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Modeling and Simulation

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21COMP02H

DEPARTMENT OF COMPUTER ENGINEERING

SIMULATING A CHAIN OF SUPERMARKETS

"Group project"

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Problem Statement

The goal of this project is to help the management of a supermarket chain to reduce the number of employees in the supermarket during non-peak hours.

The non-peak hours are the of low demand their customers are less likely to visit the supermarket hence giving the management a chance to reduce labor cost as customers are less likely to form a long irritating queue.

For a supermarket, the Off-peak hours are between 8 a.m. or at 8 p.m. on weekdays, as without a doubt weekend are the busiest days in the supermarket. Mondays and Tuesdays are the least busy.

Target Beneficiaries

The beneficiaries of the project are the entity or a group of individuals who might benefit from the project or the software submitted.

- The main beneficial of this software application is the management of the supermarket. Any company management aims to reduce the costs of their institution. There are many ways to reduce the costs of the institution, but most methods can affect the quality of the service/product. However, this project aims to reduce the labor cost without affecting the quality of the service or arising a critical situation be forming to long of a queue. This software application aims to reduce the labor cost in the off-peak hours therefore, the length of the queue will not be affected, and the comfort and satisfaction of the customers will be fulfilled.

- The second beneficial of this software application are the customers. Then the management are able to reduce the labor cost, this will allow the management to add expenses in offering the customers more verities of products, introducing more discounts, and focusing on the customer’s needs.

Adopted Programming language

The programming tool that will be used to general this software application will be MATLAB R2021b for both modeling and simulation.

The programming language used will be MATLAB which is a programming language that started out as a matrix programming language to simplify linear algebra programming. MATLAB is used to analyze algorithms, data and create models. MATLAB offers an impressive library of function which will help execute this software application.

System Analysis

- **The type of the system:**
  The service process appeared to be continuous, which may lead to the failure of human resources and even inanimate objects inputs. There should also be a dynamic and efficient mechanism in place by the store management to search out new products optimum use of the system.
- **The objective of doing the simulation:**
  This would aid in lowering the Costs linked with system usage to have a propensity to escalate as time goes on.
- **The elements that represent the system:**
  i) The employees (cashiers, baggers)
  ii) Items sold in the supermarket
  iii) Activates done by the customs
    (1) Coming to the store
    (2) Picking items
    (3) Checking out
    (4) Bagging items
    (5) Loading items back to their cars
  iv) The queue in which the customers will be served for checking out
- **The parameters:**
  i) Customer service time
  ii) Customer arrival rate to the system
  iii) Customer arrival time to the queue
  iv) Number of customers in the queue
  v) Number of busy employees (cashiers and baggers)
  vi) Simulation time

- **The variables of interest:**
  i) Number of Customers in the system
  ii) Customers service time
  iii) The time (Off-peak or Peak hour)

- **The environment around the system:**
  i) The number of items picked by each customer
  ii) The type of items picked by each customer
  iii) The time it takes the customer to pick the items
  iv) The time it takes the customer to load the items to their car

Anticipated Time Plan

This Gantt chart provided to show the actual time spent in each phase of the project as well as the overlapping among the different activities of the project.

