RuiAn Mini Grocery Store Customer Queuing Simulation in Tondo, Manila

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Abstract—In the business industry, Queuing Theory provides extensive procedures and applications for determining queuing systems problems, which is beneficial for organizing business operations. This study reveals the concepts of queuing theory used by simulating and measuring the model's performance. The data used for this study was gathered at RuiAn Mini-Grocery Store in Tondo, Manila. This paper adopted the *M*/*M*/1 Single Server Queuing Model for modeling Discrete Event Simulation (DES) for the entity's behavior. It requires empirical data such as customers' arrival time/rate, arrival time in queue (server), etc. The dataset was simulated first using MS Excel with the appropriate probability distributions to calculate the required data. It showed that the entity's average time spent inside the store is 6.07 minutes and the queue service time is approximately 2 minutes. The obtained results were supported by using the Simio Simulation Software, which provides a demonstration for comprehensive data system modeling and validating the queuing analysis for the project. For implication, the authors recommended conducting a more inclusive and in-depth analysis of the proposed queuing system that is substantial for verifying simulated model results.

Keywords— Queuing Theory, Discrete Event Simulation (DES), Mini-Grocery Store, Single Server Queuing Model, Queuing system

I. INTRODUCTION

Over the past century, there have been numerous changes in how individuals buy food [1]. Today, food, both fresh and packaged, as well as non-food household items like paper towels, toilet paper, cleaning supplies, and over-the-counter medications are all sold in grocery stores [2]. People often go to small grocers, also referred to as mini-grocery stores, when they are looking for specific items or ingredients that cannot be obtained at the corner store or neighborhood supermarket. These retail businesses offer food and other products that larger supermarkets don't have [3].

In a supermarket or grocery store, long queues often occur. This queue usually occurs while waiting to make a purchase payment at the cashier. In this instance, it is inefficient for the customers to stay for quite a while [4]. RuiAn Grocery Store is a retail business unit that sells all the necessities of daily life such as groceries, beverages, household products, and so on. The various needs provided by RuiAn Grocery Store make the store always filled with customers, causing a long queue at the cashier. To improve efficient service, it is necessary to do queue simulation with the aim of reducing waiting time and work in progress on the cashier system.

The general purpose of this study is to develop a simulation model of the queueing system of RuiAn Grocery Store in Tondo, Manila that will analyze the customer's arrival and evaluate the data parameters involved.

Specifically, this project aims to:

1. To acquire data from the RuiAn Grocery Store
2. To determine the queuing system requirements and elements for project modeling.
3. To implement proper probability distributions for the data observation using MS Excel.
4. To discuss the proposed solution for better service provision in improving customer satisfaction, making the checkout process faster, and decreasing the waiting time of the customers.
5. To construct a queuing simulation table and verify the obtained results in each parameter.
6. To measure the customer queuing system performance and compare the complete findings

The system's scope and limitations for customer's flow are listed below:

- This study covers the arrival, service, queue of the customers at the cashier and the efficiency of the cashier system.
- The study looked at the utility factor of cashier work and customer arrivals and exits at the store.
- This research is not calculated for changing work shifts/changing hours of rest
- The arrival of customers is the same throughout the service time. There is no busy time or free time.
- The simulation system the researchers designed for 11 hours, from 9am to 8pm.

This paper shows the literature review in Section 2. The methodological procedures are explained in Section 3. Next, section 4 exhibits the implementation of the queuing

system in customers arrival and Simio Simulation modeling . Section 5 displays the summary of results. Then, Section 6 provides a summary and conclusion of the project. Finally, the implication will be presented in Section 7.

II. Review of Related Literature and Studies

There are various existing research studies and literature about queuing system applications in Grocery stores or markets. This section reveals and roughly explores their distinct approaches, analysis, and techniques in designing customer queuing modeling and simulations.

