A discrete event Simulation model for Pasig ferry stations

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***Abstract*—Simulating the operation of one system or process by modeling the operation of another is known as simulation. Models must be used in simulations; the model reflects the essential traits or behaviors of the chosen system or process, whilst the simulation depicts the model's development over time. The research is about the discrete event for Pasig ferry stations simulation model. The data that gathered by the researchers given by the Metropolitan Manila Development Authority (MMDA) are go through the processed cleansing. The researchers used arena simulation software to create the model of the ridership of Pasig Ferry. The researchers validated the data results of the simulation. It shows that the results of the model of Pasig Ferry that the researchers created are accurate and justifiable to the raw data gathered given by the MMDA.**

***Index Terms*—arena simulator software, cleansing, ridership**

I. Introduction

Going around Metro Manila is now easy because there are a lot of available transportation options. Many people need that transportation for many reasons like going to work or school, visiting family or friends, going to tourist spots, etc. These transport options are jeepneys, taxi, trains (LRT, MRT, PNR), ride-hailing applications, and many more. Did you know that ferry is also available for transport options and it is offering a ride to those traveling in Manila, Mandaluyong, Makati, and Pasig City. The Metro Manila Development Authority or MMDA is the one who brought back the service or operation of the Pasig River Ferry, and this is one of their solutions to lessen the traffic in Metro Manila. The Ferry service travel over 26 kilometers and have 11 terminals/stations, 5 of them are in Manila, 1 in Mandaluyong, 2 in Makati, and 3 in Pasig. As of now, the fare on Pasig River Ferry is Free because we are still in the pandemic.

This study is about creating a simulation model of the Pasig River Ferry operation in February. The data needed for simulation are the total passengers for February at each station, the time of operating each station also, and the travel time per station. The software used in this study is Arena Simulation.

II. Experiment

A. Data Gathering

To determine how active the passengers are in each station of Pasig Ferry, the researchers requested a data at the freedom of information website to have the hourly passenger for Pasig ferry for the year 2022, after some time the researcher's data have been picked at Makati City last April year 2022.

The figure below is the example of the data that the researchers have gathered:

MONTH: JANUARY 2022	3–8	10–15	17–21	24–29	31	
TIME						
7:10	69	26	56	75	17	243
7:30	52	19	61	69	17	201
8:30	23	23	39	43	9	137
9:50	31	5	30	35	9	110
11:00	12	1	4	8	3	28
12:30	10	2	7	9	3	31
2:10	11	1	0	4	2	18
4:00	11	0	5	2	1	19
TOTAL	219	77	202	245	61	804

MONTH: FEBRUARY 2022	1–5	7–12	14–19	21–26	28	
TIME	WEEK 1	WEEK 2	WEEK 3	WEEK 4	WEEK 5	TOTAL
7:10	69	88	82	84	27	350
7:30	76	75	77	66	22	316
8:30	53	47	53	82	12	247
9:50	35	51	57	74	10	227
10:20	13	19	8	6		46
12:55	8	11	5	12	3	39
13:53	2	11	0	4	2	19
14:49	10	17	0	5	3	35
15:30	0	0	0			0
TOTAL	266	319	282	333	79	1,279

MONTH: MARCH 2022	1–5	7–12	14–19	20–26	28–31	
TIME	WEEK 1	WEEK 2	WEEK 3	WEEK 4	WEEK 5	TOTAL
7:10	77	108	87	150	89	511
7:30	65	86	81	99	58	389
8:30	48	76	68	48	55	295
9:50	54	47	75	57	52	285
10:20	0	3	1	3	3	10
12:55	2	4	0	0	0	6
13:53	1	6	1	3	0	11
14:49	2	5	7	2	0	16
15:30	0	0		0	0	0
TOTAL	249	335	320	362	257	1,523

Fig. 1. Example of raw data of Ridership of Pasig Ferry.

A total of ten (10) stations from, Pinagbuhatan, San Joaquin, Guadalupe, Hulo, Valenzuela, Lambingan, Sta. Ana, PUP, Lawton, and Escolta have their weekly ridership data and collected by the researchers.

