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Analysis of Passenger Waiting Time at Basko Air Tawar Bus Stop Using Queueing Theory and Arena-Based System Simulation

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ABSTRACT

Public transportation systems play a crucial role in supporting urban mobility, particularly in densely populated cities where traffic congestion and travel efficiency remain persistent challenges. One of the most critical indicators of service quality in bus-based public transportation is passenger waiting time at bus stops, especially during peak hours. Prolonged waiting times may reduce passenger satisfaction and discourage the use of public transport. This study aims to analyze passenger waiting time at the Basko Air Tawar Bus Stop of the Trans Padang Bus Rapid Transit (BRT) system during the morning peak period by applying queueing theory and discrete-event system simulation using Arena software. The research adopts a quantitative empirical approach, with primary data collected through direct field observation conducted from 07:00 to 09:00 a.m. A total of 100 passengers served by 11 bus arrivals were observed, and data on passenger arrival times, bus arrival intervals, and individual waiting times were recorded. The service system was modeled as a single-channel single-phase queue with a first-come-first-served discipline. Simulation results indicate that passenger waiting times range from 0 to 11.47 minutes, with significant variation driven primarily by bus arrival intervals rather than service capacity. Passengers arriving earlier within a bus arrival cycle experienced substantially longer waiting times compared to those arriving closer to bus arrival times. The findings demonstrate that irregular bus headways are the dominant factor affecting system performance. This study provides practical insights for transportation operators by highlighting the importance of optimizing bus schedules and arrival frequencies to reduce passenger waiting time and improve overall service quality in urban BRT systems

INTRODUCTION

Urban public transportation systems are fundamental components of sustainable city development, as they support mobility needs, reduce traffic congestion, and contribute to environmental efficiency. Among various modes of public transport, Bus Rapid Transit (BRT) systems have been widely adopted in many cities due to their relatively low implementation cost, operational flexibility, and capacity to provide mass transportation services comparable to rail-based systems. However, the effectiveness of a BRT system is not determined solely by infrastructure or fleet size, but also by the quality of service experienced by passengers. One of the most influential indicators of service quality is passenger waiting time at bus stops, particularly during peak hours when demand is high and system performance is under greater pressure.

Passenger waiting time has a direct impact on user satisfaction, perceived reliability, and the overall attractiveness of public transportation. Excessive or unpredictable waiting times may lead to dissatisfaction, reduced trust in service reliability, and ultimately a modal shift toward private vehicles. Consequently, minimizing waiting time is a critical objective for public transport operators and urban planners. In BRT systems, waiting time is influenced by multiple interrelated factors, including passenger arrival patterns, bus arrival intervals (headways), service capacity, boarding processes, and operational scheduling policies. Understanding how these factors interact within a service system is essential for improving operational performance and passenger experience.

Queueing theory provides a well-established analytical framework for modeling and evaluating service systems in which entities arrive, wait, and receive service according to specific rules. In the context of public transportation, passengers can be modeled as customers arriving at a service facility, while buses function as service providers. Queueing models allow researchers to analyze key performance indicators such as waiting time, queue length, and service utilization under different arrival and service conditions. Due to the stochastic nature of passenger arrivals and vehicle operations, queueing theory is particularly suitable for capturing the inherent variability present in real-world transportation systems.

In recent decades, queueing theory has been increasingly integrated with discrete-event simulation techniques to enhance analytical flexibility and realism. Simulation tools, such as Arena, enable researchers to model complex systems that may be difficult to analyze using purely mathematical formulations. Through simulation, it becomes possible to incorporate empirical data, irregular arrival patterns, and operational constraints while observing system behavior under realistic conditions. This approach allows for the evaluation of system performance, identification of bottlenecks, and testing of potential improvement scenarios without disrupting actual operations.

Numerous studies have applied queueing theory and simulation methods to analyze public transportation systems. Prior research has demonstrated that mismatches between passenger arrival rates and vehicle arrival intervals are a primary cause of excessive waiting times in bus-based services. Studies on BRT systems in major metropolitan areas have shown that irregular headways and insufficient scheduling coordination significantly increase passenger waiting time, even when vehicle capacity is adequate. Simulation-based studies using Arena have further confirmed that service performance is often more sensitive to arrival interval variability than to service speed or boarding capacity, particularly in single-channel service environments such as bus stops.