Queues are a regular part of life for customers at businesses that provide certain services, such as grocery shops. Several elements define the performance level of the grocery store and have an impact on consumer satisfaction, including the availability, pricing, quality of different items and waiting times. The most significant indicator of the store's success and a major factor in customer satisfaction is the amount of time that customers spent on a cashier queueing line. Customers tend to dislike long wait periods and prefer establishments with short lines. Short queues at the checkout were cited by 86.9% of respondents in a poll by the trade publication for the grocery sector, Progressive Grocer, as a key consideration when selecting a supermarket. It follows that it is crucial that the service is quick [5].

Simulation is a recognized technique for precise, evidence-based decision making and produces outstanding results when used to evaluate and design complex and unpredictable systems. In addition to suggesting necessary changes in the controlling system and operational responsibilities, simulation is a dependable tool for assessing and analyzing the design of a new system or making necessary improvements in the existing system. It is a technique used to display data from built-in models based on observing workflow rotation in the real world and other relevant variables [6].

Analyzing the benefits of researching queuing systems includes reviewing the models' usage and waiting time efficiency, increasing the number of queues to prevent longer waiting time for clients when servers are overloaded. In other words, the goal of this study is to attempt to estimate the waiting time and length of the queue(s). A sample performance result is obtained using queuing simulation, and calculated solutions for other queuing models are also interesting. This study requires empirical data, which may include elements like the checkout operational unit's (server's) arrival time in the line, departure time, service time, etc. [7].

III. Methodology

The methodology of this paper describes the process of gathering data identifying model specification and problems, the calculations procedures that were made in the simulation, setting goals, the outcomes of running the simulation with different parameters, and ideas for how to make the queues at the store better for both customers and the grocery itself.

M/*M*/1 Queuing System (∞ / FIFO): Single-Server

A single server serves a queuing model where the customers come one at a time from the front of the queue, according to a first-come, first-served discipline. The time of service is complete when the customer leaves the queue and the number of customers in the server system decreases by one [8].

In the proposed study, the authors will acquire the data from RuiAn Mini-Store by analyzing the real-life observed data. The store's waiting line model involves a single-server, single-line, and a single-phase system. Below are the assumptions made by the authors to model this environment.

Mini-store Queuing Assumptions:

Starting Point:

i. Arrival time distribution: The interarrival time can follow one of the following distributions: A Poisson distribution, a deterministic distribution, or a general distribution.
ii. Service time distribution: The service time can be a constant, exponential distribution.
iii. Service channel: The system follows a single service channel model. Customers queue in one (1) server only.

Calling Population

iv. The entities are the customers, consumers, or shoppers. The maximum number of customers is infinite because once customers are served, they leave the grocery immediately.

Queue discipline

v. The customer's waiting line priority rule is first-come, first-served basis.

Customer behavior

vi. The customers in the queue do not leave the queue unemployed.

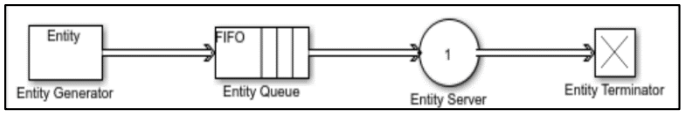


Figure 1. *Single-Server Queuing System Diagram*

Discrete Event Simulation (DES)

A discrete-event simulation (DES) model represents how a system behaves when a discrete series of events occur over time. Each event takes place at a specific point in time and causes the system's state to change. Since no change in the system is anticipated in between successive events, the simulation can move immediately from one event to the next [9]. Modeling a queue, such as customers waiting in line at a grocery store to be served by a cashier, is a perfect example of discrete-event simulations. Customer-queue and cashier are two examples of system entities. Both customer arrival and departure are system events.

Due to the constantly changing demands of the customers, an efficient production system is needed. Not only to satisfy the customer's need- but also to obtain a competitive edge. A DES model is a good tool for meeting these demands. DES can accurately simulate a flow of events and hence offer effective decision-making insights [10].

A. Data Elements and Parameters

A queuing system model can be defined as a representation that captures and quantifies the phenomenon of waiting in lines. It consists of three (3) basic elements within a queuing system are entities, servers, and queues.

Below are the project data scope to be used in modeling.

