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Optimizing Restaurant Queue Management: A Simulation-Based Approach Using Arena Software

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Abstract - **Examining the effectiveness of models in terms of utilization and waiting time is one of the anticipated benefits of analyzing queuing systems. This study uses Arena simulation software to examine the queue system of a particular restaurant. The primary objective is to assess and enhance the restaurant's service efficiency through the modelling of customer arrivals, service procedures, and queue dynamics. Data on customer arrivals and service times were collected for the restaurant's current system. The necessary expressions were developed from the observed data using the input analyzer. A conceptual model of the original queuing system was created, and two alternative Arena models were developed to reduce customer waiting times in the restaurant. The developed models were run to evaluate their performance. During a 24-hour simulation study, the average waiting time in the overall model was found to be 24.49 minutes, with a maximum of 48.69 minutes. The waiting time for server 1 was 25.30 minutes, for server 2 was 23.27 minutes, for server 3 was 25.11 minutes, and for server 4 was 22.30 minutes. The number of customers in line at server 1 was 12.65, at server 2 was 6.98, at server 3 was 8.29, and at server 4 was 8.25. Resource utilization was 57% for server 1, 35% for server 2, 27% for server 3, and 15% for server 4. By decreasing the queuing length and average waiting time in the restaurant, customer satisfaction can be increased, leading to a reduction in time wasted. The findings indicate significant potential for improving overall service quality and reducing client wait times. This research provides valuable insights for restaurant managers seeking to enhance customer satisfaction and operational efficiency.**

Keywords: **Queuing Systems, Arena Simulation Software, Customer Waiting Time, Service Efficiency, Resource Utilization**

I. INTRODUCTION

The queuing system is one of the most common and widely practiced systems across various sectors. From grocery shops to banks, and even in transportation facilities, queuing is a prevalent feature. However, in recent times, it has become increasingly problematic for people to wait in queues, leading to a loss of valuable time and patience. This issue is particularly significant in restaurants, where large crowds are observed daily, resulting in long wait times for customers. A common reason for queues in restaurants is the lack of organization among customers. Addressing the queuing problem in restaurants has been a concern for the past few decades [1]. To reduce the average waiting time and service time, a simulation model has been developed in this study. The model demonstrates that it offers a better solution compared to analytic approaches and provides improved service facilities in the restaurant. By using a simulation model, the queuing system can be easily explained, offering better clarity to customers. Due to unplanned activities and natural variability, the current system at the restaurant could not be precisely modelled and replicated.

To address the challenges faced during the study, certain assumptions were made to simplify the model and ensure consistency. It was assumed that there would be no shifting duties or work breaks, and that each counter would be staffed by a single server. For the purpose of calculating total time, customers who did not make any purchases were excluded from the analysis. In instances where sample points were unavailable, necessary data was obtained from authorities to inform the decision module. The model also accounted for variations in service durations among different workers. While it was acknowledged that customers might leave the restaurant after their orders were fulfilled, this was not considered statistically significant; "customer leaves the store" was defined as the completion of the transaction, regardless of whether the customer remained in the restaurant. Importantly, none of these assumptions were violated during the operation of the model, ensuring the integrity of the analysis. For the duration of the model's operation, each of these assumptions is considered valid. Analytical models often utilize mathematical programming techniques, but they are not practical for solving complex queuing problems. In this regard, a simulation model can be extremely beneficial. As a representation of the actual system, the simulation model presents a promising solution to the queuing problem at the restaurant.

The main objectives of this research are:

1. To study the queuing pattern in a restaurant.
2. To run the model and analyze the output.
3. To develop a simulation model for the restaurant.
4. To propose suggestions for better service provision to improve customer satisfaction.

II. LITERATURE REVIEW

A. Simulation

Simulation is the process by which a system model operates. The model allows for experimentation and reconfiguration, which, in most cases, cannot be done in the actual system it depicts, as this would be too costly or unfeasible. By observing how the model operates, one can infer features related to the behavior of the actual system or one of its subsystems. In the context of broadcasting, the process of evaluating a system's performance under different configurations of interest and over extended real-time intervals is known as simulation. This can be applied to both existing and proposed systems. Before modifying or producing a new system, simulation is employed to minimize the likelihood of failure, eliminate unanticipated bottlenecks, avoid overusing resources, and improve system performance over time [2].

