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PERFORMANCE ANALYSIS OF THE LIGHT RAIL TRANSIT'S (LRT's) TICKET-BASED SYSTEM IN STATION X USING SIMULATION SOFTWARE

MA. TEODORA E. GUTIERREZ ASST. PROFESSOR INDUSTRIAL ENGINEERING DEPARTMENT TECHNOLOGICAL INSTITUTE OF THE PHILIPPINES PHILIPPINES

ABSTRACT

The study evaluated the present performance of the light rail transit's (LRT's) fare collection ticket-based system at Station X. The goal is to measure the performance of the current system in terms of the average time that passengers spent in operation that is, procuring the ticket from vending machines and time spent in waiting lines. Total number of passengers in waiting lines was also identified as well as the number of passengers already exited from the system given the thirty (30) minutes observed time. Application of Queue theory in the field of transportation was used as model framework and Promodel simulation software was applied to calculate the present and proposed system.

KEYWORDS

Rail transit, Simulation, Queue Theory.

INTRODUCTION

The presence of rail transit in the developing countries is imperative because it reduces the travel time from one destination to another that helps both individual commuters and businesses alike. The Light Rail Transit Authority (LRTA) is a wholly owned government corporation which is recognized to provide reliable, efficient, and environment-friendly mass rail services to all residents in Metro Manila. In that case, evaluating their systems performance is critical.

The objective of the study is to conduct performance analysis of the fare collection ticket-based systems of LRTA in station X. Moreover, the intention of the study is to improve the systems performance in terms of identifying the optimum number of ticketing machines.

LITERATURE REVIEW

Queuing theory is used to mathematically measure the waiting time of an entity. An entity could be a products, customers, materials and machines. Also, this theory permits to calculate other performance indicators of a system like average time spent, average number of customers in a system, etc. On the other hand, simulation is one of a tool to understand queuing models because of its capability to measure a system performance.

Researches in the field of Queuing theory were applied mostly in transportation industry. For instance, Soh, et al (2009), uses simulation to propose a new traffic model for multilane multiple intersection based on queuing theory. Moreover, Toledo, et al (2010) presented a transit simulation model in order to support evaluation of operations, planning and control where travel time is the basis of performance.

METHODOLOGY

The Light Rail Transit Authority's fare collection system is a ticket based system, which uses two types of tickets: a single journey (one way ticket) whose cost is dependent on the destination and a stored value (multiple –use) which cost one hundred pesos (P100). The study focused on a single journey ticket which can be procured from vending machines.

The evaluation of the current performance was observed between 1:00pm to 1:30 pm at station X. Since that the station is considered as the central place and connecting place to the other rail transit, the period of time that the observation takes place is considered as peak hour. The data collected was stated in table 1. ProModel simulation software was used to measure its performance.

PEAK HOUR 1:00 PM – 1:30 PM	2EAK HOUR 1:00 PM – 1:30 PM									
	Machine 1	Machine 2	Machine 3	TOTAL	Average per Machine					
A. Number of passengers arrive	111	79	139	329	109.67					
B. Number of Minutes observed	30 minutes	30 minutes	30 minutes							
C. Total service time of all passengers arrive in 30 minutes	63.70	47.33	58.90	169.93	56.64					
A.1 Arrival Rate A.1.1 Passengers per Minute (호)	3.70	2.63	4.63	10.97	3.66					
A.1.2 Minute per passenger (A)	0.27	0.38	0.22	.091	0.29					
B.1 Service rate										
B.1.1. Passenger per minute (^C)	1.74	1.67	.87	4.29	1.43					
B.1.2 Minute per passenger $\begin{pmatrix} A \\ \end{pmatrix}$	057	0.60	1.14	2.32	0.77					

TABLE 1 – ARRIVAL FREQUENCY AND SERVICE TIME OF ALL PASSENGERS

In the above table, three machines are working during actual observation, although there are seven machines available, the other four machines are under repair. The frequency of passengers' arrival per ticketing machine within the 30 minutes observation ranges from 79 passengers to 139 passengers, which forms an average of approximately 110 passengers. On the other hand, the service time for all passengers which arrived in one ticketing machine within the 30 minutes observation ranges from 47.30 minutes to 63.70 minutes, which constitute an average service time of 56.64 minutes.