Entities/Resources

a) Temporary resources
   - Customer A (who entered the store without buying)
   - Customer B (who entered the store and bought something)

b) Permanent Resources
   - Grocery Staff

Classes/Sets/Attributes of the Entities

a) Classes:
   - Customer
   - Grocery Staff (Cashier/Bagger)

b) Sets:
   - Customer arrival,
   - Queueing
   - Service

c) Attributes:
   - A waiting customer
   - functioning cash register

Events in the Simulation

a) Arrival
b) Queueing
c) Payment/Check-out
d) Departure

Activity of Each Entities

a) Customer
   - Inter-arrival time
   - Queueing

b) Staff
   - Service time

Process

a) Arrival
b) Activity
c) Delay
d) Queue
e) Service
f) Departure

Simulation Clock

Internal Clock:

- Every activity will be measured in minutes e.g., Interval-arrival in queue: (displayed in mins)

B. Mini Grocery Store Flowchart

The scope of the simulation and the customer flow is described as follows in the flowchart below. The customer who arrives at the store will go shopping, and if the items that they need aren't available, they will automatically head outside. But if the item that they were looking for is available inside, they will go straight to the cashier's queue for checkout and payment, and they will leave when the transaction is done.

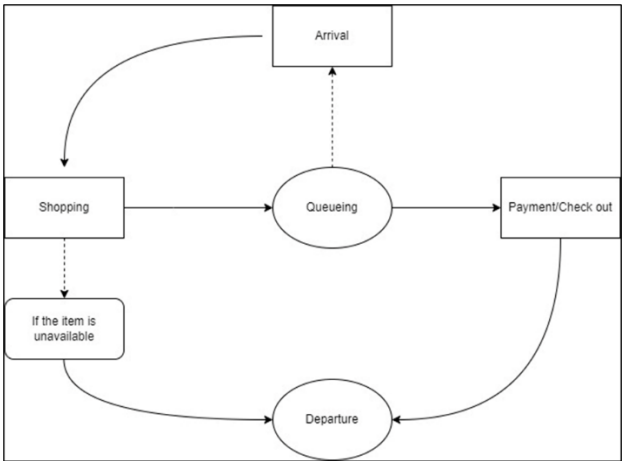


Figure 2. *System Flowchart*

Monte Carlo Simulation

For each random input variable in these simulations, a particular value is chosen based on the modeler's best forecast (a specific what-if scenario). This output can be either a single value or a single set of values, depending on the input that was chosen. The Monte Carlo simulation randomly generates values from each input variable distribution to produce the model's output [11].

The authors followed the four (4) step process and methods based on the book of Sokolowski and Banks (2010).

Step 1 Define a distribution of possible inputs for each input random variable.

Step 2 Generate inputs randomly from those distributions.

Step 3 Perform a deterministic computation using that set of inputs.

Step 4 Aggregate the results of the individual computations into the final result [11].

In this project, the Monte Carlo simulation was executed using MS Excel. The necessary components the authors used to achieve the predicted and results are probability distribution functions, random data number generator for each variable, and simulation of the system model using simulation tables.

Data Gathering

This data was recorded using a smartphone's timer and by observing the following events of entities in the store. In a span of 2 hours (3pm – 5pm), the data was primarily collected by direct observation at RuiAn Mini-Grocery Store in Tondo, Manila.

- The time of arrival of each customer.
- Waiting time of customers in queue.
- The time service of the cashier for each customer in the system.
- The departure time of the customer in the system.
- Number of customers in queue

Project Flow Overview

Here are the series of steps for accomplishing the proposed Mini-Grocery Store Simulation Modeling Project:

1. Investigating the project requirements includes system identification.
2. Data Gathering for Real-life observations.
3. Implementing Probability Distributions.
4. Constructing the proposed Model in Simio.
5. Analysis of the Queuing System Model.
6. Reporting and Validating Results.

IV. IMPLEMENTATION

The implementation of this study is divided into two(2) parts: Simulation using MS Excel data tables and Simulation modeling using Simulation software - Simio.