B. Data Cleaning

Since the data gathered for January and March are little to nothing. The researcher's following procedure is to choose a month to get the most data out of the raw data collected. After cleaning the data, the researchers also added other vital information such as the Operating Hours per each station, the Travel Time for each station going to the next station, and the number of active ferry ships that are picking up passengers. As shown in the figure below:

	HOURLY AVERAGE PASSENGER IN FERBRUARY 2022				
	Pinagbuhatan	San Joaquin	Guadalupe	Hulo	Valenzuela
	6	3	8	2	2
Total passengers for month	1279	638	2418	708	505
	Lambingan	Sta. Ana	PUP	Lawton	Escolta
	1	1	1	2	9
Total passengers for month	147	211	146	398	2449

	OPERATING HOURS				
	Pinagbuhatan	San Joaquin	Guadalupe	Hulo	Valenzuela
	7:10 - 15:30	7:15 - 16:10	7:30 - 18:30	7:35 - 18:35	7:00 - 17:30
decimal form	7.17 - 15.5	7.25 - 16.17	7.5 - 18.5	7.58 - 18.58	7 - 17.5
total hours	8.33	8.92	11	11	10.5
	Lambingan	Sta. Ana	PUP	Lawton	Escolta
	7:40 - 18:00	7:00 - 17:30	8:15 - 17:30	8:35 - 17:35	8:30 - 17:30
decimal form	7.67 - 18	7 - 17.5	8.25 - 17.5	8.58 - 17.58	8.5 - 17.5
total hours	10.33	10.5	9.25	9	9

Fig. 2. Summary of the Data for the month of February 2022.

Note: 24 Days only in a month of February. Sundays are not included.

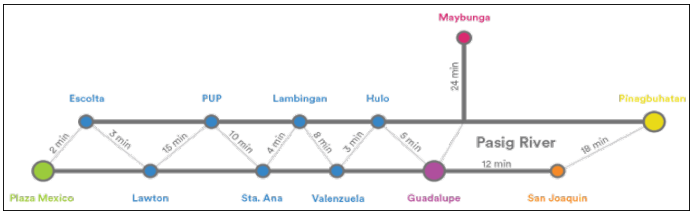

Fig. 3. Travel Time for each station.

C. Probability Distribution

The next step is to get the probability distribution of the data in each station for February. A probability distribution is a statistical function that describes all the possible values and likelihoods that a random variable can take within a given range [1].

Since the stated month has the most data active for the Pasig Ferry, the gathered numerical statistics will be beneficial for the creation of the modeling.

Time (y)	Total Passenger	p(y)	y*p(y)	[(y-mean) ^2] * p(y)
7	666	0.52	3.65	0.62
8	247	0.19	1.54	0.00
9	227	0.18	1.60	0.15
10	46	0.04	0.36	0.13
11	0	0.00	0.00	0.00
12	39	0.03	0.37	0.47
13	19	0.01	0.19	0.36
14	35	0.03	0.38	0.96
15	0	0.00	0.00	0.00
TOTAL	1279	1	8.09	2.68
AVERAGE	142.11			
AVERAGE PASSENGER \HR	6			
AVERAGE PASSENGER \MINS	10			
STANDARD DEVIATION	1.64			

TABLE I
PROBABILITY DISTRIBUTION OF PASIG RIVER FERRY RIDERSHIP IN PINAGBUHATAN STATION (FEBRUARY 2022)

Time (y)	Total Passenger	p(y)	y*p(y)	[(y-mean) ^2] * p(y)
7	200	0.31	2.19	2.99
8	44	0.07	0.55	0.30
9	55	0.09	1.78	0.10
10	58	0.09	0.91	0.00
11	98	0.15	1.69	0.13
12	32	0.05	0.60	0.18
13	61	0.10	1.24	0.81
14	30	0.05	0.66	0.72
15	27	0.04	0.63	1.02
16	33	0.05	0.83	1.81
TOTAL	638	1.00	10.09	8.06
AVERAGE	63.80			
AVERAGE PASSENGER \HR	3			
AVERAGE PASSENGER \MINS	20			
STANDARD DEVIATION	2.84			

TABLE II
PROBABILITY DISTRIBUTION OF PASIG RIVER FERRY RIDERSHIP IN SAN JOAQUIN STATION (FEBRUARY 2022)

III. Modelling and Simulation with Arena

In this section, the researchers used Arena Simulation Software to develop a simulation model that will represent the whole flow of Pasig Ferry Station

Arena is a simulation and automation software developed by Rockwell Automation Company [5]. Using the SIMAN processor and its simulation language is widely used to simulate a manufacturing or service process to analyze the current performance as well as possible alternative working modes.

By simulating a process model, the user can adjust the resource allocation and then observe the system behavior. The process blocks that stand for elements like "create process block," "dispose of the process block," "flow control process block," "information import and export process block," etc. were easy to organize. It is also simple to connect them with lines to construct a model. A process block could be

a straightforward function or a submodel where a thorough subprocess would be constructed similarly to a subprogram. Calendar schedules and time patterns regulate the formation of entities and the accessibility of resources, allowing for the accurate definition of a complicated timetable that includes exceptions.

