Final Report

Industrial Systems Simulation

Modeling and Simulation of products testing at Taif national dairy factory

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1.Introduction

Each factory has production problems, which may be a reason for delaying the production of the product or even destroying the product and causing a loss of those resources and thus leads to a deterioration in the quality of service for those factories. Taif National Dairy Factory is one of those factories that need a study to reduce the expected problems above And by using simulation programs, this will help us in dealing with the entities (products) and knowing the procedures that will reduce those problems. Therefore, this study reviews the modeling and simulation of products in Taif National Dairy Factory.

1.1 Problem context:

The time taken by samples to be tested in the laboratory causes delays in the production line of products in the factory. Because of the delay in the production line, the management needs workers to work overtime to complete the orders, and overtime costs the factory to pay the workers additional expenses. one hour of overtime costs 100 riyals per worker. Also, delaying the production line delays the delivery of orders and will reduce customer satisfaction.

1.2 Project objectives:

Our objective from this simulation are:

- Increase productivity of Taif National Dairy Factory.

-Covering the demand promptly with the required quantities .

-Decrease waiting time for the laboratory.

-Reducing laboratory problems to improve the production line.

-Improve the utilization of the testing machines.

1.3 Project Scope:

Studying the time required to test samples of the buttermilk in the laboratory to obtain approval to complete the production line.

1.4 Project Stakeholders:

- The main stakeholder is the management of the Taif National Dairy Factory:

Taif National Dairy Factory is interested in providing its products with high quality in accordance with the requirements of the Food and Drug Authority. It is also concerned with the delivery of products on time for delivery. Therefore, our study will help the factory management to achieve these points by providing an integrated analysis of the system, waiting times for products due to the time it takes inside the laboratory, problems that the factory may encounter during production, and the necessary improvements that the system needs. Therefore, the form and a detailed file of instructions for using the form will be presented to manage the factory to achieve the desired objectives of the study.

- Entities to which the factory supplies (customers):

Customers will be directly affected by the improvements that aim to achieve customer satisfaction through the commitment to cover the customer’s request in the required quantities and at the time specified by agreement between the customer and the stakeholder.

2. System Description and Modeling Approach

This section illustrates an overview of the system components and its operations.

2.1 Entities Type:

In this system, there is one type of entity, which is the samples of the buttermilk products. A sample is taken from each stage to be examined in the laboratory and to verify that it conforms to the standard specifications.

2.2 System Resources:

The Taif National Dairy Factory has a lot of resources, including the resources listed below, which were included in the system's study. These resources are divided into:

- **Human Resources:**

Laboratory Technicians: They take random samples from each stage for testing in the laboratory.

Machine operators: Workers who operate and supervise machines as well as transport samples to the laboratory.

- **Equipment:**

Fig(2.2.1) Mixing tester equipment

Fig (2.2.2) Thermometer

Fig (2.2.3) Ph meter

2.3 System Operations:

The process is divided into five main tests in the laboratory:

- Mixing test
- Pasteurization test
- Cooling test
- Storage test
- Packing test

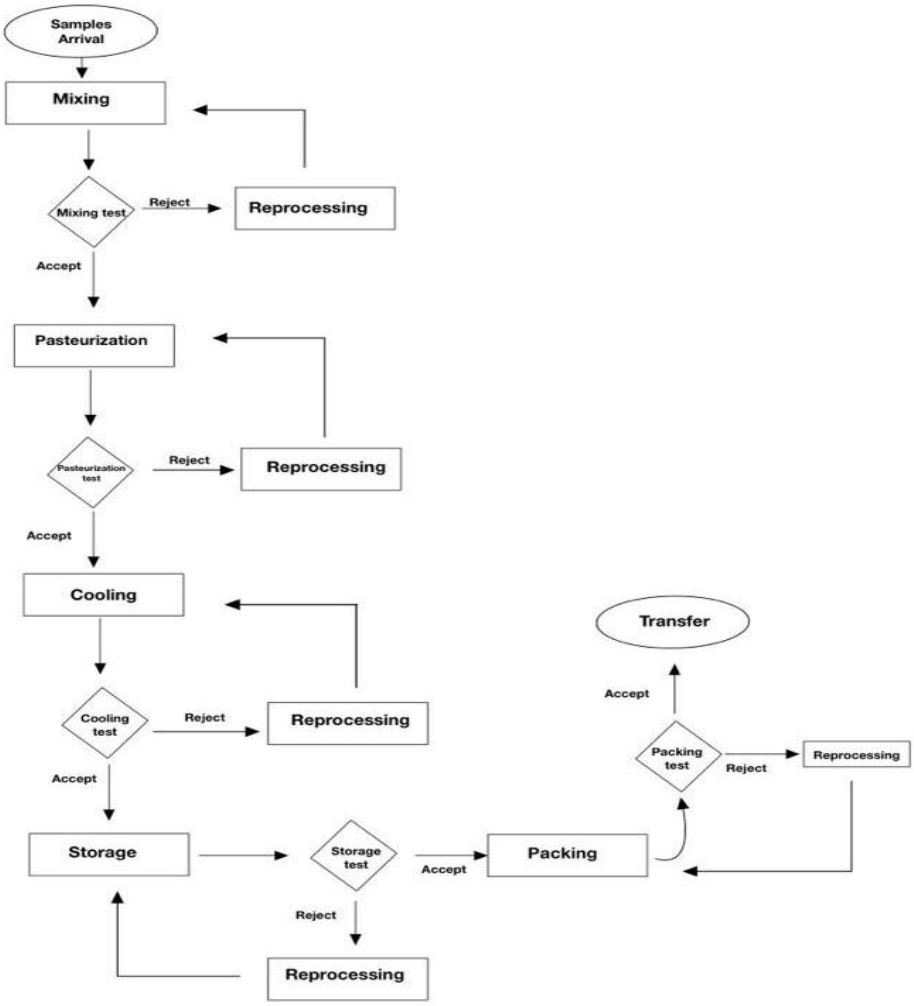


Fig (2.3.1) Process flow chart

As shown in Fig. 2.5.1 above; The five main stages will be examined in the laboratory. This is done by taking samples after completing the stage to ensure that they comply with the specifications and standards. The tests are divided into tests by devices and others by visual examination, as shown below: First, the mixture process, in this process, the ingredients needed to make the mixture are prepared and mixed. After completion, a sample is taken for examination to ensure that the mixture is completely homogeneous. In the pasteurization process, in this process, the milk is heated to 90 degrees Celsius, and after completion, a sample is taken to check whether the required heating degree has been reached. The cooling process In this process, the mixture is suddenly cooled until it reaches 40 degrees Celsius. After that, a sample is taken from it to make sure that all the microbes in the mixture are killed. Storage process, in this process, yeast is added to the mixture, and after completion, a sample is taken to check its pH value through a dedicated device (Ph meter) as well as make sure that the mixture reaches the appropriate consistency. Finally, in the packing process, at this process, the buttermilk is filled into the boxes designated for it, and after the filling is completed, a sample is taken from the packages to ensure the packing and safety of the packages, as well as to verify that the packing dates are printed on them.

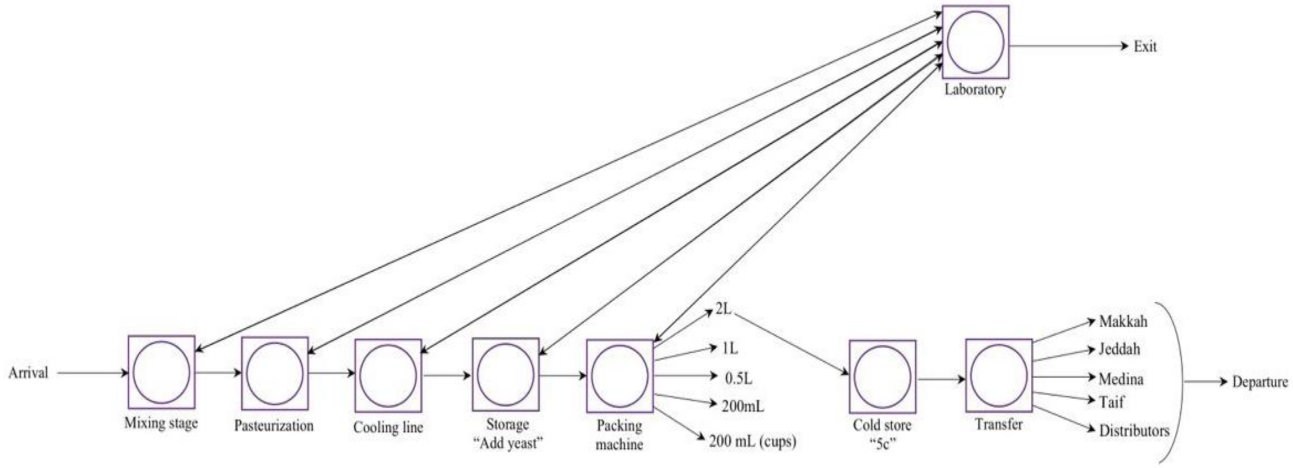


Fig (2.3.2) Queueing Network (Buttermilk)

Queue discipline: FIFO. **Queue configuration:** Single line.

2.4 Transportation:

There are two types of transportation in this system:

- Internal transportation: Transportation of product samples between stations to the laboratory is considered internal transportation. In other words, after the completion of each stage of the production line, a sample is taken to the laboratory by worker to be examined and to ensure that it conforms to the specifications.
- External transportation: External transportation includes transferring products to delivery trucks to take them to customers in different places.

3. Input Data

This section illustrates an overview of input data that required to construct the model.