For a simulation study to be successful, certain stages must be followed in the application of simulation. The procedure used to carry out the simulation is consistent regardless of the nature of the issue or the study's goal. The fundamental phases involved in the simulation process are illustrated below.

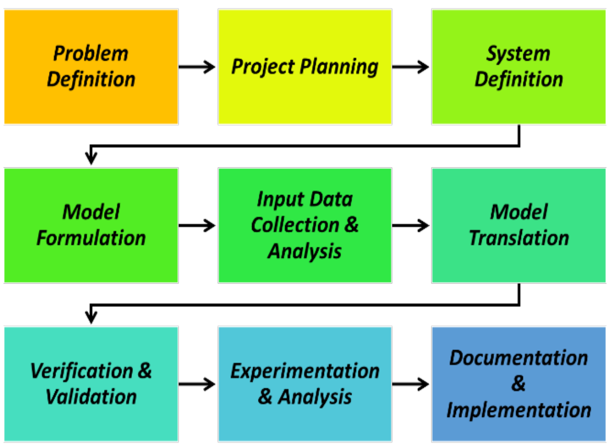

Fig. 1 Steps of Simulation [3]

B. Queuing System

Queuing theory is a collection of mathematical representations of diverse queue systems. One of its common applications is the analysis of service duration and arrival rates. When the demand for a service surpasses the system's capacity, queues begin to form [4]. This area examines mathematical systems with one or more service lines that serve input units such as clients, requests, and so forth [5]. In a restaurant, some customers must wait to receive the required service each time they visit a service station, which means they must wait in line to be served. At a service facility, there are several lines, each with a single server, where customers choose which server's queue to join. Inadequate service can sometimes result from excessive wait times, potentially caused by new hires. Service projects delayed beyond reasonable limits could cost companies potential business opportunities. Queuing models in queuing theory represent the various types of queuing systems that occur in real life. These models allow for the determination of an appropriate trade-off between service costs and wait times [6].

In this research, a simulation model was designed for the existing system at the restaurant. The output of the preliminary model was analyzed, and based on that output, the idea of developing an alternative model to reduce the average waiting time was proposed. The collected data was modified to create expressions within the model. The alternative model was then developed, and data was inputted into the model using an input analyzer. Finally, all outputs from the developed model were compared to select the best alternative for reducing average waiting and service times.

C. Modelling and Simulation

Modeling and simulation are now recognized as the third primary research methodology. With the advent of high-speed computers, mathematical representations of reality based on our theories can be converted into numerical results. These results can then be compared with data from experiments or observations. The advantage of simulation is that it allows for the alteration of model parameters and the understanding of cause and effect at a level not achievable through other means. Additionally, it enables the study of phenomena that may be too costly or risky to explore using traditional experimental techniques. Another justification for comparison is to validate the theoretical and mathematical model and suggest improvements if the findings differ [7].

D. Conceptual Model

A conceptual model is a system representation composed of ideas designed to aid in understanding, knowledge acquisition, or simulation of a subject. It is a collection of concepts. The primary objective of a conceptual model is to convey the fundamental concept and functioning of the system it represents. Additionally, a conceptual model should be designed to provide users with a clear interpretation of the system. When utilized appropriately, a conceptual model should achieve four primary objectives.

1. Strengthen understanding of the representative system.
2. Facilitate communication of system specifics among stakeholders.
3. Assist system designers in deriving system specifications by providing a point of reference.
4. Establish a channel of communication and document the system for future reference.

In the overall system development life cycle, the conceptual model is crucial. If the conceptual model is not thoroughly developed, the major system attributes may not be properly executed, leading to future challenges. Conversely, tracking the system design and development process can enhance the execution of the core goals of the conceptual modeling process. The importance of conceptual modeling is evident when systemic failures are minimized through adherence to established development objectives and procedures [8].