Simulation using data tables

In order to simulate the lines at a mini grocery store, queueing theoretical equations were employed in MS Excel platform, and a Monte Carlo simulation and analysis were run to determine the relative importance of each line. Data gathered at the store served as the basis for the simulations. It starts when the first customer that the surveyor witnesses join it. When someone leaves the line, their dropout time is also collected. Lastly, the authors will calculate the expected arrival time and transaction time.

The data collected from the Mini Grocery Store consisted of customer inter arrival time and transaction time were checked for verification and validation of the model.

a. Probability Distribution of Inter Arrival Time

The inter arrival of customers visiting the store for a day is recorded and the probability at fixed value of arrival time is calculated from the data collected as shown in ***table 1.***

Arrival in mins.		
p(y)	Cummulative	Value
0.3	0	3
0.2	0.3	6
0.15	0.5	9
0.1	0.65	12
0.07	0.75	15
0.04	0.82	18
0.03	0.86	24
0.01	0.89	27
0.1	0.9	30
1	1	

Table 1. *Arrival of Customers*

b. Probability Distribution of Transaction Time

The transaction time of customers visiting the Store section for a day is recorded and the probability at fixed values of transaction times is calculated from the data collected as shown in ***Table 2.***

Transaction in mins.		
p(y)	Cummulative	Value
0.4	0	3
0.3	0.4	5
0.2	0.7	7
0.04	0.9	9
0.03	0.94	11
0.02	0.97	13
0.01	0.99	15
1	1	

Table 2. *Service Time*

After identifying the probability distributions of the customer's arrival and transaction time, the behavior can be predicted. the whole system can be simulated to find out the average waiting time and total time by simulating the much larger number of customers.

c. Monte Carlo Table

Costumer	Next arrival in mins.	Clock time	Start Time	Transaction in mins.	Finish time	Total time	Waiting queue	Accept
1	3	3	3	7	10	7	0	1
2	6	9	10	3	13	4	1	1
3	3	12	13	3	16	4	1	1
4	6	18	18	3	21	3	0	1
5	30	48	48	7	55	7	0	1
...								
70	12	645	645	7	652	7	0	1
71	3	648	652	5	657	9	4	1
72	3	651	657	5	662	11	6	0
73	15	666	666	5	671	5	0	0
74	6	672	672	5	677	5	0	0
75	6	678	678	3	681	3	0	0
						6.070422535	1.975	

Table 3. MS Excel Simulation Table

Overall Analysis of mini-grocery store

- One checkout cashier
- Customers arrive at random times from {3,6,…,30} minutes
- Service times vary from {3,5,…,15} minutes
- The system has total **75 customers**
- The total time spend of customer is **6.07 minutes**
- Approximately the observed waiting time in queue is **2 minutes**

Simulation modeling using Simio

The authors simulated our Mini Grocery Queueing System using Simio to build the model. It is a tool for building and executing dynamic system models to analyze how they work, and it displays an animation in three dimensions(3D).

Here are the steps for implementing the data into Simio model

- Automate the collection of precise queuing data
- Calculate typical wait times, wait times in line, cashier idle times, and overall transaction service times in real time.
- Using Simio, enter the data and process it.
- Keep an eye on and foresee lines
- Run the queueing model and check its accuracy.