3.1 Type of Input data:

The input data is a discrete data which are time values, there are two kinds of values which are the arrival time of the product and the service time that the product take it in each server in the laboratory.

3.2 Collection Plan and Execution:

At the beginning of the data collection process, we were provided with data of demand of 30 days, i.e. 30 orders from the buttermilk producer. We held some meetings with the factory manager and the production manager to get acquainted with the layout of the factory and how the products move inside it and through each station. We were also taken on a tour inside the factory, in order to get clear vision so that we could model and simulate the process, so we assigned the tasks among the team members as shown below:

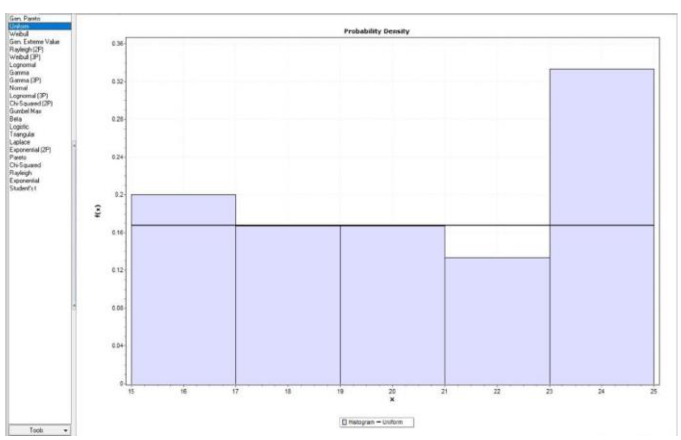
- Upon entering the factory, Three members of the team observed the mixing tester and pasteurization tester to know the service time and the arrival time for the prouducts.
- Four members of the team observed the cooling tester, storage tester, and packaging tester to know the service time and arrival time for the prouducts.

3.3 Data Analysis and Fitting Distribution:

We modeled the system as stochastic model where the input are random draws from probability distribution , stochastic model has the capability to forecast thousands of potential future scenarios, that develops every time based on the data, it's also modeled the variation of those data also one of the main benefits of a stochastic model is that it is totally explicit about the assumptions being made it allow us to test our assumptions and test different scenarios that maybe happening in the system.

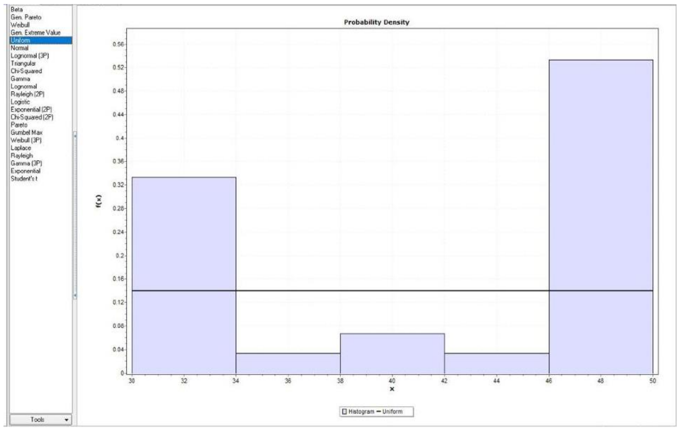
So we analyzed the data to find the best distribution fit with it, we used EasyFit program and input parameters at SIMIO. The analysis results showed the following:

- The mixing tester data which is Uniform, we used EasyFit to find the best distribution for this data. As figure below shows the appropriate distribution was Uniform based on chi squared ranking. After that we exported the appropriate expression to use in SIMIO which is (Random.Uniform(15,25)).



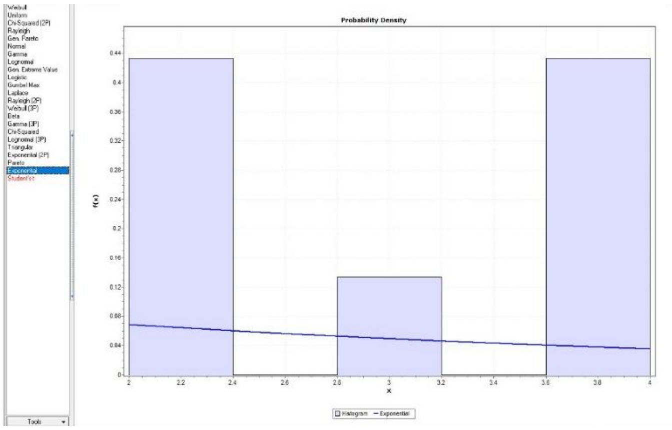
Fig(3.3.1) The distribution of the service time of mixing tester

- The pasteurization tester data which is Uniform, we used EasyFit to find the best distribution for this data. As figure below shows the appropriate distribution was Uniform based on chi squared ranking. After that we exported the appropriate expression to use in SIMIO which is (Random.Uniform(30,50)).



