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Designing a Simulation Model for the Milk Carton Filling Line

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Abstract: *This research built a simulation model of the cans line mobilization process yogurt in the Mosul dairy factory to see average waiting time per can and the average number of cans that remain in the queue before the filling process. Where the model was built using Microsoft Excel and queuing model used for this study is the kind of M/M/1: (FeFs,00,00). The results are that the time of waiting for each packet in the queue about (17) minutes and the average number of cans in the queue is (206) can of the total cans (1440 packqge) for that day.*

Key word: *Model, Simulation, Queues.*

1. INTRODUCTION

Simulation is a powerful and widely used tool in science in general, which is concerned with studying and analyzing complex systems. Simulation can be defined as a method by which the operations of a real system can be imitated (simulated) over a period of time. This method can be obtained by developing a simulation model, and this model usually takes the form of a set of assumptions about the system process expressed in the form of mathematical or logical relationships between the elements of the model under study. In contrast to the purely mathematical solutions associated with analytical models, simulation methods are used to implement the model over a period of time, real data representing real performance measurements. Waiting is a condition that most people go through and notice, you see them at bus stops or in front of reservation windows, and the waiting theory aims to determine the time period for waiting in the long term and make that period as short as possible, as well as to determine the length of the waiting line (i.e. the expected number of units joining the waiting line.

History of the Dairy Factory:

The Oyoun Al-Rafidain Dairy Factory is one of the important and vital factories in Iraq, as it contributes to providing the basic food needs necessary for daily consumption of citizens, so the factory is one of the effective economic units that aim to ensure food security for the country.

The Oyoun Al-Rafidain Dairy Factory is one of the private sector factories supervised by the Ministry of Industry and Minerals, established in 2016, and began actual production on March 20, 2016. The factory provides dairy products with standard specifications to meet part

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of the citizens' need for the following dairy products (milk of all kinds, qaymar, yogurt, cheese of all kinds, animal fat).

Research Problem: It was noted during the researchers' visit to the laboratory that there is a waiting line for the filling process of milk cartons (250 gm. capacity).

Research Objective:

The aim of the research is to know the average waiting time for each carton of 250 gm. type and the average number of cartons that remain in the waiting line until they are filled, in order to reduce the waiting line for cartons in the waiting lines, and thus lead to the speed of preparing the cartons filled with the product.

Simulation models

Models are one of the most important means that researchers use to understand complex systems whose details are difficult for the analyst to comprehend by simply observing them. In such cases, the analyst builds a model of what he wants to study that is an honest representation of the reality in the system and an abstraction of its components and details, and then deals with the model instead of the system. Models are divided into several known types, including: physical models such as objects, mathematical models such as equations and algorithms, and logical models such as computer simulation models.

Computer simulation applications extend to many specializations and interests, including: administrative decision support, engineering applications (computer networks - industrial engineering - chemical engineering - scientific applications - natural phenomena - chemical reactions - environmental and geological systems), in addition to the uses of computer simulation in education and training.

The computer simulation model is a representation of the static components of the system and the relationships that link them together, in addition to a logical representation of the dynamic behaviors and characteristics of the system over a specific period of time, and under certain hypotheses related to the operation of the system and its components. The simulation model enables the researcher to conduct hypothetical experiments on the model instead of conducting them on the real system in order to test certain theories about this system or answer questions about the system's reaction as a result of the fulfillment of certain conditions or the occurrence of certain events in this system. The use of computer simulation models is usually the last choice after exhausting the possible options of different types of models, due to the difficulty of applying these models, which may usually happen in the case of mathematical models compared to the reasons for the unavailability of data and to test the validity of the mathematical model. In such cases, computer simulation comes as a strong and available alternative to represent these complex systems and how they work on the computer, as it allows conducting a set of well-designed experiments to answer the questions raised about these systems related to the interactions of the studied system with its environment or perhaps the extent to which the system's outputs affect changing a certain number of inputs.

Stages and steps of computer simulation study (Ramadan, 2007, 23-28)

The following are the stages that computer simulation study goes through and the steps that must be followed to complete it. Figure 1 illustrates these stages and the relationship between them:

1-Problem definition

It is important before starting to implement the simulation study that it be preceded by a planning stage in which the study objectives, feasibility, and suitability of the simulation method as a means of achieving the desired are determined. Also, in this step, the variables that determine the decision (Decision Variables) and the parameters (Parameters) that cannot be controlled, and the performance indicators (Performance Indicators) whose performance will be measured by monitoring their values must be defined.