Below is the example model of the Pasig Ferry:

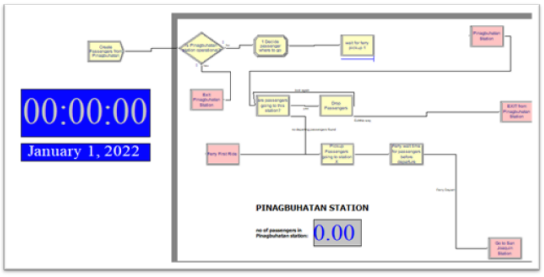

Fig. 4. Arena model for Pinagbuhatan Station

The researcher's model is a collection of Create, Hold, Decide, PickUp, DropOff, and dispose processes that will display how the Pasig Ferry. Each process contains all the parameters that are connected to the data gathered as shown earlier.

For example, the Decide "is Pinagbuhatan Station Operational?" process, is built with an expression relating to the hours and days of the operation for the assigned station, therefore, the passengers cannot just enter the station when it is closed, connected to the time and date of the simulation.

The following parts are the explanation of how each component of the model is connected to the gathered data:

A. Passenger

For Creation of passenger, A created entity is placed with a Random exponential value of 2 per minute is created, this is based on the computed average passengers for all stations as seen in the figure below.

All stations passenger	
7	1176
8	677
9	724
10	660
11	693
12	684
13	882
14	770
15	777
16	1144
17	624
18	88
Total	**8899**
Hour Per Month	**741.5833**
Hour per Day	31
Passenger per minute	2

Passengers arrive per 2 minutes based on average

Fig. 5. Average passenger for all stations

Then a decision process and a go-to label connected after the create entity to decide where station the created passenger will go, then the entity will go to the selected label that connects as the entrance of every station, the decision process is divided into .10 chance each for where the created entity will go, for equal distribution.

For Passenger Destination, each passenger created at every station is assigned to where they will go, but since there are no data gathered for each passenger to what station they will drop off, the researchers then use the DISC function in the arena that can distribute each passenger to all stations evenly.

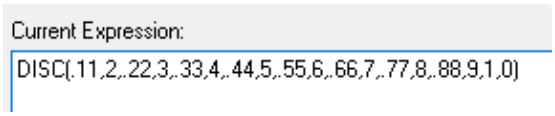

Fig. 6. Discrete Expression in Arena for the Assignment of Passenger Destination

In figure above shows an example for the First Station, Pinagbuhatan where there is a probability of .11 for the passenger to go the station type 2, which is the second station San Joaquin, and a .22 probability where the passenger will go to station 3, which is the Guadalupe Station and so on.

B. Stations

For Stations, each station has different operating hours, and travel times between stations, since the figure 1 shows that there are data for this component, the researchers simply apply the data to the process.

Stations	Operating Hours	Total Hours
Pinagbuhatan	7:10 - 15:30	8.33
San Joaquin	7:15 - 16:10	8.92
Guadalupe	7:30 - 18:30	11
Hulo	7:35 - 18:35	11
Valenzuela	7:00 - 17:30	10.5
Lambingan	7:40 - 18:00	10.33
Sta. Ana	7:00 - 17:30	10.5
PUP	8:15 - 17:30	9.25
Lawton	8:15 - 17:30	9
Escolta	8:30 - 17:30	9

TABLE III
OPERATING TIME OF FERRY

In operating hours, it is used in the decide process in the model where a condition is built.

Example will be the Pinagbuhatan Station,

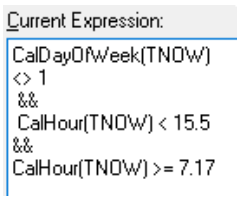

Fig. 7. Condition in Arena for the Operation Hours of the Pinagbuhatan Station

The CalDayOfWeek(TNOW) returns an integer from 1-7 that represents the day of the week of the calendar date corresponding to the simulation time(TNOW) where day 1 is Sunday.

And CalHour(TNOW) returns the integer hour portion in 24-hour format (0-23) of the calendar time (TNOW).

So, the built expression for the Operation Hours in Pinagbuhatan Station can be read as:

If the Day of the week is not equal to Sunday and the time now is greater than 7.17(operating hours in decimal form) and less than 15.5, the station will be open.

And this expression is applied to all ten (10) stations.