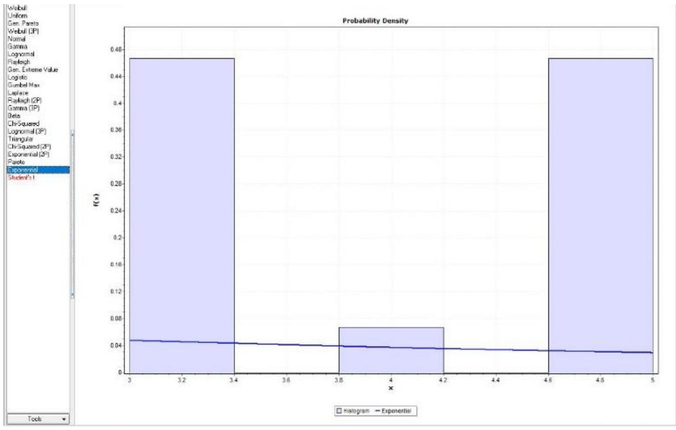
Fig(3.3.2) The distribution of the service time of pasteurization tester

- The cooling line tester data which is Exponential, we used EasyFit to find the best distribution for this data. As figure below shows the appropriate distribution was Exponential based on chi squared ranking. After that we exported the appropriate expression to use in SIMIO which is (Random.Exponential(3)).



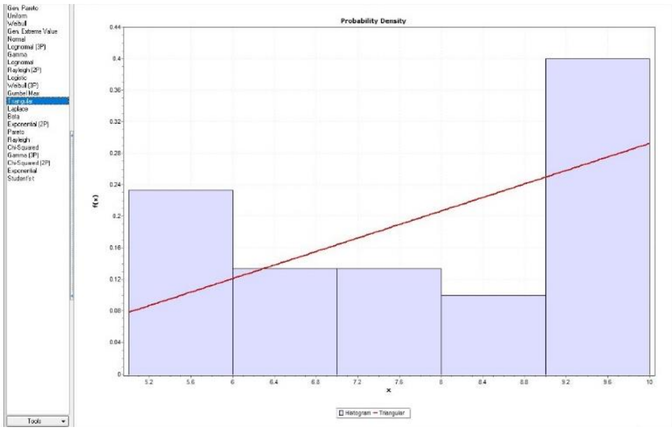
Fig(3.3.3) The distribution of the service time of cooling line tester

- The storage tester data which is Exponential, we used EasyFit to find the best distribution for this data. As figure below shows the appropriate distribution was Exponential based on chi squared ranking. After that we exported the appropriate expression to use in SIMIO which is (Random.Exponential(4)).



Fig(3.3.4) The distribution of the service time of storage tester

- The packing tester data which is Triangular, we used EasyFit to find the best distribution for this data. As figure below shows the appropriate distribution was Triangular based on chi squared ranking. After that we exported the appropriate expression to use in SIMIO which is (Random.Triangular(5,7.5,10)).



Fig(3.3.4) The distribution of the service time of packing tester

4. Verification and validation processes for the initial model

This section illustrates how we verified & validated our model, we used two methods to do that which are Developing expectations and Animation.

4.1 Developing Expectations:

We assumed three expectations to validate the model

1- The system is stable and the model results (with exponential distribution) close to the queuing theory results. In the first expectation, we use queueing theory to get the results nearly for steady state performance metrics, after that we assumed exponential distribution for each station to get the steady state in SIMIO, moreover, we were run the model for a long time (30 days), 2000 replications and 20 hours warm-up period, helps in that, we obtained the results shows in Table 1. The table shows the result for each station for both queueing and SIMIO model. It appears very close to each other with half-widths. Since we were not interested in queuing because no samples were waiting to be served in the laboratory, we calculated the number of samples and their total waiting time in the system. These results match our expectations and show that our system is stable.

Server	Queuing Theory Results			Model Results		
	Utilization (P)	Time in system (W)	Number in System (L)	Utilization (P)	Time in system (W)	Number in System (L)
Mixing Tester	0.0139	20.3537	0.0141	0.0140±0.0001	19.9257±0.1581	0.0140±0.0001
Pasteurization Tester	0.0287	42.5195	0.0295	0.0302±0.0002	41.5031±0.3314	0.0302±0.0007
Cooling Tester	0.0021	3.0063	0.0021	0. 0021 ± 0.0000	2.9846±0.0239	0.0021±0.0000
Storage Tester	0.0028	4.0111	0.0028	0.0030±0.0000	4.0165±0.0322	0.0030±0.0002
Packing Tester	0.0052	7.5393	0.0052	0.0056±0.0000	7.4949±0.0582	0.0056±0.0004

