Simulation of Passenger Ridership in Metro Rail Transit (MRT) Line 3 North Avenue Station

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***Abstract*—Passenger ridership simulations are one of the ways to determine the fine details of railway transit from the perspective of commuters. In this study, the researchers simulate the daily average ridership of railway commuters in the MRT-3 North Avenue Station in Quezon City. The objective of the study was to reveal bottlenecks and determine alternatives to improve upon to reduce queueing times. Using a rough model of the station with accurate number of servers, processing, and waiting times, the researchers utilized SIMIO Simulation Software. The result reveals that the majority of the bottleneck comes from manual ticketing lines, train headway, and the process of boarding and leaving the train itself. The study concludes with proposing various alternatives to reduce queueing and processing times in the station.**

Keywords—railway simulation, passenger ridership, SIMIO simulation, commuting, Metro Rail Transit

I. Introduction

Commuting is a big aspect in the lives of many people living in metropolitan areas. This goes doubly so for Filipinos whose lives are massively hindered by traffic congestions and unsatisfactory commuting that leads to the loss of productivity [1]. Several factors contribute to the overall satisfaction of commuters when it comes to public transportation such as mode of choice, travel conditions, and the length of the commute itself [2]. Walking distance, transfers, and queueing times have also been observed to be factors in commuter satisfaction [3]. In the Philippines, 70% of the commuters rely on the public transportation system but are generally unsatisfied with it overall [4].

Metro Manila has one of the worst traffic and transportation problem in the world [5]. Commuting in the capital region takes many forms, each having their own way of utilizing public spaces as their own transportation terminals. In these terminals, people spend a large amount of their time queueing and waiting in line just to get where they want. Buses and jeepney rides entail having to wait hours for a ride, only to stand in a cramped public vehicle, enduring hours of traffic on the way to your destination. A trip on the Metro Rail Transit (MRT) sometimes have worse queues than other means of commuting complemented by many delays due to trains breaking down. It is found that in MRT, the waiting times contribute significantly to the stress that people experience in commuting [6]. Another study finds that factors such as travel fare, waiting time, in-vehicle travel time, and perceived conditions like risk and air quality largely predict commuter satisfaction when using MRT [7]. Fallaria et al. (2019) finds that the commuting culture is mainly perpetrated by the lack of PUV's, inefficient public transport systems, and the overall policies on road and traffic management [8]. Factors such as unfavorable environments and poor ergonomic conditions also inhibit commuters from attaining better experiences.

Commuters have expressed their desires for better commuting experiences such as time efficiency, amendments to transport and traffic laws (and a stricter enforcement), more organized public transport system, and proper commuting etiquette. Various approaches have also been proposed for a better public transport system in Metro Manila such as a single, streamlined payment system, interconnection of transport terminals and culture hubs, proper wayfinding signs and signboards, cooperation with all transport groups, higher quantity and efficiency of public transport vehicles, and an efficient waiting time for every ride, among other things [9]. For the MRT as a mode of transportation, commuters deem that interchangeability between transfer terminals of buses and trains are a necessity to improve the situation of commuting in Manila. They also note that the improvement of amenities and quality of service (specifically an increase in non-failure of train operations) are a major desire for MRT commuters [10].

The majority of proposals in improving the situation with public transport involve a massive overhaul in the way existing infrastructure is utilized. For commuting satisfaction and experience, it is a combination of improving the transport system and enriching the terminal spaces as a form of community hub. In light of these solutions, this paper takes on the approach of focusing on improving commuter satisfaction by tackling on the queueing and waiting times that people have spent an inordinate time with due to the inefficiency of the transport system. To this end, the purpose of this study is to present a simulation of passenger ridership in one of the stations of the MRT3—the North Avenue Station in Quezon City. The study's main objectives are to identify factors that affect commuting and queueing times that are major aspects of commuter satisfaction, to simulate the patterns of commuters and transport terminal managers, and to evaluate and improve the queueing times and the quality of transport terminals.