E. Modeling

Modeling is the process of developing a representation of how a system of interest is constructed and functions. A model is a simplified representation that resembles the actual system. One of the goals of a model is to help analysts predict the outcomes of system changes. The model should closely resemble the real system and incorporate most of its notable features, but it should not be so complex that it becomes difficult to understand and use. A well-designed model balances simplicity and realism appropriately. Simulation practitioners recommend gradually increasing the model's complexity. Model validity is an important factor to consider when modeling. Two methods for validating models are comparing model and system outputs and reproducing the model under known input conditions [9]. A mathematical model created using simulation software is typically used for simulation research. Mathematical models can be categorized as stochastic (at least one input or output variable is probabilistic), deterministic (input and output variables have fixed values), dynamic (time-varying interactions among variables are considered), or static (time is not considered). The majority of simulation models are stochastic and dynamic [2].

F. Analytical Model and Simulation Model

TABLE I DIFFERENCE BETWEEN ANALYTICAL MODEL & SIMULATION MODEL [10]

Analytical Model	Simulation Model
1.When a problem is solved by means of analytical method its solution may be exact.	1. When a problem is solved by means of numerical method its solution may give an approximate number to a solution.
2. It does not follow any algorithm to solve a problem.	2. It is the subject concerned with the construction, analysis and use of algorithm to solve a problem
3. This method provide exact solution to a problem.	3. It provides estimates that are very close to exact solution.
4. These problems are easy to solve and can be solved with pen and paper.	4. This method us prone to error.
5. It is quantitative in nature and used to answer a specific question or make a specific design decision.	5. It is the process of creating and analyzing a digital prototype of a physical model to predict its performance in the real world.
6. Analytical models are used to address different aspects of the system, such as its performance, reliability, or mass properties.	6. It can't be solved with pen and paper but can be solved via computer tools like Arena Simulation Software.

G. Introduction to Arena

Systems Modeling Developed Arena, a discrete event simulation and automation program that was acquired by Rockwell Automation in 2000. Arena is a discrete event simulation program created by Rockwell Automation that utilizes flowcharts. Using Arena software, companies can leverage the power of modeling and simulation. It is designed for evaluating the effects of modifications requiring large-scale and intricate redesigns related to logistics, distribution and storage, manufacturing, supply chain, and service systems. With Arena software, users can model any desired level of complexity and depth with significant flexibility and comprehensive coverage across applications [11]. Simulation is advantageous in various corporate settings, including manufacturing, customer service, and healthcare. Additionally, users need only follow five simple procedures with Arena to analyze either a new emergency room plan or an existing supply chain,

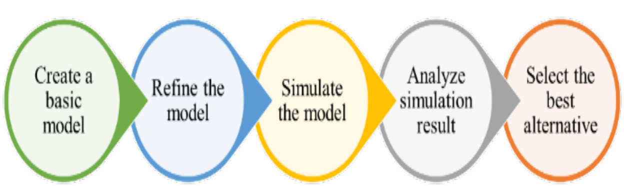

Fig. 2 Procedures of Arena Simulation [12]

H. Element of Arena

1. *Entities:* These are the elements that connect different modules. As soon as an event is initiated, each entity moves through the system.
2. *Resources:* These are essential components required to complete a task.
3. *Queues:* These are components where entities wait until resources become available.
4. *Variables:* These are global data structures that entities have access to and control over.
5. *Attributes:* These are local variables unique to each entity. An attribute could be a characteristic such as gender or skin tone. For example, a variable might represent the proportion of male and female pedestrians [8].

I. Arena Modules

1. *Create Module:* The purpose of this module is to provide entities in a simulation model with their initial state. Entities are created based on a timetable or the interval between arrivals. After exiting this module, entities begin to navigate the system for processing. This module includes the specification of the entity type.

2. *Assign Module:* This module allows for the assignment of new values to variables, entity types, attributes, photographs, and other system variables. Multiple assignments can be created using a single "Assign Module."
3. *Process Module:* This module serves as the primary processing mechanism in the simulation. It includes options to capture and release resource constraints. Additionally, a "submodel" can be used to create hierarchical user-defined logic. Process time is allocated to the entity and can be classified as transfer, wait, non-value added, or value added.
4. *Decide Module:* This module facilitates decision-making within the system based on conditions or probabilities, including attribute values, variable values, entity types, or expressions, ensuring efficient and accurate operations.
5. *Dispose Module:* The objective of this module is to serve as the endpoint for an entity in a simulation model. Before the entity is disposed of, statistics can be recorded [8].