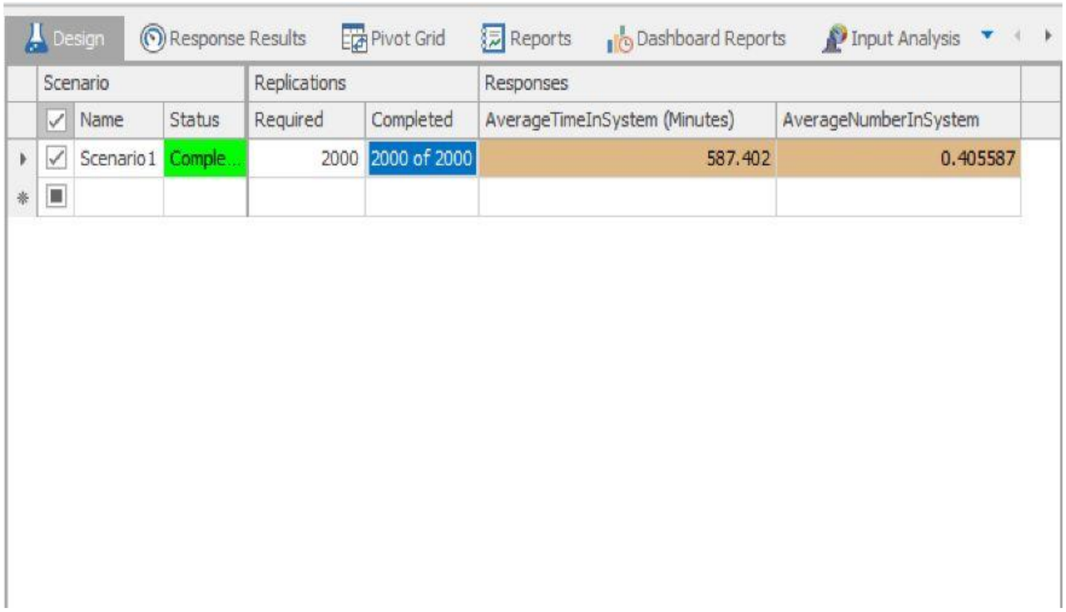
Table 4-1-1 Expectations 1 Resultes

2- The time in system and the number in system (with the fit distribution) will be less than the exponential distribution of the model.

In the second expectation, we assumed the time in the system and the number in the system (with the fit distribution) will be less than the exponential distribution of the model. We run the model with the same condition in the previous expectation 30 days run,2000 replication, and 20-hour warm-up period. We obtained the result shown in Table 2. These results appear to match our expectation where time in a system in expectation 2 decreases by 1.5846 and the Number in a system decreased by 0.0011

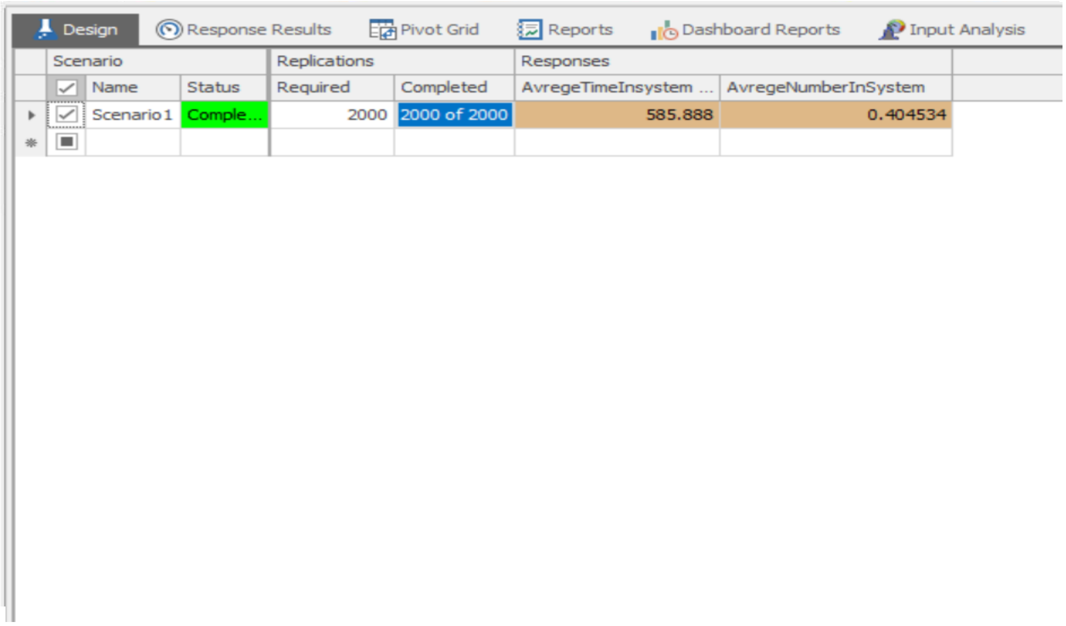
Metrics	Expectation 1	Expectation 2
Time in system (W)	587.4016	585.8877
Number in system (L)	0.4056	0.4045