In Travel Time between Station, the time travel table per station will be used in this process,

Travel Time from Station to Station (Minutes)

	Pinagbuhatan	San Joaquin	Guadalupe	Hulo	Valenzuela	Lambingan	Sta. Ana	PUP	Lawton	Escolta
Pinagbuhatan		18	30	35	38	46	50	60	75	78
San Joaquin	18		12	17	20	28	32	42	57	60
Guadalupe	30	12		5	8	16	20	30	45	48
Hulo	35	17	5		3	11	15	25	40	43
Valenzuela	38	20	8	3		8	12	22	37	40
Lambingan	46	28	16	11	8		4	14	29	32
Sta. Ana	50	32	20	15	12	4		10	25	28
PUP	60	42	30	25	22	14	10		15	18
Lawton	75	57	45	40	37	29	25	15		3
Escolta	78	60	48	43	40	32	28	18	3	

Fig. 8. Travel time from station to station in Minutes

A Station and Route transfers is use

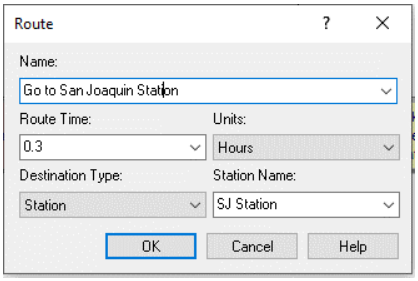

Fig. 9. Route Dialogue Box

A Route transfer will now travel to its assigned Station name, where you will set the Station name, in the figure above, a route named “Go to San Joaquin” is created and will travel to “SJ Station” with a .3-hour route time that is based on the travel time in the figure 8 above and this is applied to all ten (10) stations.

C. Ferry

For Ferry, the ferry conditions of travel are the same as the passengers, if the station is closed, the ferry will not operate.

for the pickup and drop-off process, after the ferry pickup passengers from the queue at each station, the ferry will now go to each station and will drop-off passengers that are destined to embark in station X.

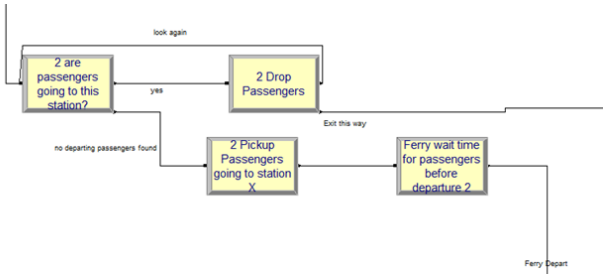

Fig. 10. logic for passenger drop off, and pick up

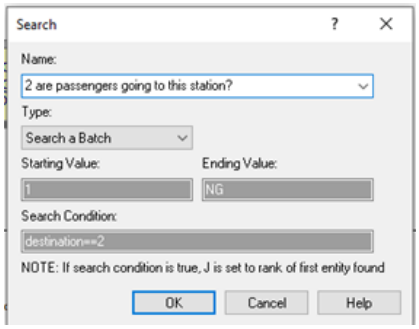

Fig. 11. Search Dialogue Box

A Search process is used to find if a passenger is destined to depart from the set station as shown in figure 10 assign passenger destination, if the passenger is set to go to “station 2”, then the ferry will search for the condition “destination==2” for example, for each passenger and will drop the passenger and repeat it until all passengers are dropped, if no departing passengers found, the ferry will now pickup passengers that will now depart to other stations and repeat.

D. Model process

First, several boats will be created and will go to each station for pickup. While each station has the create process that will randomly generate a person, from the ranges of average hourly consumers based on the data. But the person created cannot enter the station until station conditions are met, the conditions are: if it’s open between the operating hours and if it’s not Sunday, the day when all stations are closed. When conditions are met, all the created entities can now enter and will be assigned where station the passenger will go. It has a probability of 11% at all stations, meaning the passenger has an 11% chance that will go to another station. After being assigned, the passenger will wait for the ferry to pick up. And then the ferry will pick up all passengers on the waiting platform.

The ferry will drop off passengers one by one at its corresponding station. And then, the passengers will exit the station and will count as successful travel. All ferries will go to each station with a different travel time based on the data gathered.

IV. Related Works

The discrete event in Pasig Ferry Station can be related to the study titled "A Discrete Event Simulation Model of the Viennese Subway System for Decision Support and Strategic Planning" [3]. The paper presented that transfer and travel time of passenger, and vehicle's travel and turning maneuver times are stochastic and there are capacity restrictions applied to the number of waiting passengers on a platform and within the vehicle. The model consists of the following components:

A. Subway Network Modeling – this shows the structure of the subway, where it has 2 lines and each line consists of several logical stations. Each logical station is divided into an upstream and a downstream direction. Every direction has its own queue for waiting passengers whose capacity depends on its respective surface area.