Despite the growing body of research on queueing analysis in public transportation, empirical studies focusing on local or regional BRT systems in developing urban contexts remain limited. Many existing studies concentrate on large-scale systems or focus primarily on terminal stations, transfer hubs, or toll gate facilities. As a result, there is a lack of detailed empirical evidence regarding passenger waiting time dynamics at intermediate bus stops, especially during peak periods when service demand fluctuates rapidly. Moreover, limited attention has been given to combining direct field observation with simulation-based validation in evaluating BRT service performance at specific urban locations.

The Trans Padang BRT system serves as a key public transportation mode in the city of Padang, Indonesia, facilitating daily mobility for commuters, students, and other urban residents. Among its service points, the Basko Air Tawar Bus Stop experiences relatively high passenger activity during morning peak hours, coinciding with work and school commuting periods. Preliminary observations indicate that passenger accumulation and waiting time variability frequently occur at this location, suggesting potential inefficiencies in service scheduling or bus arrival regularity. However, systematic analysis of passenger waiting time at this bus stop has not been comprehensively conducted.

This study addresses this gap by analyzing passenger waiting time at the Basko Air Tawar Bus Stop using a combined approach of queueing theory and discrete-event simulation. Unlike studies that rely solely on theoretical assumptions, this research employs empirical field data collected through direct observation to model actual passenger and bus arrival patterns. The service system is conceptualized as a single-channel single-phase queue with a first-come-first-served discipline, reflecting the operational characteristics of the bus stop. Arena simulation software is then utilized to replicate the observed system behavior and analyze waiting time performance under real conditions.

The novelty of this study lies in its location-specific empirical focus and its integration of observational data with simulation modeling to evaluate BRT service performance at a non-terminal urban bus stop. By concentrating on a peak-hour scenario, the study provides insights into the most critical operational period affecting passenger experience. Furthermore, the findings contribute to applied transportation research by demonstrating how relatively simple queueing structures, when combined with simulation tools, can effectively capture and explain waiting time variability in urban public transport systems.

The primary objective of this research is to analyze passenger waiting time at the Trans Padang Basko Air Tawar Bus Stop during the morning peak period and to identify the dominant factors influencing waiting time variability. Specifically, the study aims to [1] characterize the queueing structure of the service system, [2] measure passenger waiting time based on empirical observations, [3] evaluate system performance using Arena-based simulation, and [4] assess the impact of bus arrival intervals on passenger waiting time. The results of this study are expected to provide practical insights for transportation operators and policymakers in optimizing bus schedules, improving service reliability, and enhancing passenger satisfaction in urban BRT systems.

METHODS

Research Design and Approach

This study employs a quantitative empirical research design with a discrete-event system simulation approach to analyze passenger waiting time at the Trans Padang Basko Air Tawar Bus Stop. The research focuses on evaluating the performance of the service system during the morning peak period, when passenger demand is highest and service variability is most pronounced. A combination of direct field observation and simulation modeling is used to capture real operational conditions and assess system behavior under observed arrival patterns. This approach enables a rigorous evaluation of passenger waiting time while maintaining realism and reproducibility.

Study Location and Observation Period

The research was conducted at the Basko Air Tawar Bus Stop, located in Padang City, Indonesia. This bus stop is one of the busiest service points within the Trans Padang BRT network, particularly during weekday morning commuting hours. Data collection was carried out during the morning peak period from 07:00 a.m. to 09:00 a.m., which corresponds to peak travel demand associated with work and school activities. This time window was selected to ensure that the analysis captures the most critical operational conditions affecting passenger waiting time.

Data Collection and Observed Variables

Primary data were obtained through direct on-site observation of passenger and bus activities at the bus stop. The observation process involved recording the arrival time of each passenger entering the bus stop area, the arrival time of each Trans Padang bus, and the time at which passengers were served by boarding the arriving bus. A total of 100 passengers were observed during the study period, served by 11 bus arrivals. The collected data allowed for the calculation of individual passenger waiting times, defined as the time difference between passenger arrival at the bus stop and the arrival of the bus that provided service.

The observed variables in this study include passenger interarrival time, bus arrival intervals (headways), and passenger waiting time. These variables form the basis for both the analytical description of the queueing system and the input parameters used in the simulation model. All data were recorded manually and subsequently organized into structured datasets for analysis and simulation input.