III. RESEARCH METHODOLOGY

A. Simulation Tools

Simulation software models real phenomena using mathematical formulas, allowing users to observe operations without performing them. It is widely used in equipment design to achieve design specifications without costly process modifications. Simulating mathematical phenomena on computers is challenging due to the influence of numerous factors. Key factors affecting simulation goals must be determined for effective development. There are several simulation tools available, including AnyLogic, PLE Simulation Software, Arena, Autodesk, SIMUL8, FlexSim, ExtendSim, COMSOL Multiphysics, MATLAB, SimulationX, CONSELF, MathWorks, and Simio. Arena Simulation Software (Student Version) was used for this project. The steps involved in developing an Arena simulation model to simulate the queuing system of the restaurant are-

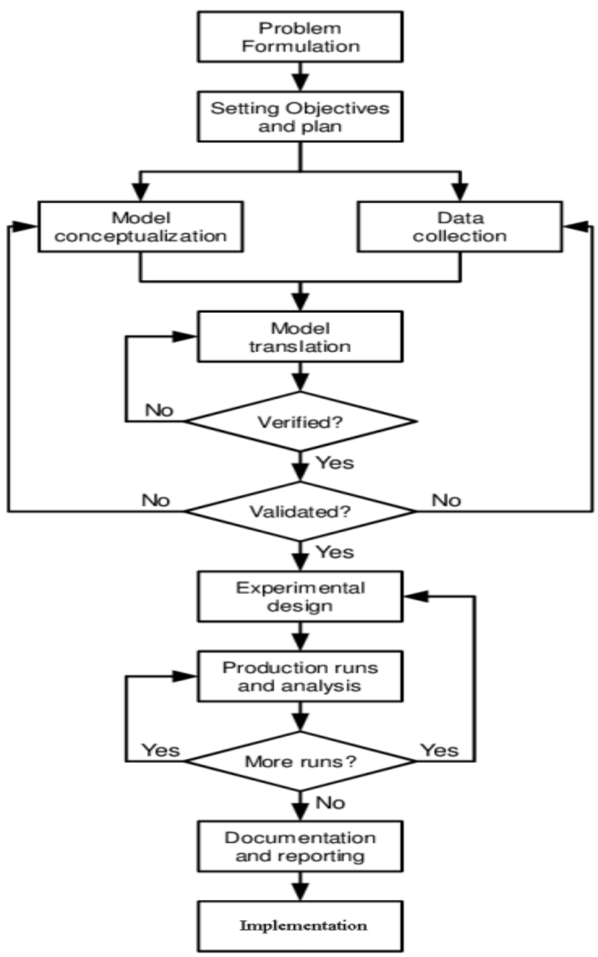

Fig. 3 Steps followed for this Research [7]

IV. DATA ANALYSIS, DISTRIBUTION FITTING, AND RESULT

A. Data Collection and Analysis: The data were collected for 2 hours from 7:40 PM to 9:40 PM from the 4 available servers which is the rush hour at restaurant for a day.

TABLE II SYSTEM AND RESOURCE DATA

<table>
<tr><th>The System</th><th>A Restaurant</th><th>Resources</th><th>Service Provider</th></tr>
<tr><td>Entity</td><td>Customer</td><td rowspan="4">Measure of Performance</td><td>1.Average Service Time</td></tr>
<tr><td>Variable</td><td>Number of customers in queue</td><td>2.Average Waiting Time</td></tr>
<tr><td rowspan="2">Event</td><td>1.Customer arrival</td><td>3.Average Queue time</td></tr>
<tr><td>2.Customer departure</td><td>4.Server Utilization</td></tr>
<tr><td>Server</td><td>Table</td><td></td><td></td></tr>
</table>

TABLE III INTER ARRIVAL TIME AND SERVICE TIME

No. of customers	Inter arrival time (min)	Service time (min)	No. of customers	Inter arrival time (min)	Service time (min)
1	0	25	21	2	19
2	3	23	22	6	18
3	1	19	23	1	17
4	3	18	24	5	11
5	1	21	25	6	29
6	1	26	26	4	28
7	0	31	27	1	24
8	3	29	28	5	15
9	2	31	29	1	17
10	3	30	30	3	28
11	1	22	31	4	21
12	2	27	32	1	35
13	0	25	33	3	27
14	7	17	34	2	26
15	2	20	35	0	32
16	4	8	36	4	22
17	6	16	37	3	22
18	1	15	38	8	25
19	4	15	39	4	20
20	7	24	40	9	16

