Diary Factory Modeling, Simulation and Layout Assessment and Improvement

Khaled M. Toffaha, Shi Dongyan

Abstract— **Recently, dairy farming has been transformed into an industrialized system. As a result, dairy industry has been endeavouring to develop their operations through the adopting of several improvement methods and techniques. The current paper aims at evaluating existing operations and processes at a Dairy Factory in the state of Palestine, and to improve the efficiency of its operations and thus obtain maximum productivity. The scope of work in this paper is to use simulation techniques to build a model that represents the processes at the factory, the model runs for 2000 hours using (ProModel) also using Facility plant layout approach to evaluates current factory layout and suggests new improved one based on certain calculations.**

Index Terms— Diary factory, Plant Modeling and Simulation, Process Flow chart, Plant Layout, Layout assessment and improvement.

I. Introduction

A. Introduction to The Dairy Factory

Dairy factory is one of the major productive charitable projects in the state of Palestine. It produces dairy products such as, Ultra heat temperature (UHT), Choco, cheese, condense milk, sour milk, sour milk up, yogurt, Shemaint and juice. At 2001, the factory started Ultra heat temperature milk production. This project was extracted to implementation site in order to help Palestinian farmers to utilize their farms and sell their own milk, also to provide dairy products to the Palestinian national economy. At the beginning, Tetra Park Company provided the factory with machines, prepare design, equipment and training to the technical cadres according to the latest Quality System.

B. Introduction to The Analysis

Methods engineering is a technique used to improve productivity and reduce costs in both direct and indirect operations of manufacturing and non-manufacturing business organizations. It can be defined as the systematic procedure for subjecting all direct and indirect operations. We used engineering methods to draw the process flow chart which is “a type of diagram that represents an algorithm, workflow or process, showing the steps as boxes of various kinds, and their order by connecting them with arrows, in this chart we draw each operation step for each manufacturing process, in order to analyze the steps and try to eliminate combine or improve it.

Plant Simulation is a computer application for modeling, simulating, analyzing, visualizing and optimizing production systems and processes, the flow of materials and logistic operations. Simulation can optimize material flow, resource utilization and logistics for all levels of plant planning from global production facilities, through local plants, to specific lines. The application allows comparing complex production alternatives, including the immanent process logic. Plant Simulation is used primarily to strategically plan layout, control logic and dimensions of large, complex production investments.

Plant layout design has become a fundamental basis of today’s industrial plants which can influence parts of work efficiency. It is needed to appropriately plan and position employees, materials, machines, equipment, and other manufacturing supports and facilities to create the most effective plant layout. A plant layout study is an engineering study used to analyze different physical configurations for a manufacturing plant.

II. Methodology

A. Process Flow Chart

We have followed the flow chart principles: by defining each process in order to be diagrammed, discussing and deciding on the boundaries of each process: Where or when does, the process start, also where or when does it end, discussing and deciding the level of the details to be included in the diagram. Brainstorm the activities that take place, determining the process sequence, and arranging the activities in proper sequence.

B. Plant Simulation:

In order to perform diary plant simulation, we used ProModel which is a discrete-event simulation technology that is used to plan, design and improve new or existing manufacturing, logistics and other operational systems. It empowers you to accurately represent real-world processes, including their inherent variability and interdependencies, in order to conduct predictive analysis on potential changes. Optimize your system around your key performance indicators. The ProModel Methodology:
Visualize: Create a dynamic, animated computer model of your business environment from CAD files, process or value stream maps, or Process Simulator models. Clearly see and understand current processes and policies in action.

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Analyze: Brainstorm using the model to identify potential changes and develop scenarios to test improvements which will achieve business objectives. Run scenarios independently of each other and compare their results in the Output Viewer developed through the latest Microsoft® WPF technology.

Optimize: Immediately test the impact of changes on current and future operations, risk free, with predictive scenario comparisons. Determine optimal business performance with a high probability of meeting your business goals.