Queueing System Characterization

Based on field observations, the service system at the Basko Air Tawar Bus Stop is characterized as a single-channel single-phase queueing system. In this system, passengers form a single queue while waiting for service, and service is completed in a single phase when passengers board the arriving bus. The queue discipline follows a first-come-first-served (FCFS) rule, where passengers are served in the order of their arrival at the bus stop. This characterization reflects the actual operational conditions observed at the study location and provides a suitable framework for modeling passenger waiting behavior.

Simulation Model Development Using Arena

Discrete-event simulation was conducted using Arena simulation software to replicate the observed queueing system and analyze passenger waiting time performance. In the simulation model, passengers are represented as entities generated according to observed arrival patterns, while the bus arrival process is modeled as a service mechanism with variable interarrival times corresponding to empirical bus headways. The simulation incorporates Create, Process, and Dispose modules to represent passenger arrival, waiting and service, and system exit, respectively.

The simulation was run for a duration of 120 minutes to match the observation period, with a total of 100 passenger entities processed through the system. Input parameters for passenger arrival times and bus arrival intervals were derived directly from the observed data to ensure consistency between the real system and the simulation model. The primary output of interest from the simulation is passenger waiting time, which is analyzed to evaluate system performance and validate the consistency of simulation results with empirical observations.

Performance Measures and Analysis

The main performance indicator evaluated in this study is passenger waiting time, measured in minutes. Descriptive analysis is used to examine the distribution and range of waiting times observed in the system. Simulation output is analyzed to identify patterns and variability in waiting time and to assess the influence of bus arrival intervals on system performance. The results obtained from the Arena simulation are compared with empirical waiting time data to ensure that the model accurately represents real operational conditions. This combined analytical and simulation-based approach provides a robust foundation for evaluating service performance and identifying opportunities for operational improvement.

Table 1. Table of Observation Results

No	Passenger Arrival Time	Bus Arrival Time	Passenger Waiting Time (minutes)	Bus Sequence
1	07:00:34	07:07:00	6.43	1
2	07:01:24	07:07:00	5.6	1
3	07:02:01	07:07:00	4.98	1
4	07:03:14	07:07:00	3.77	1
5	07:04:26	07:07:00	2.57	1
6	07:05:55	07:07:00	1.08	1
7	07:06:59	07:07:00	0.02	1
8	07:08:14	07:18:00	9.77	2
9	07:08:46	07:18:00	9.23	2
10	07:09:46	07:18:00	8.23	2
11	07:10:33	07:18:00	7.45	2
12	07:11:28	07:18:00	6.53	2
13	07:11:58	07:18:00	6.03	2
14	07:12:48	07:18:00	5.2	2
15	07:13:33	07:18:00	4.45	2
16	07:14:39	07:18:00	3.35	2
17	07:16:08	07:18:00	1.87	2
18	07:17:01	07:18:00	0.98	2
19	07:18:17	07:24:00	5.72	3
20	07:19:13	07:24:00	4.78	3
21	07:20:27	07:24:00	3.55	3
22	07:21:56	07:24:00	2.07	3
23	07:23:03	07:24:00	0.95	3
24	07:24:01	07:34:00	9.98	4
25	07:24:52	07:34:00	9.13	4
26	07:25:56	07:34:00	8.07	4
27	07:26:54	07:34:00	7.1	4
28	07:28:06	07:34:00	5.9	4
29	07:29:13	07:34:00	4.78	4
30	07:30:07	07:34:00	3.88	4
31	07:30:47	07:34:00	3.22	4
32	07:32:14	07:34:00	1.77	4
33	07:32:54	07:34:00	1.1	4
34	07:34:07	07:43:00	8.88	5
35	07:34:54	07:43:00	8.1	5
36	07:36:20	07:43:00	6.67	5
37	07:37:36	07:43:00	5.4	5
38	07:39:06	07:43:00	3.9	5
39	07:40:16	07:43:00	2.73	5