Using the input analyzer tool, we have found the following data distribution,

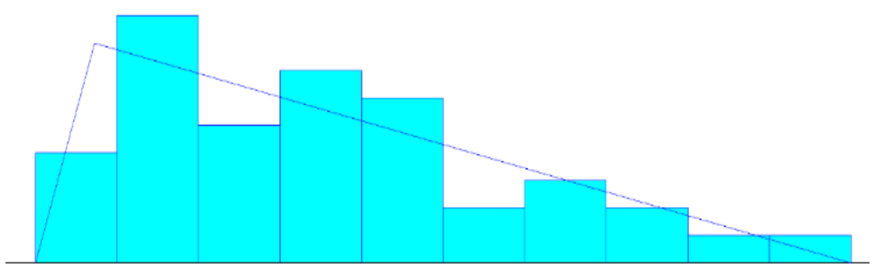

Fig. 4 Histogram for Inter Arrival Time of Customers

Distribution

1. Type: Triangular
2. Formula: TRIA (-0.5, 0.225, 9.5)
3. Square Error: 0.008484

Data

1. No. of Data Points = 40
2. Minimum Data Value =0
3. Maximum Data Value = 9
4. Sample Mean = 3.08
5. Sample Std. Dev = 2.32

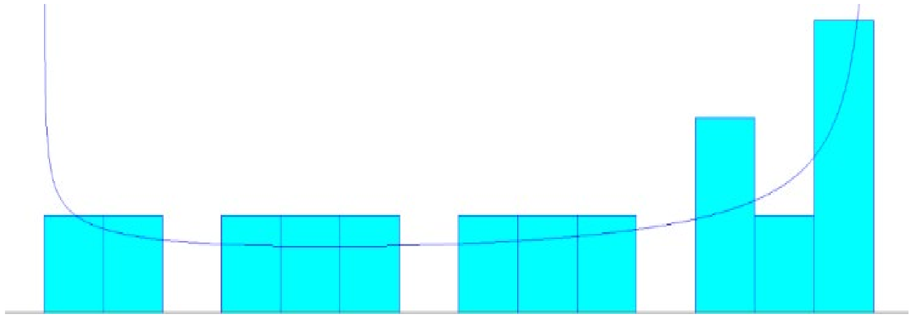

Fig. 5 Histogram for Service Time of Process-1

Here, inter arrival time is same and 30% of service time in this process.

Distribution
1. Type: Beta
2. Formula: 17.5+14*BETA (0.74,0.5)
3. Square Error: 0.018160

Data
1. No. Data Points = 14
2. Minimum Data Value =18
3. Maximum Data Value = 31
4. Sample Mean = 25.9
5. Sample Std. Dev = 4.59

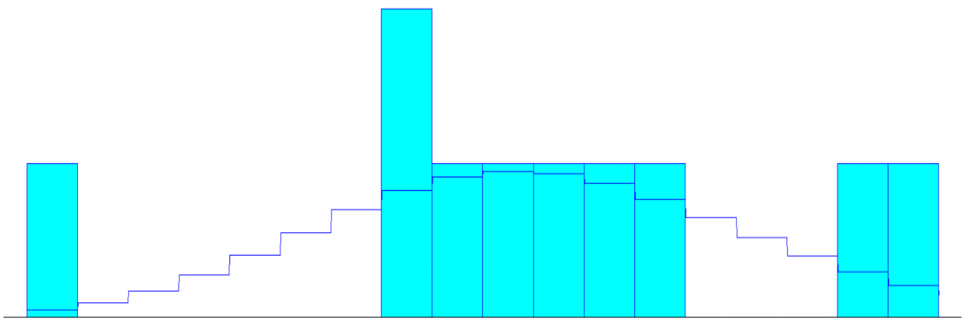

Fig. 6 Histogram for Service Time of Process-2

Here, inter arrival time is same and 25% of service time in this process.