2- Building the initial model

this step includes identifying the fixed components of the model from the following elements:

a. **Entities:** defined as anything related to the system that has attributes (activities) and performs activities (attributes).
b. **Events:** which are the temporal facts that result in a change in the state of the system .
c. **State variables:** which are the set of variables necessary to describe the state of the system at any time according to the study objectives.

In this step, data about the system is generated either manually or automatically according to the study objectives and the required degree of accuracy in exchange for the financial and time cost. This data is also statistically analyzed in order to infer the statistical pattern of the data using one of the known statistical distributions. If this is not possible, the sample of data collected can be used directly in the simulation program, although this makes the program implementation slow.

4- Converting the model into a computer program

In this step, the computer simulation program is developed based on the initial model and statistical information extracted about the system. The development process includes designing the program as a plan, then choosing the programming language and development tools. Specifically, the theoretical model required to be simulated, which was prepared based on a survey and analysis of this system, is converted into a computer model that represents a detailed design for the simulation program required to be developed. This step necessarily requires establishing the type of simulation model and choosing its construction method from among the methods known to specialists.

5- Model Verification and Validity

The model verification process aims to ensure the internal coherence of the computer model and its compatibility with the initial model. The model validation process aims to compare the computer model with the real mathematical model to ensure the quality of the computer simulation model's representation of the real mathematical model, whether in terms of appearance or in terms of representing the transformation process that takes place inside it on the inputs to convert them into outputs. The testing and quality assurance process is one of the main tasks in any simulation study after the completion of the programming and software development process. the developed program in terms of the logical and functional correctness of the programming. It also includes ensuring the validity of the simulation program as a model that accurately expresses the behaviors of the real mathematical model.

Queues:

Queues are a very common phenomenon in daily life, and there are very few individuals in any modern society who do not have to stand in line to get on an elevator, get a train boarding pass, or get fuel from gas stations. Many of us consider queues an unavoidable phenomenon in modern cities in light of the development of urban and regional planning in general (Al-Hanawi, 2022, 253-254). The phenomenon of waiting is a direct result of the randomness in the operation of service centers. The arrival of customers to request the service and the time of performing the service are generally not known in advance, otherwise it would be possible to schedule the operation of service centers in a way that might lead to avoiding waiting completely. Our goal in studying the operation of service centers under random conditions is to arrive at some characteristics of measuring the performance of the service system under study. For example, measuring the period that a customer is expected to wait before receiving the service is a logical measure of performance. Measuring the percentage of time that service centers remain unused is also a logical measure of performance. It is noted that the first measure looks at the system from the customer's point of view, while the second measure assesses the degree of utilization of the service center. We can see that the longer the customer waits for the service, the smaller the percentage of the service center remaining unused and vice versa. Therefore, these performance measures can be used to choose the service level (or service rate) that will achieve a balance between these two conflicting situations (Taha, 2018, 739-740).

