantations. The one-way operational characteristic of this route segment further supports the consideration of route diversion. However, a comprehensive re-examination of other factors relevant to route diversion is necessary to assess the efficiency of potential alternative routes.

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