Distribution
1. Type: Poisson
2. Formula: POIS (17.7)
3. Square Error: 0.053525

Data
1. No. of Data Points = 10
2. Minimum Data Value =8
3. Maximum Data Value = 25
4. Sample Mean = 17.7
5. Sample Std. Dev = 4.85

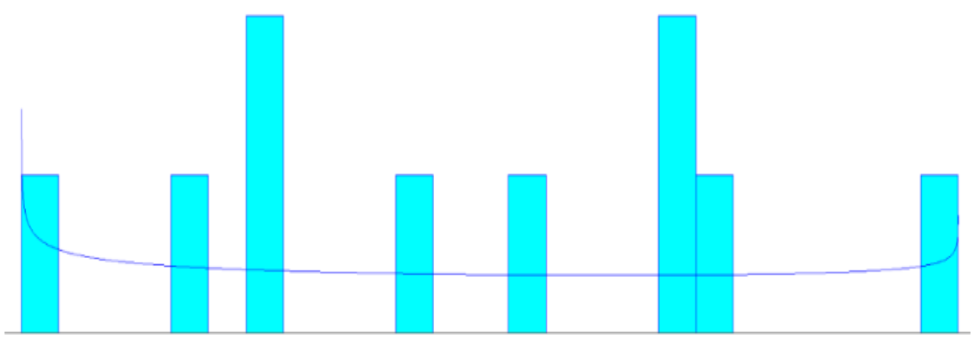

Fig. 7 Histogram for Service Time of Process-3

Here, Inter arrival time is same and 25% of service time in this process.

Distribution
1. Type: Beta
2. Formula: 10.5+25*BETA (0.835,0.905)
3. Square Error: 0.098574

Data
1. No. of Data Points = 10
2. Minimum Data Value =11
3. Maximum Data Value = 35
4. Sample Mean = 22.5
5. Sample Std. Dev = 7.55

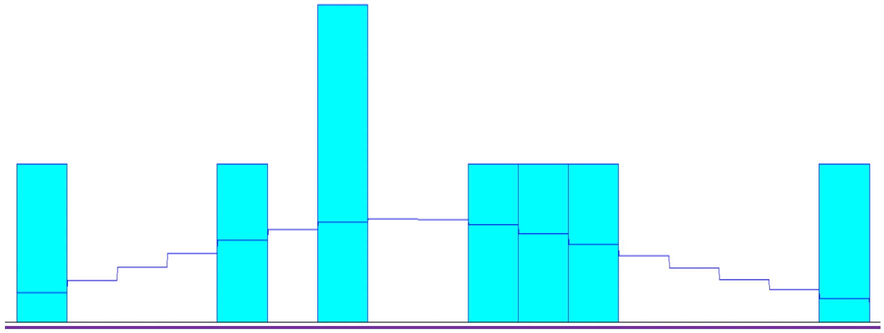

Fig. 8 Histogram for Service Time of Process-4

Here, inter arrival time is same and 20% of service time in this process.

Distribution
1. Type: Poisson
2. Formula: POIS (23.8)
3. Square Error: 0.088274

Data
1. No. of Data Points = 8
2. Minimum Data Value =16
3. Maximum Data Value = 32
4. Sample Mean = 23.8
5. Sample Std. Dev = 4.86