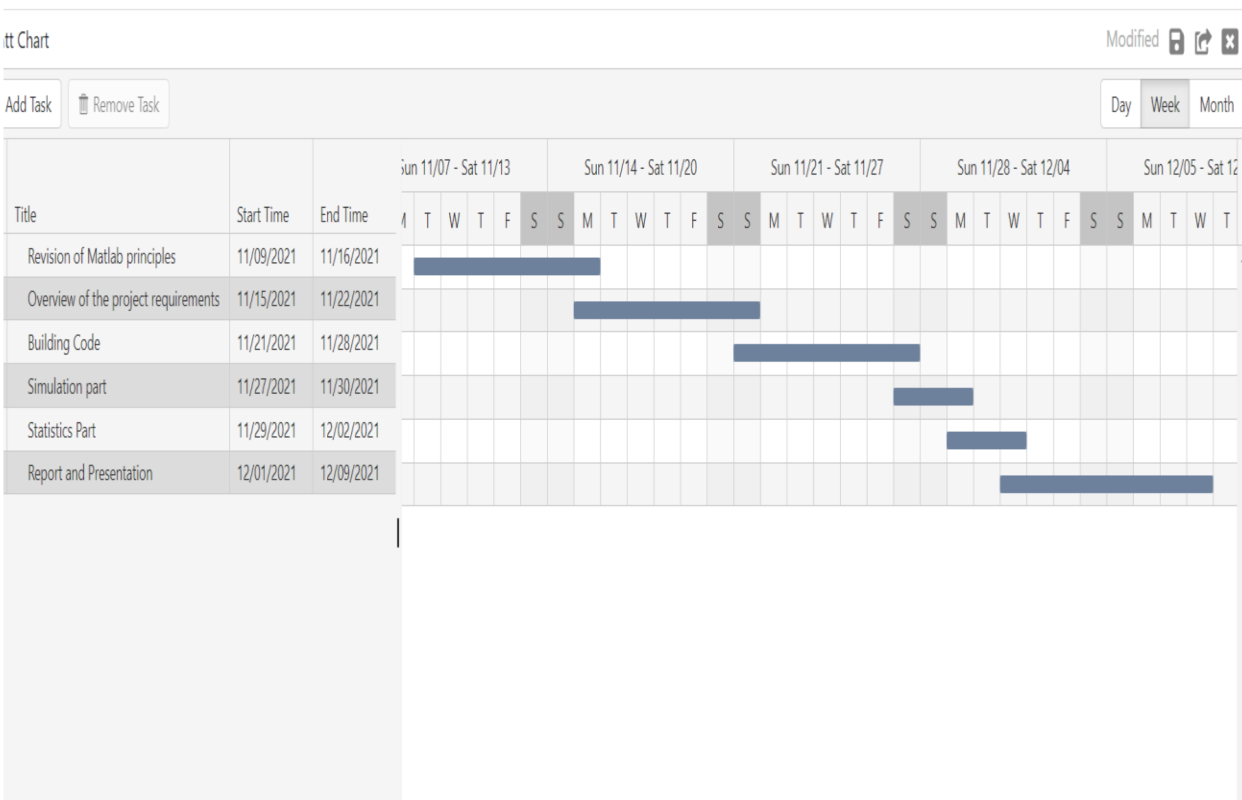

Figure 1 time plan

Input analysis

In the system of supermarket, we use two types of distribution. First passion distribution which means the number of events occurring in a fixed period of time. Events occur with a known average rate and are independent. Poisson distribution is characterized by the average rate (lambda). Lambda in the code refers to the arrival rate. The average number of arrivals in the fixed time period. We use passion distribution to calculate:

1- Inter arrival.
2- Customer arrival to the supermarket.

And second type is exponential distribution describes the times between events in a Poisson process, in which events occur continuously and, independently at a constant average rate. A random variable X is exponentially distributed with parameter mu=1/lambda. Mu in the code refers to service rate. We use exponential distribution to calculate:

1- Customer service time.
2- Probability distribution of the customer to pick items.

Conceptual Simulation Model

The Conceptual model clarifies the behavior of the process steps from the customer side, the customer goes through several steps in our model simulation, in the first the customer enters the supermarket store by defined arrival rate that is used to know the customer arrival distribution, then the customer picks the items for shopping and get in the queue by service rate during waiting in the queue, pay for the items, bagging and checking out.

Resources Needed

The tool used in the project for simulating the model is MATLAB software program which was used for creating the model and testing it. The model was first written on MATLAB script and then simulated by running the code. Below are some built-in functions used in the model.