II. RELATED WORKS

Mijares et al. (2016) developed a passenger satisfaction model that incorporates the waiting time, in-vehicle travel time, fare, air quality, risk perception, and adaptation using several data collection methods. The estimation of the passenger satisfaction model using ordered logit showed that actual conditions (fare, waiting time, in-vehicle travel time) and perceived conditions (risk and air quality) predict passenger satisfaction with MRT-3. Mental adaptation tends to increase passenger satisfaction, which can be both beneficial and detrimental. On a positive note, it helps reduce the negative effects of an unfavorable commute. However, it may lower expectations and keep commuters complacent, thus they do not demand better services from the operator, and it may also expose them to actual physiological harm. The results of the preliminary analysis showed that eliminating waiting time due to passenger overload delay would double passenger satisfaction levels, which suggests that increasing the capacity of MRT-3would be an effective countermeasure [6].

Rith et al. (2020) analyzed that the improvement of residential areas with low accessibility to crucial destinations can improve traffic flow and reduce energy consumption and CO2 emissions. Their study evaluated the multi-criteria accessibility measure of critical destinations at the traffic analysis zone level (TAZ) using the gravity method based on the distance. Their findings suggest that improvement on areas like hospitals, schools, and markets to low accessibility TAZs can drastically improve social development and discourage individual vehicle dependency. They conclude that areas with high presence of culture community hubs, residential hubs, and metro and light rail density have the highest TAZs, recommending that more rail lines can improve mixed-land use for sustainable urbanism and transport mobility [11].

Prasetyo and Tabares (2020) developed simulation methods for predicting monthly inbound passengers using Monte Carlo Simulations. Their goal was accurately determining the passenger flow in MRT-3 and use Monte Carlo Simulations to generate random numbers from data distributions to produce reasonable forecasts. Their simulation results yield viable data regarding passenger capacity and flow within acceptable margins of error. Their study was stated to have limitations regarding the interval of passenger flow and their performance metric but is still a viable resource for reforming policies regarding train capacities and allocations [12].

Africa et. al (2017) studies the usage of RFID tag systems to implement an automated transportation system and lessen passenger congestion. They created the interface for the RFID system and simulated its usage in everyday commute on the MRT-3. Their RFID system accepts manual user inputs and inputs from the tag reader systems and has been made with the guidelines and contemporary situation of the MRT-3 in mind. They also formulated a scheduling system and algorithm when accounting for the proposed RFID system to help reduce passenger congestion. The system was evaluated to have 90% reliability, provide insight on the number of trains and commuting flow, and provide experimental scenarios for different inputs according to different stations [13].

Estember et. al (2020) presents an operational efficiency model for MRT by assessing factors, utilizing analytics tests, and various industrial engineering analyses. Their study focuses on the performance of operations in the entirety of railway transit in the Philippines to reduce queueing times. They assessed the factors affecting queueing times with statistical tests like ANOVA and Turkey's Post Hoc Test and industrial engineering factors such as motion and time, forecasts of passengers, and queueing analyses. Various simulated experimental scenarios were conducted regarding additional trains, number of servers, train schedules and speed, and fixed times were conducted to model a more efficient alternative in the railway transit system. They conclude with having more cars on trains, more servers, higher train speed, and fixed dwell times as the most effective combination of alternatives for railway transit [14].

III. METHODOLOGY

A. Datasets and Simulation Software

Data regarding MRT-3's tabulated passenger ridership from September 2019 was gathered from the Department of Transportation website [15]. The researchers utilized this specific timeframe as opposed to more recent ones due to the lack of availability and the preference for datasets formatted in terms of entering and exiting passengers. Daily averages were recorded hour by hour. Table 1 presents the daily September 2019 averages for North Avenue Station.