Table 4-1-2 Expectations 2 Resultes

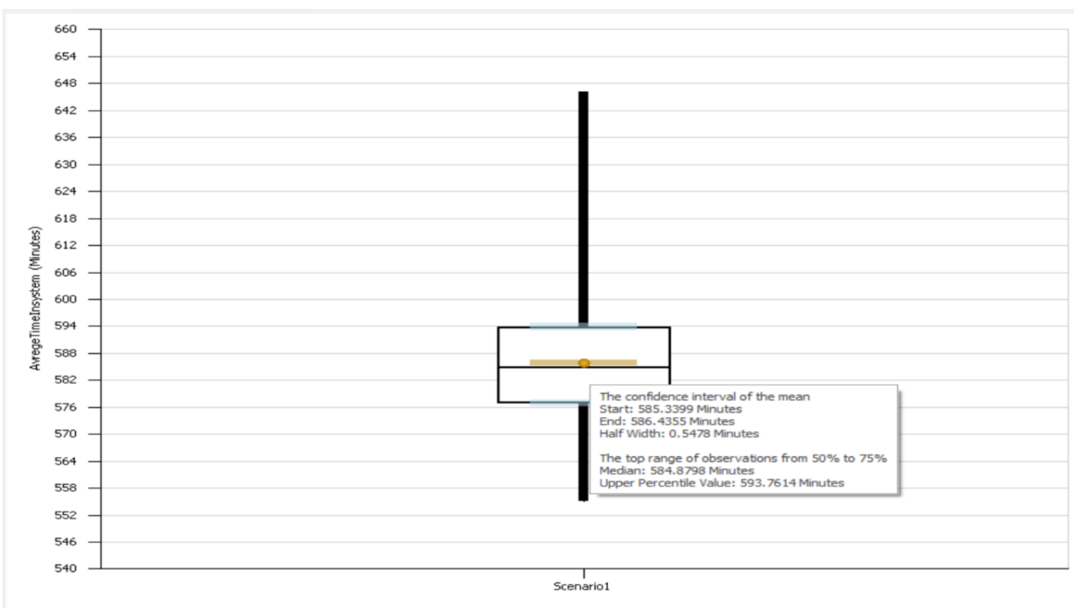


Fig(4.1.1) SMORE Result of exponential distribution

Fig(4.1.2) SMORE Plot of exponential distribution



Fig(4.1.3) SMORE Result of fitting distribution



Fig(4.1.4) SMORE Plot of fitting distribution

3- The time in the system will be increased by about 1.0678 minutes because we assumed that all entities travel a meter per second (the total distance is equal to 173 meters).

In the last expectation, we assumed the time in the system will be increased by about 1.0678 minutes (the lengths of paths), we run the model with lengths of paths unlike previous models with connectors at the same conditions (30 run days, 1500 replication and 20 hour warm-up period). We obtained the result shown in Table 3. Thus 64.068 seconds = 1.0678 min, then: 584.7492+0.6307= 585.3799. These results seems to match our expectation.

Metrics	Expectation 3	Expectation 4
Time in system (W)	584.7492	585.8877

Table 4-1-3 Expectations 3 Resultes

4.2 Animation:

We modeled our system as 3D animation to provide a visual system that allows for better communication with factory management and a better understanding of how the system works. Also, we used a 3D animation model in Validation & verification process, because there are many components for effective model verification, animation allowed us to study the details by watching model progression step by step. Also, 3D animation helped us to ensure that the model behaves as we intended. we used the SIMIO standard library to build our animation model. The following Figures show the result of this, the layout of the laboratory as well as the factory, internally and externally.

Fig (4.2.1) External layout of the factory

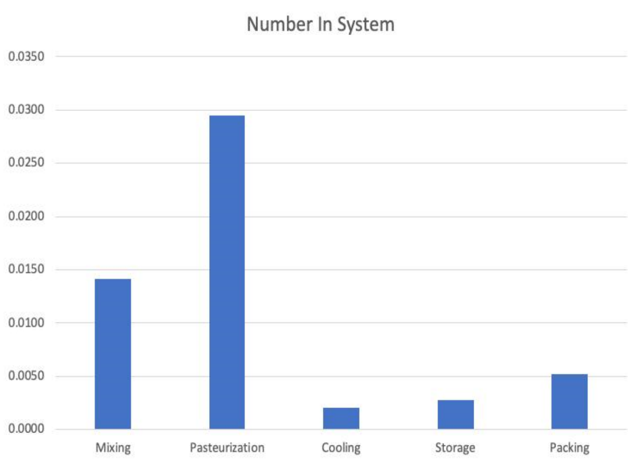
Fig (4.2.2) Enteral layout of the factory