The actual observation of passenger's arrival rate was done from 1:00 pm to 1:30 pm, but the total time consumed in directly observing the system of LRTA station X is 4.5 hours, because all passengers arrived from 1:00 pm to 1:30pm were monitored up to the time they exit the system. The system defined here is where passengers procured their ticket through vending machines.

Given the observed data, in order to measure the performance of the Light Rail Transit's (LRT) ticketing machine, the study will use Promodel Simulation software. First step in promodel simulation is to build Location, where it involves identifying the fixed locations of the waiting lines and the ticketing machines in which passengers are routed for processing their transactions. The structure of the system is that each machine has its own waiting line (See figure 1).

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Second step in Promodel simulation is to identify Entity, it refers to the items being processed in the system (Benson, 1997). In this case, the entity is the passenger.

Third step is to build Arrival rate. The total number of passengers arrived within the thirty (30) minutes observation is 329 passengers. Hence, arrival rate is 10.97 passengers per minute or 0.091 minute per passenger. The arrival rate is assumed to have exponential distribution in which it characterizes the independencies of arrival. Therefore, the arrival rate encoded in the Promodel has a syntax of E (0.91) MIN.

The last step is to build Processing. The highlight of this step is to identify the service rate. In this study, the service rate is assumed to have uniform distribution with an average of 1.4 passengers per minute per machine or equivalent to 0.77 minute per passenger per machine. It is interesting to note that the service rate becomes longer when the arrival rate increases as implied in the above table where machine 3 has the longest service rate. The service rate ranges from 0.57 minute per passenger to 1.14 minute per passenger. Therefore the service rate encoded in the Promodel has syntax of U (0.77, 0.37) MIN, which means that the service rate has an average of 0.77 minute per passenger per machine and variance of 0.37 minute per passenger per machine.

RESULTS

Below are the results of the simulation after the abovementioned procedures.



FIG. 2 – PROMODEL OUTPUT REPORTS ON LOCATIONS WITH THREE MACHINES

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	General Report (Norn	nal Run - Avg. Reps)											
G	ieneral Locations	Location States Multi Location	i States Single	Entity Activity	Entity States								
				lrt_cubao_fin	al.MOD (Normal Run	Avg. Reps)							
	Name	Scheduled Time (HR)	Capaci ty	Total Entries	Avg Time Per Entry (MIN)	Avg Contents	Maximum Contents	Current Contents	% Utilization				
	waiting lines	0.50	9999	334.80	9.94	110.87	218.00	216.80	0.01				
	machines.1	0.50	1.00	40.20	0.75	1.00	1.00	1.00	100.00				
	machines.2	0.50	1.00	38.80	0.77	1.00	1.00	1.00	99.75				
	machines.3	0.50	1.00	39.00	0.76	0.99	1.00	1.00	99.26				
ĺ	machines	1.50	3.00	118.00	0.76	1.00	3.00	3.00	99.67				

To validate the built model in relation to the actual data collected, the simulation run hours is set to thirty (30) minutes. Actual observation reflected that a total of 329 passengers arrived in the system within the time period of thirty (30 minutes), and in the simulation output report total entries is 334.80 passengers. Moreover, in figure 3, simulation output revealed that the average time the passengers is in operation or procuring the ticket is 0.77 minutes. Hence, there's a little discrepancy if not none in terms of the data collected and the simulation output report, thus, the simulation model validates the actual fare collection's ticket based system of LRTA station X.

The current performance of the ticketing system of LRTA's station X after thirty (30) minutes of observation time during peak hours an average number of 110.87 passengers that are still waiting in lines. Each machine had already served an average of 40 passengers.

	FIG. 3 – PROMODEL OUTPUT REPORTS ON ENTITY ACTIVITY											
👶 li	t_cubao_final.rdb - Output Viewer 3DR											
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	III General Report (Normal Run - Avg. Reps)											
G	eneral Locations	Location States Mu	Iti Location States Single	Entity Activity Entity States								
	lrt_cubao_final.MOD (Normal Run - Avg. Reps)											
	Nomo	Total	Current Qty In	Avg Time In	Avg Time In Move	Avg Time Waiting	Avg Time In	Avg Time Blocked				
	Name	Exits	System	System (MIN)	Logic (MIN)	(MIN)	Operation (MIN)	- (MIN)				
	Commuters	115.00	219.80	10.35	0.00	0.00	0.77	9.58				

Each passenger spent 10.35 minutes in procuring a ticket. Comprises of 0.77 minutes spent in procuring the ticket, and 9.58 minutes were spent in the waiting lines. Moreover, 115 passengers have already been served or exited in the system and 219.80 passengers are still waiting in line.