Animated 3D Model of the store

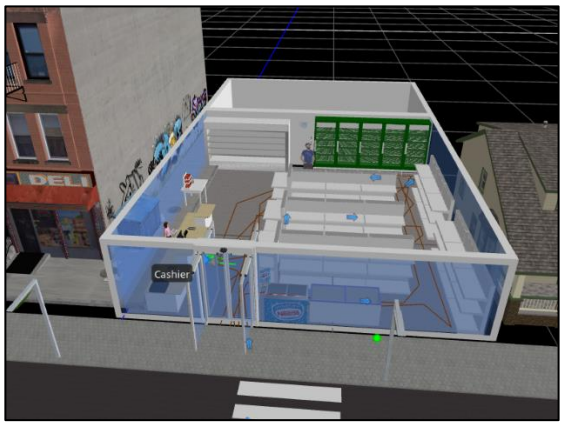


Figure 3. *Outside view of the store*

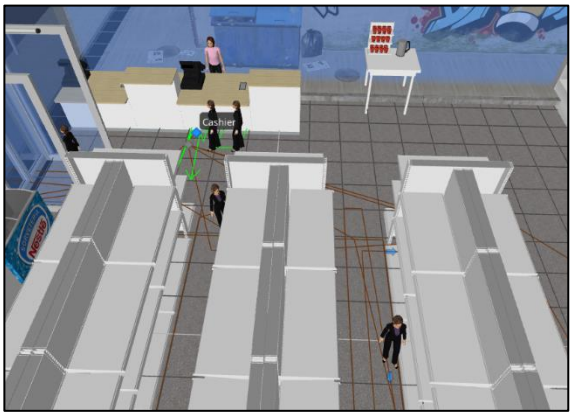


Figure 4. *Customer queue inside the store*

V. RESULTS

Based on our store observation in Tondo, Manila, we've come up with 75 customers. Out of all those 75 customers, 71 are accepted during store hours starting from 9am to 8pm. The mini groceries queueing network was based on how long they spent their time buying and waiting inside the store. The first to finish on choosing the item that they'll be buying is the first one to get in the cashier line.

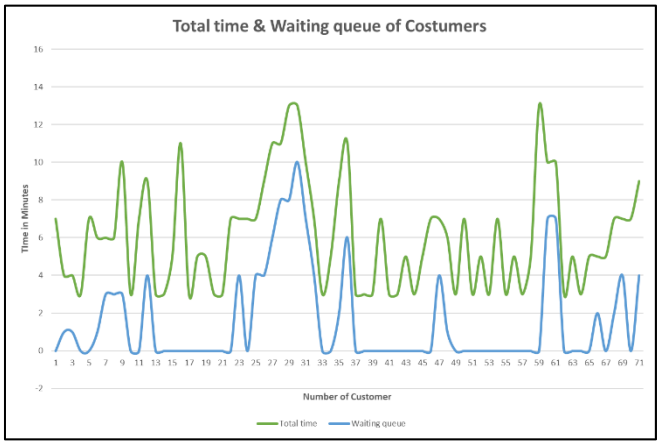


Figure 5. *Total time & Waiting queue of Customers*

The green line represents the total time that the customers spent inside the store, and it ranged from 3-13 minutes while the blue line is the waiting queue that took 1 to 10 minutes.

Furthermore, the first graph shown below is the comparison between average total time spent in minutes and the waiting queue of 71 customers while the second graph represents the results in the Simio Model. It shows the average customers during the 11-hour duration of store's service. Also, it exhibits the number of customers that are inside the market.

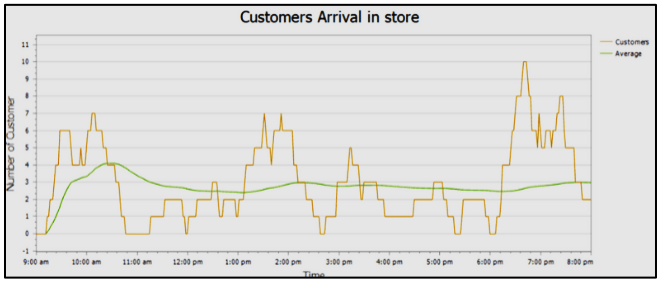


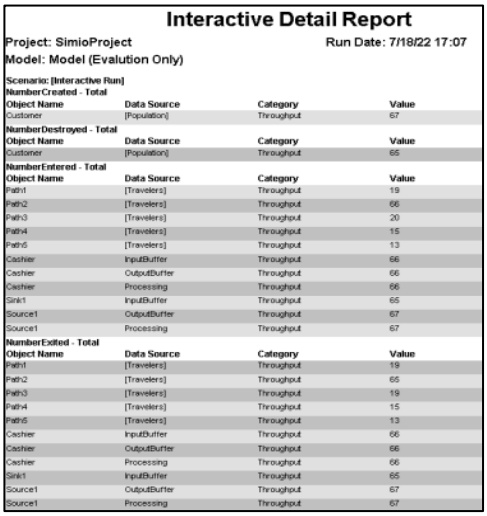
Figure 6. *Customers Arrival in Simio model Store*

The yellow line is the number of customers arriving from 9am to 8pm while the green line is the average time of their arrival.