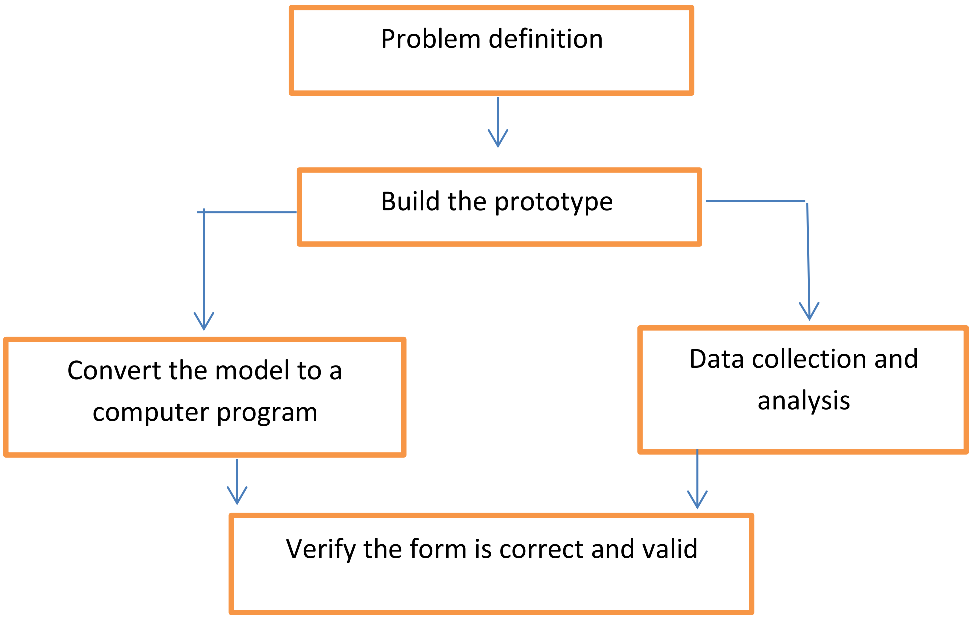


Figure 1 Steps and stages of the simulation study

Waiting Systems: There are four basic forms of waiting lines that represent in themselves the general framework of the waiting line and the service performance center (Jazza, 2005, 469-494):

1- A waiting system with a service performance center and a single stage, which is the form used for this study.

exit Service Performance Center entrance

Figure 2

A single-stage service centered queuing system

2.A single-stage, multi-service center-based queuing system .

3.A multi-stage, multi-service center-based queuing system .

4.A multi-stage, multi-service center-based queuing system .

Examples of queuing models (Al-Najdi, 20200, 7):

1-(M\M\1): (FcFs\∞\∞)

2- (D/M/1): (GD/∞/∞)

3-(M/M/3): (fcFs/∞/∞)

4- (GI/G/1): (GD/∞/∞)

Since the model used is (M/M/1): (FcFs/∞/∞)

Where:

M stands for the probability distribution of entry time, which is a negative exponential distribution.
M stands for the probability distribution of departure time or service time (which is a negative exponential distribution).
1 .It stands for the number of service centers
FcFs stands for the **fifo** service system (i.e. first come first served)
∞It stands for the system capacity .
∞It stands for the type of entry community.
Performance measure for waiting lines.
These are the measures by which the efficiency of the waiting line is determined in terms of the entry rate.
Service rate, waiting line length, and waiting time in it (Al-Najdi, 2021, 8-10)

1-**Waiting line length Lq:**

It represents the number of customers in the waiting line at a specific time, and is one of the most important measures for measuring the efficiency of the system, as the waiting line increases, the efficiency of the system decreases.

2- System waiting line length Ls

It is the number of customers in the waiting line plus the number of people in the service center at a certain time, as there are often a number of customers who receive service even if the waiting line is empty, and thus the system is affected as its efficiency decreases when the number of people in the service units increases.

3-Expected waiting time in the waiting line: Wq

It is the expected waiting time inside the waiting line excluding the time spent inside the service center, and increasing the waiting time reduces the efficiency of the system.

4-Expected waiting time in the system Ws

It represents the expected waiting time in the waiting line plus the time spent inside the service center.

5- λ: It represents the average number of people entering the waiting line during time and with an increase in the value of , over the system capacity, this leads to a decrease in the efficiency of the system.

6- **μ:** It is the average number of people leaving (served) during time. The more the average number of people entering is greater than the average number of people leaving, the less efficient the system is.

7-(t) N: It is a random variable that expresses the number of customers in the system at time.. The more customers there are, the less efficient the system is.

8- λ' is the average time to enter the waiting line during the time unit (t) and is equal to ($\frac{\lambda}{1}$). The higher the value of (λ'), the smaller the size of the waiting line, and the lower the value of (λ'), the longer the waiting line is.

9-μ': The average service time during time and is equal to ($\frac{\mu}{1}$). The higher the value of (μ'), the longer the waiting line will be, and the lower the value of (μ'), the shorter the waiting line will be.