	FIG. 4	- ENTITY STATE								
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	lrt_cubao_final.MC)D (Normal F	lun - Avg. Reps)							
Name	% In Move Logic	% Waiting	% In Operation	% Blocked						
Commuters	0.00	0.00	7.46	92.54						

The passenger's state in the present system with only three (3) *available* vending machines revealed that each passenger spent 92.54% of the total time waiting in line and only 7.46% of the time spent in procuring a ticket.

The present performance of the system revealed poor customer service because it depicts the purpose of the passengers to arrive at their destination with lesser time for reason of them spending almost ten (10) minutes in queue or waiting lines.

Hence, another scenario could be evaluated by having more available ticketing machines. During the actual observation, four ticketing machines are under repair. Measuring the systems performance when all ticket vending machines were used, reveals the following output:

FIG. 5 – PROMODEL OUTPUT REPORTS ON LOCATIONS WITH SEVEN MACHINE

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Name	Schedule d Time (Capaci ty	Total Entries	Avg Er	Time Per try (MIN)	Avg Contents	Maximum Contents	Current Contents	% Utilization
waiting lines	0.50	9999	331.50		2.54	28.57	61.40	58.90	0.00
machines.1	0.50	1.00	38.60		0.78	1.00	1.00	1.00	99.56
machines.2	0.50	1.00	39.40		0.76	1.00	1.00	1.00	99.60
machines.3	0.50	1.00	39.80		0.75	0.99	1.00	1.00	99.04
machines.4	0.50	1.00	38.60		0.77	0.99	1.00	1.00	98.68
machines.5	0.50	1.00	39.30		0.75	0.99	1.00	1.00	98.70
machines.6	0.50	1.00	39.20		0.75	0.98	1.00	1.00	97.56
machines.7	0.50	1.00	37.70		0.78	0.98	1.00	1.00	97.59
machines	3.50	7.00	272.60		0.76	0.99	7.00	7.00	98.68

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If seven (7) vending machines were used, the average number of passengers waiting in line is 28.57, which resulted to a possible reduction of approximately 200 passengers as compared to the previously observed scenario. Moreover, there is a huge reduction in terms of number of passengers in queue evident by only one passenger left waiting in line in each machine.

	FIG. 6 – PROMODEL OUTPUT REPORTS ON ENTITY ACTIVITY WITH SEVEN MACHINES												
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G	ieneral Locations Lo	cation States Mult	i Location States Single	Entity Activity Entity State	25								
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	Name	Total	Current Qty In	Avg Time In	Avg Time In Move	Avg Time Waiting	Avg Time In	Avg Time Blocked					
		Exits	System	System (MIN)	Logic (MIN)	(MIN)	Operation ((MIN)					
	Commuters	265.60	65.90	3.24	0.00	0.00	0.77	2.47					

If there are seven machines working, the passenger will spend 3.24 minutes in the system which *comprises* of both operation time and waiting time. The waiting time is 2.47 minutes as compared to the previous scenario of 9.58 Minutes. Moreover, the total passengers exited in the system after thirty (30) minutes is already 265.60 as compared to the previous scenario which is 115 passengers.

CONCLUSION

The performance of the actual observed system which was also termed as present system with three (3) vending machines reflects poor customer service since the time spent by each passenger is 10.3 minutes, which contradicts the purpose of Light Rail Transit (LRT), known to provide efficient and fast service. On the other hand, the proposed scenario, that is the usage of all seven (7) ticket vending machines, resulted to 3.24 minutes passenger's time spent in the

system. This is much lower when compared to the present scenario or the observed system which resulted to a reduction of 69% of the total time spent in the system. Also, the total number of remaining passengers after thirty (30) minutes is 65.90 passengers, a difference of 153.90 passengers or a 70% reduction of passengers. Nonetheless, further study in the analysis of increasing the number of vending machines and its effect to the system performance measure is recommended.

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