TABLE I. NORTH AVENUE STATION DAILY AVERAGE PASSENGERS

Time	**North Avenue Station**	
	Entrance	***Exit***
03:00 - 03:59		
04:00 - 04:59	478	0
05:00 - 05:59	2,953	1
06:00 - 06:59	4,744	420
07:00 - 07:59	4,695	840
08:00 - 08:59	4,488	975
09:00 - 09:59	3,847	1,029
10:00 - 10:59	3,438	1,091
11:00 - 11:59	3,472	1,181
12:00 - 12:59	3,381	1,364
13:00 - 13:59	2,890	1,358
14:00 - 14:59	2,361	1,531
15:00 - 15:59	2,064	1,839
16:00 - 16:59	2,159	2,281
17:00 - 17:59	2,477	2,859
18:00 - 18:59	2,538	3,520
19:00 - 19:59	2,477	3,339
20:00 - 20:59	2,068	2,643
21:00 - 21:59	333	1,785
22:00 - 22:59	0	1,241
23:00 - 23:59	0	30
00:00 - 00:59	0	0
01:00 - 01:59		
02:00 - 02:59		
Average	50,863	29,329

Boarding process time queues and usages were gathered from De Los Reyes et al. (2020) previous study on the North Avenue Station's boarding processes [16]. Based on their results, the processes adopted various time usages for calibrating paths, sources, servers, and sinks. Table 2 summarizes each boarding process and their time usages applied for this study. The study will utilize the free version of the SIMIO simulation software with limited entities.

TABLE II. BOARDING PROCESS ALLOCATION

Boarding Process	Time Allocated (s)
Security Checks	1.21
TVM Usage	43
BOM Usage	20
Gate Passing	1.4
Boarding Time	240
Train Headway	420

B. *Passenger Simulation Model*

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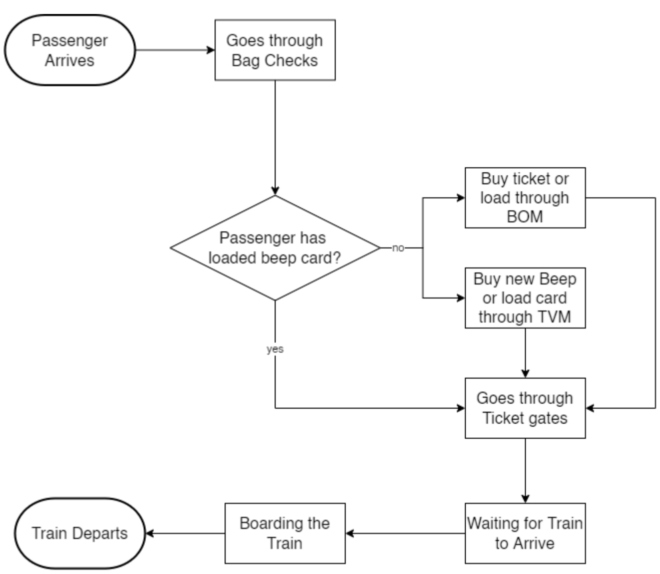

Fig. 1. Simulation Process

Sources

The passenger sources in the simulation are the general passenger entry and exit ways to and from the station that includes entrance stairways and elevators from both sides. It exists as a single source object in the model. These are not as intricately modeled and does not depict the realistic views of the station but are accurate with the volume of the passengers.

Sinks

The sinks in the simulation were essentially the moment the passenger is able to ride the trains. This is preceded by the queuing process and the waiting of the passenger before being able to ride. It exists as a single sink object in the model. It is not realistically detailed to model trains and does not depict the realistic view but are accurate with the time and pathing of the boarding process and reflects the volume of passengers.

Servers

The servers reflect the standard boarding process and the rules set out by the Department of Transportation regarding railway transportation systems in the Philippines. The Booking Office Machines and the Ticket Vending Machines are part of the North Avenue Station as the primary ways of purchasing journey tickets and loading Beep cards. The number of these machines were not accounted for due to a lack of data regarding the current systems and the limitations of entities in the simulation software. The security check is a regulation present in every single station in the MRT-3 Line. The gates are standard in every existing railway transportation system in the Philippines for accepting journey tickets. The servers were simplified and do not reflect the real positioning present in the station but are accurate with the time usages and queues regarding each phase of the boarding process.