No	Passenger Arrival Time	Bus Arrival Time	Passenger Waiting Time (minutes)	Bus Sequence
40	07:40:48	07:43:00	2.2	5
41	07:41:45	07:43:00	1.25	5
42	07:43:09	07:52:00	8.85	6
43	07:44:15	07:52:00	7.75	6
44	07:45:18	07:52:00	6.7	6
45	07:46:23	07:52:00	5.62	6
46	07:47:25	07:52:00	4.58	6
47	07:48:10	07:52:00	3.83	6
48	07:49:29	07:52:00	2.52	6
49	07:50:53	07:52:00	1.12	6
50	07:51:26	07:52:00	0.57	6
51	07:52:32	08:04:00	11.47	7
52	07:53:12	08:04:00	10.8	7
53	07:54:05	08:04:00	9.92	7
54	07:55:10	08:04:00	8.83	7
55	07:56:03	08:04:00	7.95	7
56	07:57:01	08:04:00	6.98	7
57	07:57:58	08:04:00	6.03	7
58	07:59:03	08:04:00	4.95	7
59	07:59:55	08:04:00	4.08	7
60	08:01:21	08:04:00	2.65	7
61	08:02:34	08:04:00	1.43	7
62	08:03:39	08:04:00	0.35	7
63	08:05:00	08:12:00	7	8
64	08:05:36	08:12:00	6.4	8
65	08:06:45	08:12:00	5.25	8
66	08:07:24	08:12:00	4.6	8
67	08:08:39	08:12:00	3.35	8
68	08:09:58	08:12:00	2.03	8
69	08:10:34	08:12:00	1.43	8
70	08:11:43	08:12:00	0.28	8
71	08:12:54	08:21:00	8.1	9
72	08:13:47	08:21:00	7.22	9
73	08:14:28	08:21:00	6.53	9
74	08:15:08	08:21:00	5.87	9
75	08:15:48	08:21:00	5.2	9
76	08:16:42	08:21:00	4.3	9
77	08:17:15	08:21:00	3.75	9
78	08:17:55	08:21:00	3.08	9
79	08:18:38	08:21:00	2.37	9
80	08:19:54	08:21:00	1.1	9
81	08:21:00	08:21:00	0	9
82	08:22:01	08:29:00	6.98	10

No	Passenger Arrival Time	Bus Arrival Time	Passenger Waiting Time (minutes)	Bus Sequence
83	08:23:14	08:29:00	5.77	10
84	08:24:32	08:29:00	4.47	10
85	08:26:00	08:29:00	3	10
86	08:27:12	08:29:00	1.8	10
87	08:28:20	08:29:00	0.67	10
88	08:28:50	08:29:00	0.17	10
89	08:30:08	08:41:00	10.87	11
90	08:31:06	08:41:00	9.9	11
91	08:32:02	08:41:00	8.97	11
92	08:32:52	08:41:00	8.13	11
93	08:33:27	08:41:00	7.55	11
94	08:34:28	08:41:00	6.53	11
95	08:35:16	08:41:00	5.73	11
96	08:36:04	08:41:00	4.93	11
97	08:36:59	08:41:00	4.02	11
98	08:38:15	08:41:00	2.75	11
99	08:39:42	08:41:00	1.3	11
100	08:40:46	08:41:00	0.23	11

Based on Table 1, data were obtained for 100 passengers served by 11 bus arrivals during the observation period from 07:00 to 09:00 WIB. Passenger waiting times ranged from 0 to 11.47 minutes. The longest waiting time of 11.47 minutes occurred for the 51st passenger, who arrived at 07:52:32 WIB and was served by the seventh bus, which arrived at 08:04 WIB. Meanwhile, the shortest waiting time of 0 minutes occurred for the 81st passenger, who arrived simultaneously with the arrival of the ninth bus. These results indicate that bus arrival intervals are the dominant factor in determining passenger waiting time.

The model shown in Figure 1 represents a single-channel–single-phase queueing system with one service facility, namely the Trans Padang bus. The simulation was run for 100 passenger entities served by 11 bus arrivals, in accordance with field observation data. This model was used to analyze the variation in passenger waiting time, which ranged from 0 to 11.47 minutes.