- **poissrnd**: random Poisson probability distribution
- **exprnd**: random exponential probability distribution
- **cumsum:** cumulative sum
- **syms:** creates symbolic scalar variables

Model Validation

This section explains how the model was validated as reliable. Firstly, building the model as whole was based off real-life supermarkets and how they function. All data assumptions were based off researching the real numbers in an average supermarket, such as daily number of visitors during rush and non-rush hours, number of products in an average sized supermarket, and number of servers in a supermarket.

Since Inter-arrival time for customers is randomly distributed it was obtained by applying random Poisson distribution which will return the most possible accurate values to be used in the simulation. Similarly, exponential distribution was used to get the average customer service time for all customers in the queue. The number of customers can be entered by the user during the simulation which allows the model to depict the output in a realistic manner.

Performance Analysis

Our investigation revealed that the value of an arrival rate that will produce congestion differs between analytical and simulation results. However, at arrival rates that are smaller or much higher than the value, both models showed nearly identical performance metrics. The findings may provide insight into the range of arrival rates that will maximize the source corridors' throughputs.

- **The probability that there are zero people or units in the system P0=**

$$\frac{1}{\left[\sum_{n=0}^{C-1}\left[\frac{1}{n!}\right]\left[\frac{\lambda}{\mu}\right]^{n}\right]+\frac{1}{C!}\left[\frac{\lambda}{\mu}\right]^{C} * \frac{C\mu}{C\mu-\lambda}}$$

=1440/1849

- **The average number of units (Customers in the system) L=**

$$\frac{\lambda\mu\left[\frac{\lambda}{\mu}\right]^{C}}{(C-1)!(C\mu-\lambda)^{2}} * P_0+\frac{\lambda}{\mu}$$

= 6934/27735

- **The average time a unit spends in the system (W) =**

$$\frac{\mu\left[\frac{\lambda}{\mu}\right]^{C}}{(C-1)!(C\mu-\lambda)^{2}} * P_0 + \frac{1}{\mu} = \frac{L}{\lambda}$$

= 6934/138675

- **The average number of customers waiting in the queue (Lq) =**

$$L - \frac{\lambda}{\mu}$$

= 1/110940

- **The average time a customer spending waiting in the queue (Wq) =**

$$W - \frac{1}{\mu} = \frac{L_q}{\lambda}$$

= 1/554700

- **Utilization factor of the system (ρ)**

$$\rho = \text{utilization factor for the system} = \frac{\lambda}{\mu C}$$

=0.84584552

Proposed improvement scenarios

1- Reducing the number of employees as the cashiers and baggers by the half during the non-peak hours as it reduces the salary costs for the supermarket management as they feel there is excess of workforce as a process improvement for the system will have only two cashiers and two baggers during these non-peak hours and our system provides the user to input the number of customers entering the supermarket store and through some calculations the system outputs if there is non-peak our or not and also outputs the number of cashiers and baggers needed in the system.

2- the management could come up with a software application that displays to the user if there are certain discounts on certain items

3- It is also a good idea for the supermarket to invest in a server less cashier cashing system for customers with light items less than ten. At the beginning of such investment the management might find a higher cost, however as time passes the labor cost will be reduced significantly.

Conclusion

To reduce supermarket queue times, we use many characteristics to create a systematic queue allotment, such as quantity first, followed by time. MATLAB may be used to observe the entity using an exponential input and the provided figures. Organize managers and staff to study and train on the latest trends in customer behavior, as well as modern management approaches and experiences, in supermarkets. Modern technology allows clients to receive better service without having to spend more time, and with better results.

References

1- (Efficiency of Controlled Queue system in Supermarket using MATLAB / Simulink, Balaji, 2017;)

2- (A Discrete Event Simulation Model for Evaluating the Performances of an M/G/C/C State Dependent Queuing System, Khalid R, Mohd M et al., 2013;)

3- (QUEUING THEORY AND ITS APPLICATION, Sc, 2007)