B. Passenger Modeling – the creation of passenger is driven by a time-dependent Poisson process where it starts at 4:50 AM until 1:00 AM. Once a passenger is created, its route is determined consisting of logical stations. If a passenger at p0 wants to travel at p8, it would have to travel the stations between the first and last station.

C. Vehicle Modelling - The Viennese subway has two types of vehicles, the first one can carry 878 passengers and used on line U1 to U4, while the second one is used at line U6 and has a capacity of 776 passengers. The vehicle starts its tour at either one end of each line. It is released based on the respective line's current headway. These headway potentially change hourly so as to meet the time-dependent demand

The purpose of this model is to support strategic decisions by studying the what-if scenarios in the subway. Decisions like how many vehicles needed to be released to achieved certain headway and what are the consequences.

V. Validation

For the validation of the model, t-test validation has been used. To evaluate whether there is a significant difference between the means of two groups that may be related in some ways, a t-test is a sort of inferential statistic that is utilized. It is typically employed when data sets, such as the one representing the results of tossing a coin 100 times, would follow a normal distribution and might contain unidentified variances. A t-test is a method for hypothesis testing that enables the testing of a population-applicable assumption. the researchers ran the model into 2 separate replications, the first one is at 100 replications where the second run is at 20 replications, then an R program is used to create the t-test for automatic computation.

```
#null and alternative hypothesis
## null: there is no significant difference in passenger count between 100
  ## and 20 simulated data
        Two Sample t-test

data:  TOTAL by REPLICATION
t = 1.619, df = 118, p-value = 0.1081
alternative hypothesis: true difference in means between group A and group B is not equal to 0
95 percent confidence interval:
 -5.28093 52.60849
sample estimates:
mean in group A mean in group B
       3444.381        3420.717

# t = 1.619
# p-value = 0.1081
#since the value of P is > than the alpha .05 therefore, null hypothesis is rejected.
```

Fig. 12. R program T-Test Result

The result shows that the value of P is greater than the alpha with an accuracy of 95%, therefore the researcher's null hypothesis is rejected and the data result for the validation is valid.

VI. Conclusion

In this paper, we created a simulation model of Pasig Ferry transports using the arena simulation. The model-built shows how the passenger waits for the ferry to pick it up. Since there are only 7 vessels the number of passengers can build up while waiting for the ferry to arrive. Since there is no traffic, the travel time per station is constant. There are instances where more passengers arrived at each station compared to other stations.

A transport simulation consumes a lot of work because of the stations that are included. The Pasig ferry transport consists of 10 stations. Also, the researchers tried to create a model that can go a full back and forth simulation of all the stations but Arena Simulation student limits how many processes you can create because of the free trial. However, the built model shows reasonable and accurate results and can be used for other studies.

References

[1] A. Hayes, "What are the odds? how probability distribution works," Investopedia, 08-Jul-2022. [Online]. Available: https://www.investopedia.com/terms/p/probabilitydistribution.asp.

[2] C. LIONG and C. LOO, "A simulation study of warehouse loading and unloading systems ... - UKM," journalarticle, 2009. [Online]. Available: http://journalarticle.ukm.my/1933/1/jqma-5-2-04-liong.pdf.

[3] C. Wang, "Arena Simulation for Aviation Passenger Security-Check Systems," Sci-hub, 2017. [Online]. Available: https://sci-hub.hkvisa.net/10.1007/978-3-319-48490-7_12.

[4] "Simulation using arena," cs.tlu. [Online]. Available: https://www.cs.tlu.ee/ jaagup/uk/ds/chp8/c8-09.htm. https://doi.org/10.1080/09537280902938605.

[5] T. Wang, A. Guinet, A. Belaidi, and B. Besombes, "Modelling and simulation of emergency services with ARIS and Arena. Case study: the emergency department of Saint Joseph and Saint Luc Hospital," Taylor and Francis Online, 28-Sep-2009. [Online]. Available: https://doi.org/10.1080/09537280902938605.

[6] Schmaranzer, R. Braune, and K. F. Doerner, "A discrete event simulation model of the Viennese subway system for Decision Support and Strategic Planning," IEEE Xplore, 2016. [Online]. Available: https://ieeexplore.ieee.org/document/7822280/.