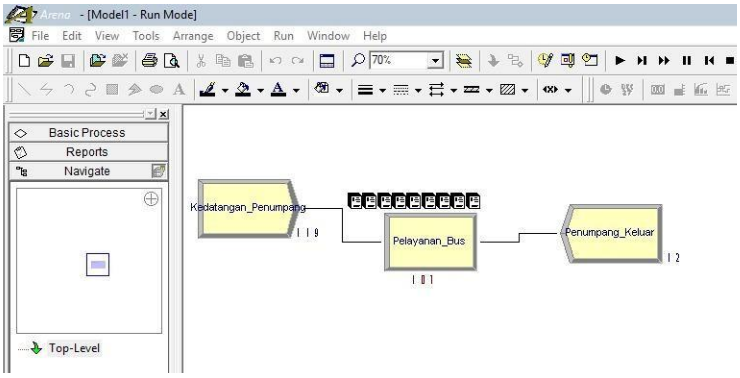


Figure 1. Initial Arena Model

Figure 2 illustrates the Create module, which generates 100 passenger entities during a 120-minute simulation period. Passenger arrivals are non-uniform, with certain time intervals experiencing higher arrival rates, particularly before bus arrivals, which subsequently trigger an increase in waiting time.

12:36:13PM **Category Overview** January 3, 2026

Unnamed Project

Replications: 1 Time Units: Hours

Key Performance Indicators

System	Average
Number Out	12

Figure 2. Passenger Arrival Module (Create)

Figure 3 presents the Process module, which models the passenger waiting activity until the bus arrives. Based on the simulation results, the generated waiting times range from 0 to 11.47 minutes, with the maximum value occurring during the period preceding the arrival of the seventh bus, which has the longest arrival interval.

Unnamed Project

Replications: 1 Time Units: Hours

Entity

Time

	Average	Half Width	Minimum Value	Maximum Value
VA Time				
Entity 1	0.1567	(Insufficient)	0.1567	0.1567
NVA Time				
Entity 1	0.00	(Insufficient)	0.00	0.00
Wait Time				
Entity 1	0.7691	(Insufficient)	0.00	1.5382
Transfer Time				
Entity 1	0.00	(Insufficient)	0.00	0.00
Other Time				
Entity 1	0.00	(Insufficient)	0.00	0.00
Total Time				
Entity 1	0.9258	(Insufficient)	0.1567	1.6948

Figure 3. Passenger Waiting Process Module (Process)

Figure 4 shows the Dispose module, indicating the exit of passengers from the system after receiving service. All 100 passengers successfully exited the system, demonstrating that no permanent congestion or service failure occurred during the simulation period.

Other

Number In	Value
Entity 1	119.00

Number Out	Value
Entity 1	12.0000

WIP	Average	Half Width	Minimum Value	Maximum Value
Entity 1	54.0166	(Insufficient)	0.00	107.00

Figure 4. System Exit Module (Dispose)

Figure 5 displays the configuration of passenger interarrival times, which were adjusted based on actual observational data. During the period from 07:00 to 09:00 WIB, passenger arrivals exhibited fluctuations, with the highest arrival volume occurring between 07:30 and 08:00 WIB. This condition contributed to increased waiting times in several bus cycles.

12:36:13PM **Category Overview** January 3, 2026

Unnamed Project

Replications: 1 Time Units: Hours

Queue

Time

Waiting Time	Average	Half Width	Minimum Value	Maximum Value
Pelayanan_Bus.Queue	0.8390	(Insufficient)	0.00	1.6780

Other

Group #3 Name (String)

Number Waiting	Average	Half Width	Minimum Value	Maximum Value
Pelayanan_Bus.Queue	53.0166	(Insufficient)	0.00	106.00

Figure 5. Passenger Arrival Time Parameters

Figure 6 shows the configuration of Trans Padang bus arrival times, with a total of 11 bus arrivals during the observation period. The bus arrival intervals vary between approximately 7 and 12 minutes, with the longest interval directly correlating with the maximum passenger waiting time of 11.47 minutes.

Resource

Usage

Instantaneous Utilization	Average	Half Width	Minimum Value	Maximum Value
Bus	1.0000	(Insufficient)	0.00	1.0000

Number Busy	Average	Half Width	Minimum Value	Maximum Value
Bus	1.0000	(Insufficient)	0.00	1.0000