In a span of 11 store hours, the researchers observed that 69 out of 71 or a total of 98% were able to check out in 3-9 minutes using Monte Carlo Simulation. The remaining 2% took 11-13 minutes. Meanwhile, the average total time spent in the mini grocery store is 6.07 minutes while the average queueing time is 1.97 minutes.

Validation of Results

For verification and validation of results, the model's results accuracy is evaluated and replicated using the Simio Software. The simulated model will be considered valid and accepted if the data results showed a close outcomes or findings in the real–life predicted data results that the researchers executed.



Interactive Detail Report

Project: SimioProject — Run Date: 7/18/22 17:07
Model: Model (Evalution Only)
Scenario: [Interactive Run]

NumberCreated - Total

Object Name	Data Source	Category	Value
Customer	[Population]	Throughput	67

NumberDestroyed - Total

Object Name	Data Source	Category	Value
Customer	[Population]	Throughput	65

NumberEntered - Total

Object Name	Data Source	Category	Value
Path1	[Travelers]	Throughput	19
Path2	[Travelers]	Throughput	66
Path3	[Travelers]	Throughput	20
Path4	[Travelers]	Throughput	15
Path5	[Travelers]	Throughput	13
Cashier	InputBuffer	Throughput	66
Cashier	OutputBuffer	Throughput	66
Cashier	Processing	Throughput	66
Sink1	InputBuffer	Throughput	65
Source1	OutputBuffer	Throughput	67
Source1	Processing	Throughput	67

NumberExited - Total

Object Name	Data Source	Category	Value
Path1	[Travelers]	Throughput	19
Path2	[Travelers]	Throughput	65
Path3	[Travelers]	Throughput	19
Path4	[Travelers]	Throughput	15
Path5	[Travelers]	Throughput	13
Cashier	InputBuffer	Throughput	66
Cashier	OutputBuffer	Throughput	66
Cashier	Processing	Throughput	66
Sink1	InputBuffer	Throughput	65
Source1	OutputBuffer	Throughput	67
Source1	Processing	Throughput	67

Figure 7. *Simio Grocery Model Report*

First experimentation, the project model showed an inaccurate finding where the authors concluded that the simulated model is invalid and requires improvement in the data, however, the final outcome of the model report displayed a validity of the data. The average observed data in customer arrival of the store within a day is approximate 69-71 shoppers. In the simulated model, it presented approximately 67-69 customers a day that was accepted by the store in its service hours.

VI. CONCLUSION

The objective of this study is to compute the average waiting time of customers inside the mini grocery store. The simulation operation of the RuiAn Mini Grocery store was modeled and simulated using Discrete Events and Monte Carlo simulation. The simulation model is meant to replicate the real-life situation of the store to provide more insight into how the given data can affect the performance of the store. The data gathered at the store serves as the basis for this project. And by getting the probability distribution of it, the average time spent inside the store is calculated at 6.07 minutes, and the queuing time is 1.97 minutes. The Simio model presented invalid and valid results since the authors exhibited numerous experiments, whereas the second experiment was considered valid where the average customer arrival in a day is approximately 67-69 shoppers.

VII. RECOMMENDATIONS

This section offers various recommendations that can assist the store in reducing the allotted waiting time, such as:

- Increasing the number of cashier registers.
- Hiring more employees to assist the customer.
- One additional operator on each server serves as a packer of goods

The researchers suggest performing a more thorough and detailed investigation of the suggested queuing system, which is crucial for validating the outcomes of the simulated model. It is also recommended to look more closely at the issues raised in this study and determine whether the solutions chosen are practical.

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