Path

The paths of the passengers as they go through each boarding process served as the connections in the simulation. Each connection takes into account the volume of passengers and the adjustments for time. The standard path used for this simulation is described as well in Figure 1.

IV. RESULTS

A. *Model View*

Figure 2 shows a 2D model that doesn't reflect geographical dimensions but is accurate in simulation process and allocation times. This model depicts the passenger flow inside of the North Avenue station which involves the objects named security servers, ticketing servers, gate servers, boardQueue, and Onboard.

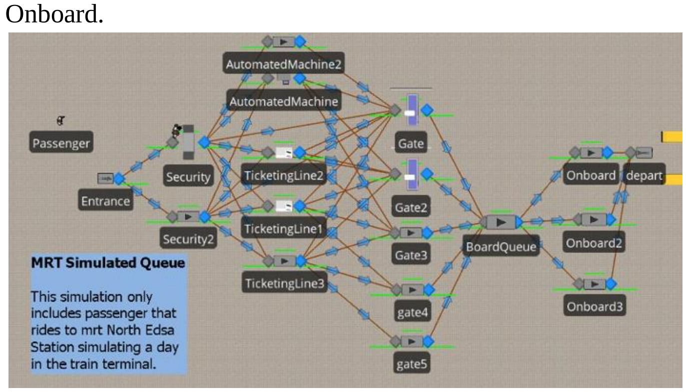

Fig. 2. Model View of the Simulartion

- **Security Server** performs luggage check and security check to passengers to prevent of carrying dangerous substance and weapons inside the public terminal.
- **Ticketing Server** performs the issuance of tickets to passenger by collecting fare fees in either BOM or TVM.
- **Gate Server** is a queueing process to get inside the boarding platform in which the passenger taps their Beep card or a single journey ticket.
- **Board Queue** is the line inside the boarding platforms and the process of waiting for the train due to headway
- **Onboard** is the entire process of waiting for passengers to dismount, getting inside, and waiting for the train to start

B. *Simulation Results*

Figures 3-5 shows a graph of the total number passengers simulated in the system of the North Avenue Station. The peak crowdedness of passengers starts from 6am to 10am with maintaining average of 1,500 passengers in the system. This shows that there are lot of passengers on average within the station which reveals that somewhere in the system, there are bottlenecks and overly used servers.