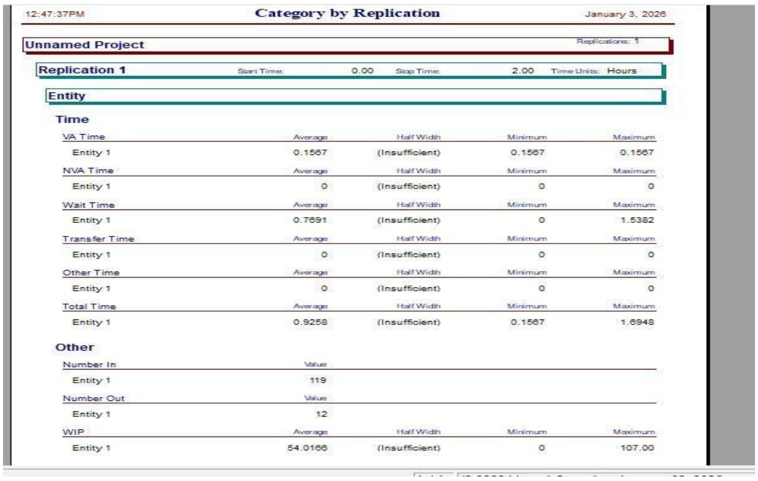
Number Scheduled	Average	Half Width	Minimum Value	Maximum Value
Bus	1.0000	(Insufficient)	1.0000	1.0000

Scheduled Utilization	Value
Bus	1.0000

Total Number Seized	Value
Bus	13.0000

Figure 6. Bus Arrival Time Parameters

Figure 7 illustrates the animation of passenger queue formation at the bus stop. Visually, the longest queue occurs before the arrival of the seventh bus, which is consistent with the numerical data presented in Table 1, where passenger waiting time reaches its maximum value.



12:47:37PM — Category by Replication — January 3, 2026

Unnamed Project — Replications: 1

Replication 1 — Start Time: 0.00 — Stop Time: 2.00 — Time Units: Hours

Entity

Time

VA Time	Average	Half Width	Minimum	Maximum
Entity 1	0.1567	(Insufficient)	0.1567	0.1567

NVA Time	Average	Half Width	Minimum	Maximum
Entity 1	0	(Insufficient)	0	0

Wait Time	Average	Half Width	Minimum	Maximum
Entity 1	0.7691	(Insufficient)	0	1.5382

Transfer Time	Average	Half Width	Minimum	Maximum
Entity 1	0	(Insufficient)	0	0

Other Time	Average	Half Width	Minimum	Maximum
Entity 1	0	(Insufficient)	0	0

Total Time	Average	Half Width	Minimum	Maximum
Entity 1	0.9258	(Insufficient)	0.1567	1.6948

Other

Number In	Value
Entity 1	119

Number Out	Value
Entity 1	12

WIP	Average	Half Width	Minimum	Maximum
Entity 1	54.0166	(Insufficient)	0	107.00

Figure 7. Animation of Passenger Queue Formation

Figure 8 presents the Arena simulation output representing the performance of the queueing system based on 100 passenger entities. The output confirms that variations in passenger waiting time are primarily influenced by bus arrival intervals rather than service capacity, as all passengers are served within a single service phase.

Replication 1 — Start Time: 0.00 — Stop Time: 2.00 — Time Units: Hours

Queue

Time

Waiting Time	Average	Half Width	Minimum	Maximum
Pelayanan_Bus.Queue	0.8390	(Insufficient)	0	1.6780

Other

Number Waiting	Average	Half Width	Minimum	Maximum
Pelayanan_Bus.Queue	53.0166	(Insufficient)	0	106.00

Resource

Usage

Instantaneous Utilization	Average	Half Width	Minimum	Maximum
Bus	1.0000	(Insufficient)	0	1.0000

Number Busy	Average	Half Width	Minimum	Maximum
Bus	1.0000	(Insufficient)	0	1.0000

Number Scheduled	Average	Half Width	Minimum	Maximum
Bus	1.0000	(Insufficient)	1.0000	1.0000

Scheduled Utilization	Value
Bus	1.0000

Total Number Seized	Value
Bus	13.0000

System

Other

Number Out	Value
System	12

Figure 8. Simulation Output Results from Arena

RESULT AND DISCUSSION

The service system at the Trans Padang Basko Air Tawar Bus Stop operates with a single service channel, in which passenger service is provided only when a bus arrives at the stop. During the observation period from 07:00 to 09:00 a.m., passenger arrivals exhibited noticeable variability, with higher arrival density occurring during early and mid-morning peak intervals. This fluctuation in passenger arrival patterns, combined with non-uniform bus arrival intervals, resulted in the formation of passenger queues and variations in waiting time.