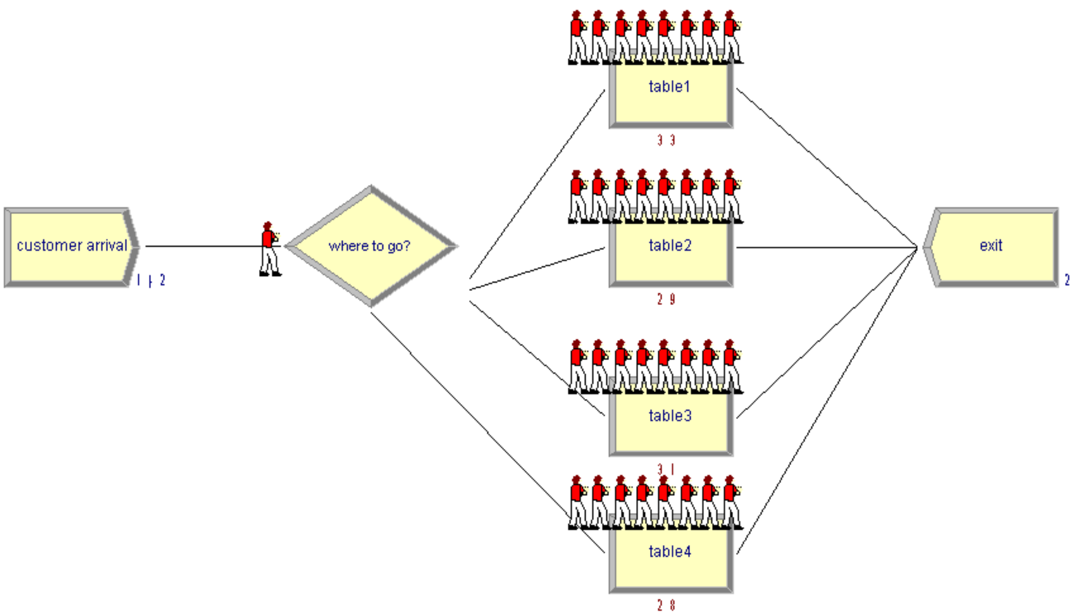

Fig. 9 Designed Model in Arena Simulation Software

B. Result

The following snaps from the Arena Software shows the results.

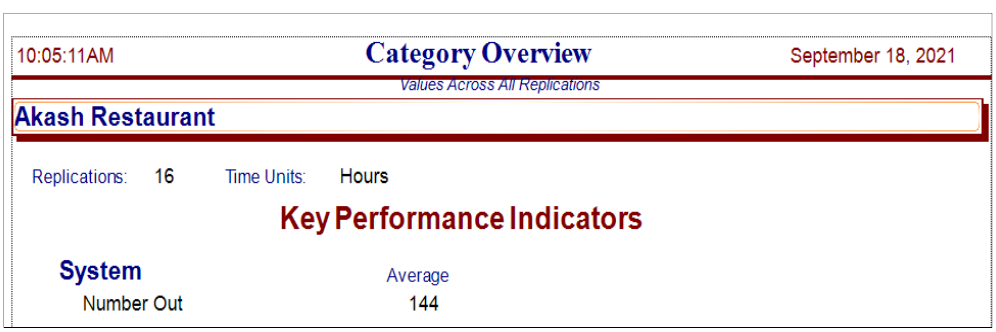

Fig. 10 System Output Overview

Replication 1 Start Time: 0.00 Stop Time: 100.00 Time Units: Hours

Entity

Time

VA Time	Average	Half Width	Minimum	Maximum
Entity 1	0.3797	(Insufficient)	0.1490	0.5966

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

Wait Time	Average	Half Width	Minimum	Maximum
Entity 1	24.1144	(Insufficient)	0	48.4181

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	24.4941	(Insufficient)	0.2371	48.6918

Fig. 11 Time Summary for Entity

Other

Number In	Value
Entity 1	150

Number Out	Value
Entity 1	150

WIP	Average	Half Width	Minimum	Maximum
Entity 1	36.7412	(Insufficient)	0	129.00

Queue

Time

Fig. 12 Resource utilization and waiting line by replication.

The average value-added time is 0.3797 minutes, with a minimum of 0.1490 minutes and a maximum of 0.5966 minutes. The average waiting time is 24.114 minutes, with a minimum of 0 minutes and a maximum of 48.4181 minutes.

The average total time is 24.4941 minutes, with a minimum of 0.2371 minutes and a maximum of 48.6918 minutes. The total number of outputs is 150. The average work-in-process time is 36.7412 minutes, with a maximum of 129 minutes.

10:16:34AM **Entities** September 18, 2021

Akash Restaurant Replications: 16

Replication 1 Start Time: 0.00 Stop Time: 100.00 Time Units: Hours

Entity Detail Summary

Time

	NVA Time	Other Time	Total Time	Transfer Time	VA Time
Entity 1	0.00	0.00	24.49	0.00	0.38
Total	0.00	0.00	24.49	0.00	0.38

Other

	Number In	Number Out
Entity 1	150	150
Total	150	150

Fig. 13 Entity Detail Summary

Here, total number in is 150 and total number out is 150.