10. Traffic density: (ρ) is the ratio of those entering to those leaving the waiting line during a unit of time.

When $\rho < 1$, the arrival community is limited (N) and is useful in measuring the balance of the waiting line, whereas when $\rho > 1$, meaning that the entry community becomes unlimited (∞)

11- **System State:**

If (t) Pn is the probability of having (n) customers in the system at time (t), then the system is described as being in a time-independent state (stationary) if the behavior of the system does not depend on time, i.e. the probability (t) Pn does not depend on time, so it is symbolized by (Pn) and the system is in a state of:

$$\lim_{t \to \infty} pn(t) = \text{Pn}$$

12- Busy period

It is defined as follows: "It is the period of time from the moment the first unit enters the system after it was empty until it returns empty again. The longer the busy period, the longer the waiting line, and the less efficient the system is." $Pn \geq 1 = 1 - P0$, taking into account the periodic, transient and sudden variables of the system.

The applied or practical aspect

After the researchers visited the Oyoun Al-Rafidain dairy factory on (11/5/2024) and watched the production flow and the process of filling milk cartons (as the filling that day was for milk and placing it in 250-gram cartons), it was noted that the carton flow has a fixed time and takes 5 seconds until it reaches the milk pipes, i.e. (λ^'=5) and then takes 7 seconds to complete the filling process for each carton, i.e. the service time as well, which represents (μ^'=7) during the time period from 8:00 am to 10:00 am (which is the period allocated for the filling process on that day), and Figure 3 represents the flow chart of the process.

Since the service time and arrival time are in seconds and the duration of completing the filling process is two hours, therefore the simulation cannot be done manually, a computer program was designed using Microsoft Excel as in Table (1), in order to calculate:

Since the service time and arrival time are in seconds and the filling process takes two hours, the simulation cannot be done manually. A computer program was designed using Microsoft Excel as in Table (1), in order to calculate:

The average waiting time for each box during a period of (2) hours (because the time allocated for the filling process during that day is two hours) according to the following law:

The average waiting time for each box = the total waiting time for the boxes / the number of boxes

The number of boxes was also found in the simulation time period, by drawing a chart representing the change in the number of boxes in the waiting line and the simulation time, and Figure 4 illustrates this.

The average number of cans in the waiting line was also obtained by finding the area under the curve (which represents the number of cans * waiting time) and dividing it by the simulation time period (2 hours) according to the following law:

Average number of cans in the waiting line = Area under the curve / Length of the simulation period

Where the area under the curve is calculated by finding the sum of the product of the length of the time period and the number of cans in the waiting line, where from (08.00.05) to (08.00.07) one can is waiting, so the area for that part will be (2*1), so the (total) area under the curve = 1*2+1*4+2*6+... etc.

The traffic density was also calculated according to the following law:

$$P = \frac{Average\ service\ time}{Average\ entry\ time} = \frac{\mu'}{\gamma'}$$