Based on empirical observation, a total of 100 passengers were served by 11 Trans Padang bus arrivals during the study period. Passenger waiting times ranged from 0 to 11.47 minutes, indicating substantial variability in service experience among passengers. The longest waiting time occurred for passengers who arrived shortly after the departure of a previous bus and were therefore required to wait for the next bus arrival. In contrast, passengers arriving close to the time of bus arrival experienced minimal or zero waiting time. This pattern highlights the critical role of bus arrival intervals in shaping passenger waiting time dynamics.

The empirical results demonstrate that waiting time is not evenly distributed among passengers, even within the same peak period. Passengers arriving earlier within a bus headway cycle experienced significantly longer waiting times compared to those arriving later. This finding is consistent with fundamental queueing theory principles, which indicate that in systems with batch or periodic service, waiting time increases as the gap between service opportunities widens. In the context of the studied bus stop, longer bus headways directly translated into higher accumulated waiting times for early-arriving passengers.

The Arena-based simulation model was developed to replicate the observed queueing system and evaluate waiting time performance under empirical arrival conditions. Simulation outputs confirmed the observed waiting time range of 0 to 11.47 minutes, indicating strong consistency between the simulated system and real-world observations. The model successfully captured passenger accumulation during longer bus headways and the rapid reduction of queues upon bus arrival, demonstrating the adequacy of the single-channel single-phase queue representation.

Simulation results further revealed that bus arrival variability had a more pronounced impact on waiting time than passenger arrival intensity. Even during periods of relatively high passenger arrival rates, waiting time remained manageable when bus arrivals occurred at shorter and more regular intervals. Conversely, extended and irregular bus headways resulted in sharp increases in passenger waiting time, regardless of moderate passenger demand. This finding suggests that service reliability, as reflected by consistent bus headways, plays a more critical role in determining passenger waiting time than passenger volume alone.

These findings are aligned with previous studies on BRT and bus service systems, which have reported that irregular headways are a primary contributor to excessive waiting times in public transportation. Prior simulation-based studies using Arena have similarly concluded that improving schedule regularity often yields greater reductions in waiting time than increasing vehicle capacity or boarding speed. The results of this study reinforce the importance of headway management as a key operational lever for improving service performance in urban bus systems.

From a practical perspective, the results indicate that the Trans Padang BRT system at the Basko Air Tawar Bus Stop is generally capable of serving passenger demand during peak hours, as all observed passengers were successfully served without permanent queue accumulation. However, the variability in waiting time suggests room for improvement in service scheduling. Reducing extreme headway gaps, particularly during morning peak periods, could significantly decrease maximum waiting times and improve perceived service reliability. Strategies such as dynamic scheduling, improved fleet coordination, or real-time monitoring of bus movements may help achieve more consistent arrival intervals.

Overall, the integration of empirical observation with discrete-event simulation provides a robust framework for evaluating service performance at urban bus stops. By focusing on passenger waiting time as a key performance indicator, this study demonstrates how relatively simple queueing structures, when informed by real data, can generate actionable insights for transportation system improvement. The findings underscore the value of simulation-based analysis in supporting data-driven decision-making for public transportation operations.

CONCLUSION

This study analyzed passenger waiting time at the Trans Padang Basko Air Tawar Bus Stop during the morning peak period using a combination of queueing theory and discrete-event simulation with Arena software. Based on empirical observation and simulation results, the service system at the studied bus stop can be accurately characterized as a single-channel single-phase queue with a first-come-first-served discipline. Passenger arrivals during peak hours were found to be irregular and unevenly distributed, leading to the formation of queues and variation in individual waiting times.

The results indicate that passenger waiting times ranged from 0 to 11.47 minutes, with the longest waiting times experienced by passengers who arrived early within a bus headway cycle. The analysis demonstrates that bus arrival intervals are the dominant factor influencing waiting time variability, rather than passenger arrival volume or service capacity. Even under moderate passenger demand, extended and irregular bus headways significantly increased waiting time and reduced service reliability. Simulation outputs confirmed the empirical findings and validated the adequacy of the developed Arena model in representing real operational conditions.

From an operational perspective, the findings suggest that while the Trans Padang BRT system at the Basko Air Tawar Bus Stop is capable of serving passenger demand during peak hours, improvements in schedule regularity are necessary to enhance service performance. Reducing extreme headway gaps and improving bus arrival consistency can substantially decrease maximum waiting times and improve passenger satisfaction. Future research may extend this study by evaluating alternative scheduling scenarios, incorporating multiple bus stops or routes, and integrating real-time data to support dynamic service optimization.

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