10:18:46AM **Queues** September 18, 2021

Akash Restaurant Replications: 16

Replication 1 Start Time: 0.00 Stop Time: 100.00 Time Units: Hours

Queue Detail Summary

Time

	Waiting Time
server 1.Queue	25.30
server 2.Queue	23.27
server 3.Queue	25.11
server 4.Queue	22.30

Other

	Number Waiting
server 1.Queue	12.65
server 2.Queue	6.98
server 3.Queue	8.29
server 4.Queue	8.25

Fig. 14 Queue Detail Summary

The waiting time for server 1 is 25.30 minutes, for server 2 is 23.27 minutes, for server 3 is 25.11 minutes, and for server 4 is 22.30 minutes. The number of customers waiting at server 1 is 12.65, at server 2 is 6.98, at server 3 is 8.29, and at server 4 is 8.25.

9:02:45PM **Resources** September 19, 2021

Akash Restaurant Replications: 1

Replication 1 Start Time: 0.00 Stop Time: 100.00 Time Units: Hours

Resource Detail Summary

Usage

	Inst Util	Num Busy	Num Sched	Num Seized	Sched Util
Resource 1	0.57	0.57	1.00	150.00	0.57
Resource 2	0.35	0.35	1.00	100.00	0.35
Resource 3	0.27	0.27	1.00	70.00	0.27
resource 4	0.15	0.15	1.00	37.00	0.15

Fig. 15 Resource Detail Summary

The resource utilization for server 1 is 57%, for server 2 is 35%, for server 3 is 27%, and for server 4 is 15%.

V. DISCUSSION

The purpose of this research was to acquire knowledge about modelling and simulating a system. Although the system was relatively simple, consisting of four servers, it was observed that all servers were functioning properly. The knowledge and experience gained met the research objectives. We analyzed the random effects within the system and evaluated resource efficiency through simulation.

The simulation model involved several stages. Initially, we visited the selected restaurant and requested permission from the manager to collect data. The restaurant operates approximately 14 hours a day (10:00 a.m. – 12:00 a.m.). We observed the system for two hours (7:40 p.m. – 9:40 p.m.) and collected the necessary data. Using a program called ‘Process Analyzer,’ we conducted a statistical comparison between the new model and the average customer time in the system. The results indicated that the new model showed a statistically significant decrease in average customer time compared to the previous model. This suggests potential improvements in business performance at the restaurant with certain recommended adjustments to management and operations.

There are many additional ways to enhance the model and optimize productivity from both economic and commercial perspectives; however, we have only addressed a few here. With a larger dataset, the distributions could be more accurate, providing a clearer view of the system. For this type of queuing system, the most important performance metrics are average waiting time, average queue length, and server optimization. We were able to quantify these metrics based on the collected information and outcomes.

VI. LIMITATIONS

The study had several limitations, including a small sample size, which may affect the generalizability of the findings. Additionally, data collection was limited to nighttime hours, whereas a more comprehensive analysis would require data collection over the entire 14-hour working period to better capture the variability in customer arrivals and service demands. Furthermore, although there are numerous recommendations and model modifications available to maximize productivity from both economic and commercial standpoints, this study only addressed a small portion of these potential improvements. Expanding the scope to include a broader range of strategies could provide a more thorough understanding of how to optimize the system effectively.

VII. CONCLUSION

The maximum average waiting time at the restaurant is 48.4181 minutes, which is comparatively high. The number of queues is 12.65 for server 1, 6.98 for server 2, 8.98 for server 3, and 8.25 for server 4. These figures indicate inefficiencies that could negatively impact the restaurant's profitability and reputation. Data analysis reveals that servers 1 and 2 are occupied most of the time, while servers 3 and 4 are occasionally idle. The management could consider improving service policies for servers 3 and 4 to enhance service quality and reduce service time, which would minimize customer waiting and reduce time wastage. Resource utilization is 57% for server 1, 35% for server 2, 27% for server 3, and 15% for server 4. Based on the data and findings from the simulation model, management can gain insights into their service quality and identify fundamental issues. By addressing these issues, they can focus on improving service capacity and reducing service time.

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