Fig (4.2.3) Laboratory layout

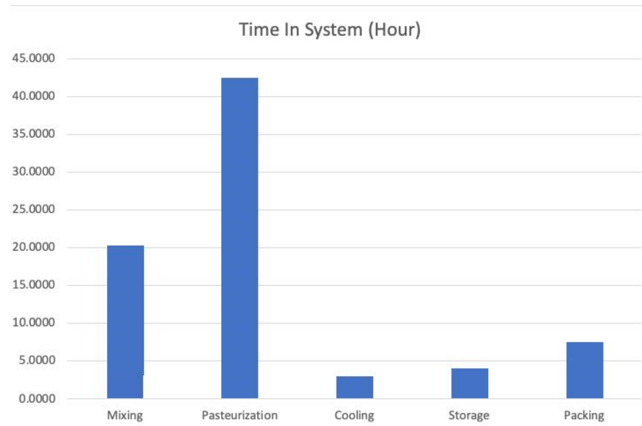
5. Initial model results

5.1 Running time and number of replications:

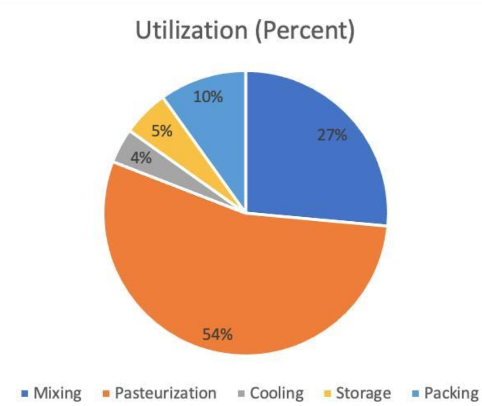
After we validated our model with developing expectations and animations. We studied the system in 30 days because we want to study the efficiency and performance of the Taif Dairy Factory in the long term, in order to achieve the project goals. 1200 replications were chosen because after many experiments we found that the results after 1200 replications were similar to what we found in the queueing theory. After running and replicating the model at different times.



Fig(5.1.1) Number in system



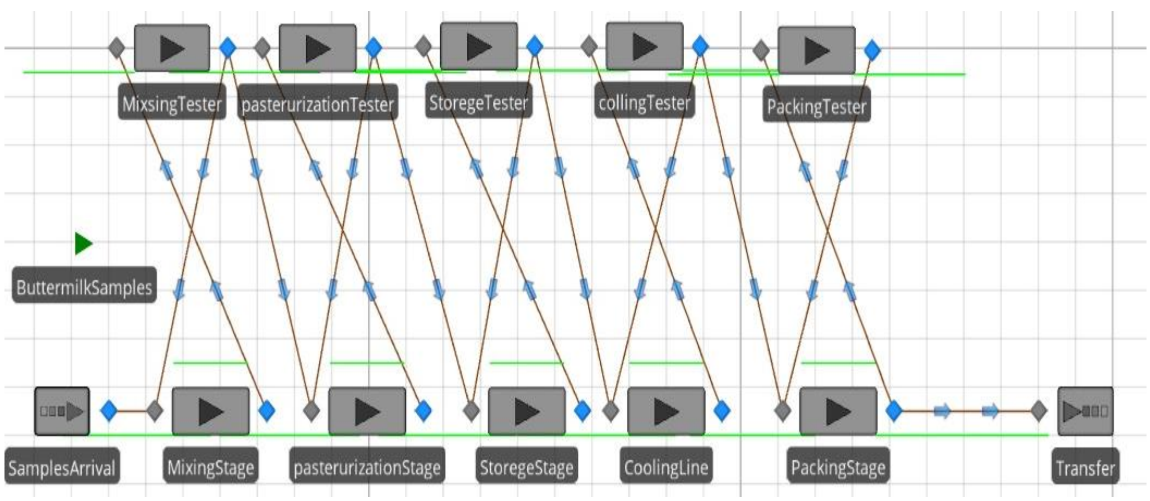
Fig(5.1.2) Time in system



Fig(5.1.3) Utilization in percent

The figure (5.1.1) shows us that the pasteurization test has the highest usage rate ,figure (5.1.2) shows that it has the highest time in the system and figure (5.1.3) shows that it has the highest number in the system because it takes 30-50 minutes to test and wait for results to appear and take approval to complete the manufacturing process. The mixing test, which takes 15-25 minutes, also causes a delay in the system because we cannot start the manufacturing process until we make sure that all the components are homogeneous through testing and obtaining approval, and this makes us wait until the entire manufacturing process is approved to complete the process. This is one of the reasons for the delay in the production line within the factory and will reduce work efficiency and completion. The graphs show us that the remaining tests are the least of the tests in terms of utilization and the number of the system because it takes a quick time to show the result.

5.2 Screenshots of the model and results:



Fig(5.2.1) Initial model structure

For more details of SIMIO results , see the Appendix section.