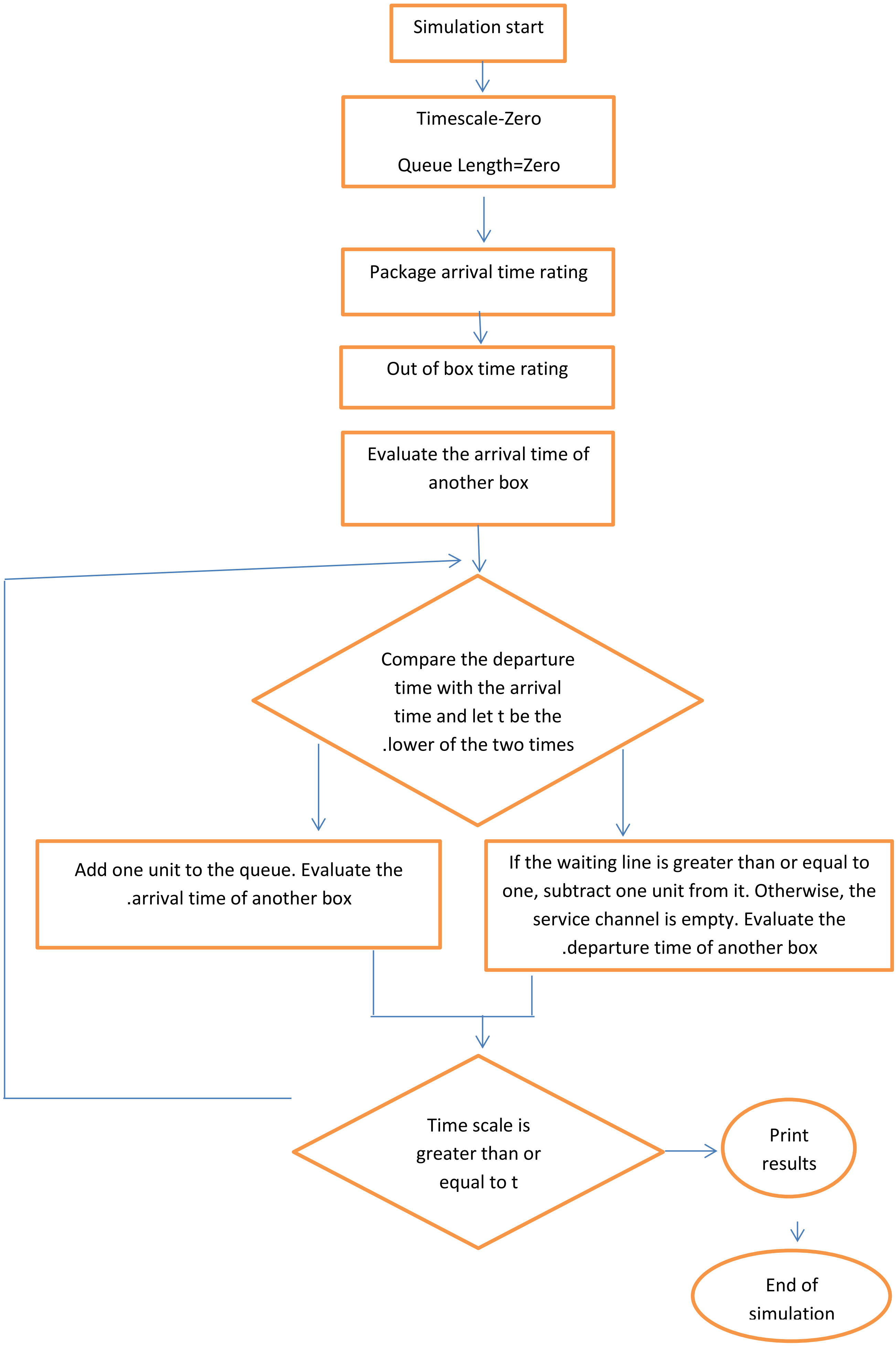
Conclusions:

-The average waiting time for each box is (1028.857) seconds, which is approximately 17 minutes.

-The average number of boxes in the waiting line is 205.7714 boxes, which is approximately 206 games

-The area under the curve is 1481554

The traffic density is 1.4


Simulation start
Timescale-Zero
Queue Length=Zero
Package arrival time rating
Out of box time rating
Evaluate the arrival time of another box
Compare the departure time with the arrival time and let t be the .lower of the two times
Add one unit to the queue. Evaluate the .arrival time of another box
If the waiting line is greater than or equal to one, subtract one unit from it. Otherwise, the service channel is empty. Evaluate the .departure time of another box
Time scale is greater than or equal to t
Print results
End of simulation

Recommendations: To reduce the time required to fill a box, we suggest increasing the number of workers, or we can say doubling the number of workers, which will reduce the time required to fill a box (service time) by almost half, which will lead to faster box filling, and thus reduce the number of boxes standing in the waiting line.

Researchers work

		comc	comc	comc	full	full	full	Waiting in queue	
08:00:00	1	0	0	0	0	0	0	0	0
08:00:01	2	0	0	0	0	0	0	0	0
08:00:02	3	0	0	0	0	0	0	0	0
08:00:03	4	0	0	0	0	0	0	0	0
08:00:04	5	1	1	1	0	0	0	0	1
08:00:05	6	0	1	0	0	0	0	0	1
08:00:06	7	0	1	0	1	1	1	0	0
08:00:07	8	0	1	0	0	1	0	0	0
08:00:08	9	0	1	0	0	1	0	0	0
08:00:09	10	1	2	2	0	1	0	1	1
08:00:10	11	0	2	0	0	1	0	1	1
08:00:11	12	0	2	0	0	1	0	1	1
08:00:12	13	0	2	0	0	1	0	1	1

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