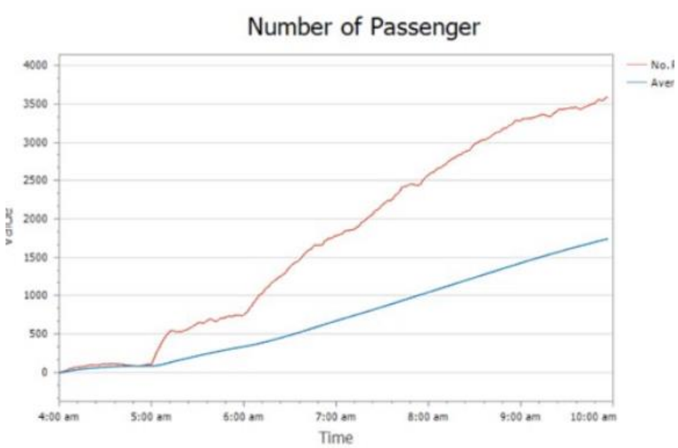

Fig. 3. 4am to 10am passenger count

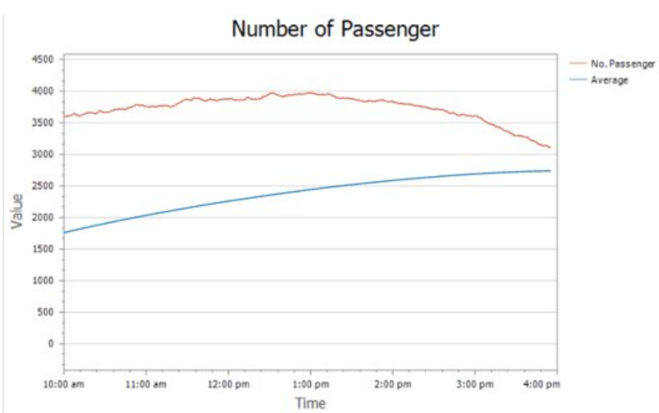

Fig. 4. 10am to 4pm passenger count

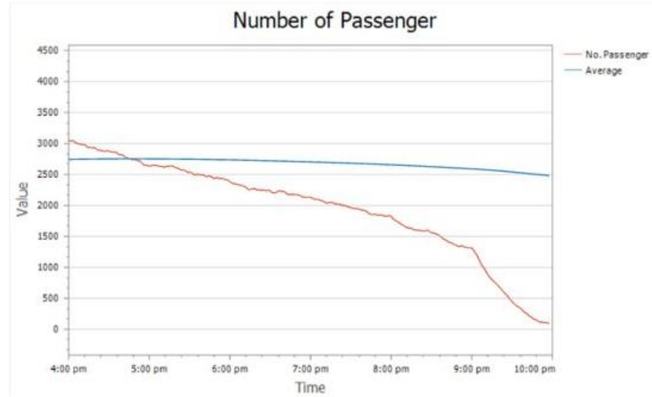

Fig. 5. 4am to 10am passenger count

Table 3 shows the average waiting time results of passengers and includes the processing time in each station such as the security, BOM, TVM, ticketing gates and boarding. The average waiting time of passengers within 1 day simulation of MRT results to 42 minutes with average process time of servers such as security with holding time of 3.96 seconds, BOM with 43.08 seconds holding time and 4.2 minutesprocess time, TVM with 38.34 second process and 20.16 second holding time, Gate servers with 1.8 seconds process time and 2.448 seconds holding time, boarding with 3.99 mins holding time, and train headway being 6.978 minutes long.

TABLE III. BOARDING PROCESS RESULTS

Boarding Process	Scheduled Utilization	Time Processing	Time Starved	Holding Times
Security Checks	78.3551 %	29.7 s	5.76 s	3.96 s
TVM Usage	40.2027 %	38.34 s	56.7 s	20.16 s
BOM Usage	49.5365 %	4.202 m	32.64 s	43.08 s
Gate Passing	22.0512 %	1.8 s	6.48 s	2.448 s
Boarding Time	18.8604 %	N/A	N/A	3.99 m
Train Headway	27.463 %	N/A	N/A	6.978 m

C. *Bottlenecks*

Manual Ticketing Lines produce inter-process bottlenecks

The process time of a one ticketing lines is equivalent to ~4 mins this process with almost equal time starved and holding means that the manual ticketing lines are experience relatively minimal queue but is burdened with large processing in the system.

Train headways need to be reduced

The train headways in the boardQueue server have ~7 mins waiting time before the arrival of train which adds to the amount of overall waiting time of passengers. This needs to be reduced in order to lessen number of passengers in the system.

Unloading and loading of trains need to be faster

There is a need of more trains in the system for frequent and more streamline process of passenger in the system.

V. CONCLUSIONS

The simulation of the North Avenue station shows a lacking number of personnel during peak crowded hours. It is shown that the peak hours create a massive number of passengers which the system cannot handle thus increases the waiting time of passengers. The average queueing time of passengers needs improvements. This involves the queue and process time of all stations, the delay created by security, ticketing, and boarding queues. Train headways create a delay of passenger departing in the system thus increasing the overall waiting time of passengers. The researchers recommend creating a timetable of personnel which helps during the peak hours in releasing tickets or loading beep cards and performing security checks of passengers, possibly adding another station platform in which the passenger may aboard to lessen congestion in the queue, and adding more trains in the system to lessen the headway delay making more frequent departure.

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