6. Alternative solutions for solving the problem

6.1 Improvement Solutions:

It is noted that there is a problem with the time of the sample testing process in the system, as it is a very large time delay and delays the production time, so we suggest these alternative solutions to the problem:

• The first solution:

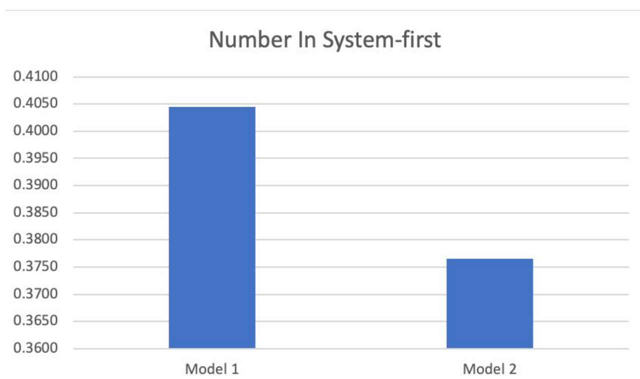
Is to replace the testing devices with developed and fast devices, because the devices in the factory are very traditional and slow.

• The second solution:

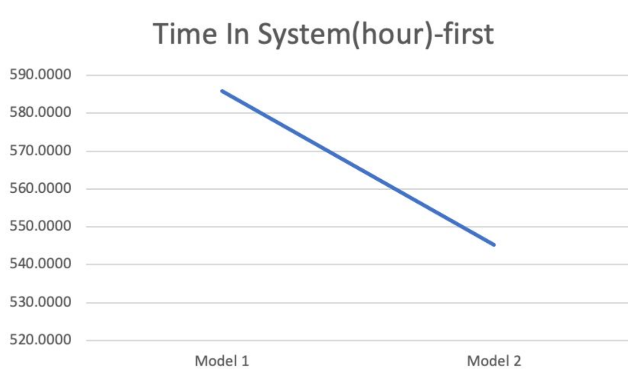
We noticed that the laboratory is very far from the production line, which makes the worker travel long distances to take the sample. This repeated scenario will delay the time for approval of the sample, and thus the production time will be delayed and the time in the system will increase. Therefore, we suggest reducing the distances between the factory and the production line and making the factory in the closest room to the production line.

6.2 Improvement Results:

1- The results of the first solution (purchasing new, developed and fast devices): This solution was very effective, by increasing the speed of the test devices and thus issuing the laboratory results faster than the previous one, and thus the waiting time in the system would be reduced from 585.8877 minutes to 545.2957 minutes, meaning that this solution would save approximately 40.6 minutes. Also, the number of samples in the system will decrease from 0.4045 to 0.3765, as shown in the following figures.



Fig(6.2.1) Bar Chart of number in system



Fig(6.2.2) 2D line of time in system

2- The results of the second solution (Reducing the distances between the lab and the production line):

This solution was not very effective, because the time in the system decreased after applying the solution but the decrease was not very high. The time in system was 585.8877 after the improvement it becomes 585.2989, meaning that this solution would save approximately 60 second. Also, the number of samples in the system will decrease from 0.4045 to 0.4041 seems without effect, as shown in the following figures.

7. Conclusion

In conclusion, we can see that our project achieved excellent success in its implementation. During this semester we applied all the tools and lessons that we learned in industrial systems simulation on a real-world system in Taif national dairy factory. Arrival date and service data were successfully gathered to apply the queuing theory and use Simio to get our final model. Also, we have suggest solutions to the problems we found in the factory to improve their productivity and enhance the satisfaction of their customers.

7.1 Recommendations:

Through our study of the system of the Taif Dairy Factory and based on the modeling of this system, we recommend the following points:

1- We recommend purchasing new and high-quality equipment in the laboratory to test samples efficiently and quickly.

2- We recommend reducing the distance between the laboratory and the production line in order to make it easier for the worker to take samples quickly without traveling long distances and thus wasting time in production.

3- We also recommend hiring a laboratory worker who has high skill in testing milk samples as well as has the skill of accuracy and speed.

4- We also recommend changing the factory logo as it looks very traditional and does not attract attention.

7.2 Future work:

1- We will reduce the time for the results to be issued from the laboratory so that the total production time will decrease; This is done by relying on previous data in estimating the percentage of materials used and the time of the process as well.

2- We will re-design the place and make it more streamlined in transporting samples and transporting the mixture completely. Collect more data about the system to reduce uncertainty and increase the accuracy of the system results.

3- Improving the SIMIO model to be more realistic, such as our development of advanced models for the laboratory and decision-making to complete.

4-Study service costs and waiting times by including costs in the simulation model and prepare the appropriate budget.

8 Appendix

The all results here:

Fig(8.1) SIMIO model and all results

https://drive.google.com/drive/folders/1Us6a9ktuVumfte3xeR9R-aOzxfWIKk7o?usp=share_link