C. Plant Layout

The six tools and techniques used for layout planning/plant layout are as follows: 1. Operation Process Chart: The manufacturing process is divided into separate operations with the help of the operation process chart. It shows the points at which materials are introduced into the process and the sequence of various operations and inspections other than material handling. 2. Flow Process Chart: This chart is a graphic representation of all the production activities occurring on the shop floor, which includes transportation, storage and delay. 3. Process Flow Diagrams: It is the diagram of building plan representing graphically the relative position of productive machinery storage space, gangways etc. and path followed by men or materials. All routes followed by different items are shown by joining symbols with straight lines. 4. Machine Data Cards: These cards give complete specification of each machine to be installed showing its capacity, space and other requirements, foundations methods of operation, maintenance and handling devices of machines etc. 5. Templates: After studying the flow process chart, process flow diagram and machine data cards, a floor plan is prepared by fixing the area occupied by each item (machine/equipment, benches, racks, material handling equipment etc.) to be erected in the shops. These templates are arranged in such a way so as to provide the best layout. This procedure makes the layout visual before actually drawn and is carefully examined. 6. Scale Models: It is an improvement over the template technique. In this tool, instead of templates, three dimensional scale model is utilized. These models may be of wood plastic or metals. When these are used on a layout, series of additional information about the height and of the projected components of the machines are obtained.

III. Results

A. Process Flow Chart “fig. 1”

B. Plant Simulation

90 readings of arrivals have been gathered and analyzed using ProModel Stat. Fit. The distribution resulted was Exponential with mean 42.9 min. In addition, scatter plot, autocorrelation and runs tests have been conducted and indicate non correlation in the data.

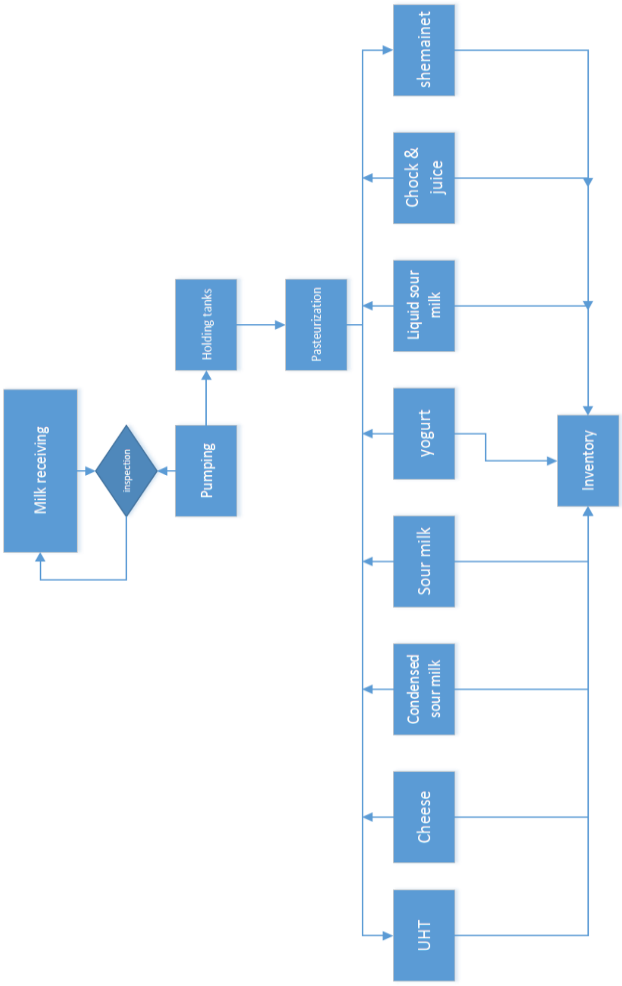

Figure 1. Process Flow Chart

The following figures show the gathered data as well as ProModel Stat results:

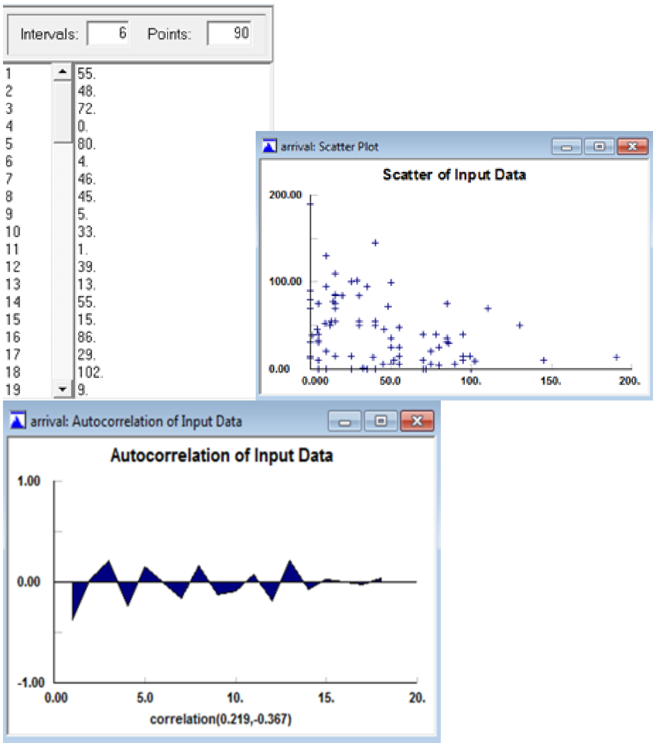

Figure 2. Inter arrivals analysis

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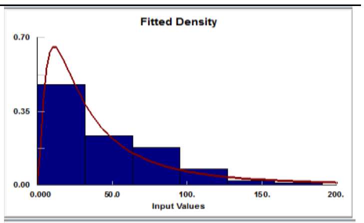
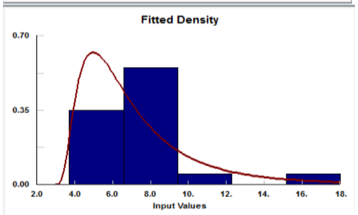
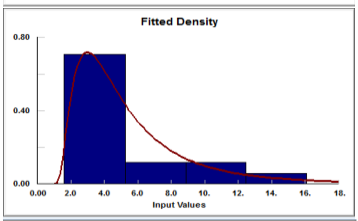
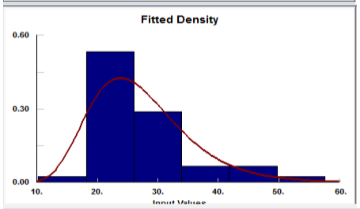
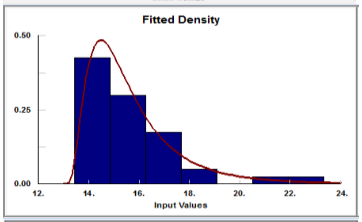
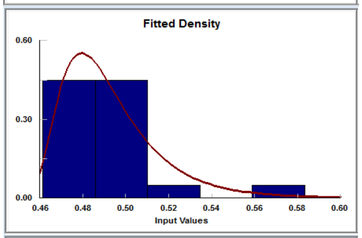
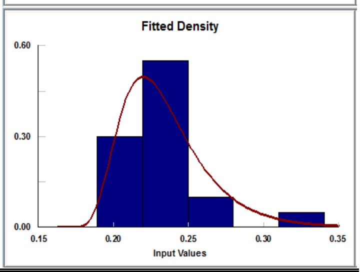
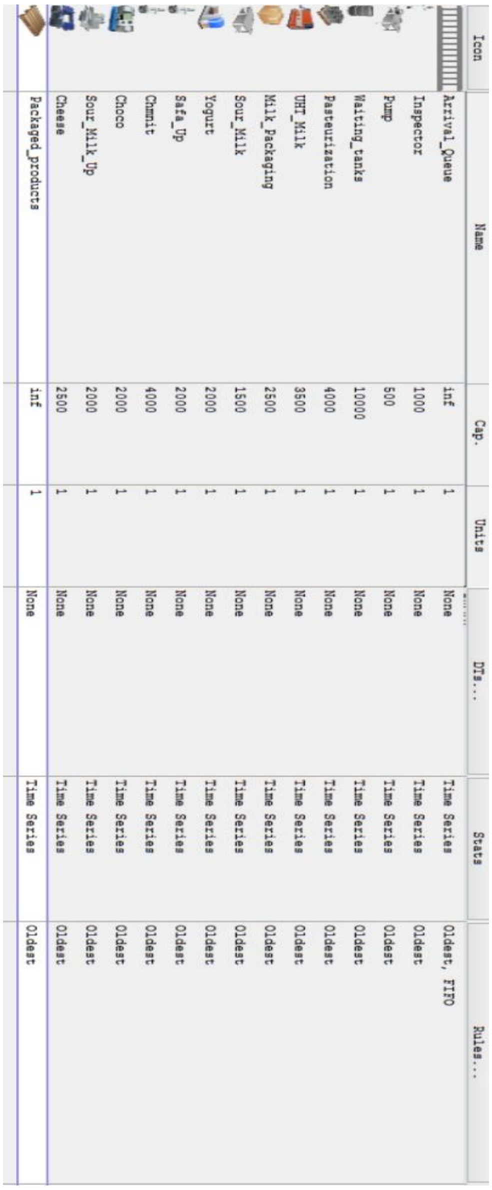
The following table illustrates the main distributions for each activity as well as its fitting plot as analyzed in Stat Fit:

Table I. Distribution fitting

Activity	Distribution	Distribution fit
Inter arrivals	Exponential (42.9)	
Inspection	Lognormal (3, 1.2)	
Pump	Lognormal (1, 1.26)	
Milk Packaging	Lognormal (0.833,3.23)	
Sour Milk	Lognormal (13, 0.8)	
Yogurt	Lognormal (0.447,3.19)	
Choco	Lognormal (0.163,2.71)	

Model Building (ProModel):

Locations
All the needed locations were built and named, there are fifteen different locations in this model, and each location represents distinct process or resource. Furthermore, each location has assigned specific capacity. The following figure shows the locations as appear in ProModel:



Icon	Name	Cap.	Units	DTs...	Stats	Rules...
	Arrival_Queue	inf	1	None	Time Series	Oldest, FIFO
	Inspector	1000	1	None	Time Series	Oldest
	Pump	500	1	None	Time Series	Oldest
	Waiting_tanks	10000	1	None	Time Series	Oldest
	Pasteurization	4000	1	None	Time Series	Oldest
	UHT_Milk	3500	1	None	Time Series	Oldest
	Milk_Packaging	2500	1	None	Time Series	Oldest
	Sour_Milk	1500	1	None	Time Series	Oldest
	Yogurt	2000	1	None	Time Series	Oldest
	Safa_Up	2000	1	None	Time Series	Oldest
	Chmmit	4000	1	None	Time Series	Oldest
	Choco	2000	1	None	Time Series	Oldest
	Sour_Milk_Up	2000	1	None	Time Series	Oldest
	Cheese	2500	1	None	Time Series	Oldest
	Packaged_products	inf	1	None	Time Series	Oldest

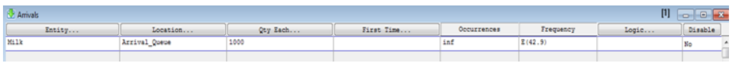
Figure 3. Locations

Entities
There is only one entity which is Milk, the milk arrives to the receiving area, route in different processes and produced in many forms. The following figure shows the entities as defined in ProModel:

Icon	Name	Speed (fpm)	Stats	Notes...
	Milk	150	Time Series	

Figure 4. Entities

Arrivals
The Milk arrive to the factory from farmers in an exponential distribution and in an average quantity of 1000 liter per farmer. The following figure shows the arrivals as defined in Pro Model:



Entity...	Location...	Qty Each...	First Time...	Occurrences	Frequency	Logic...	Disable
Milk	Arrival_Queue	1000		inf	E(42.9)		No

Figure 5. Arrivals

Layout
The following figure shows the layout of the process as

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defined in ProModel, it shows the main locations and their approximate arrangements:

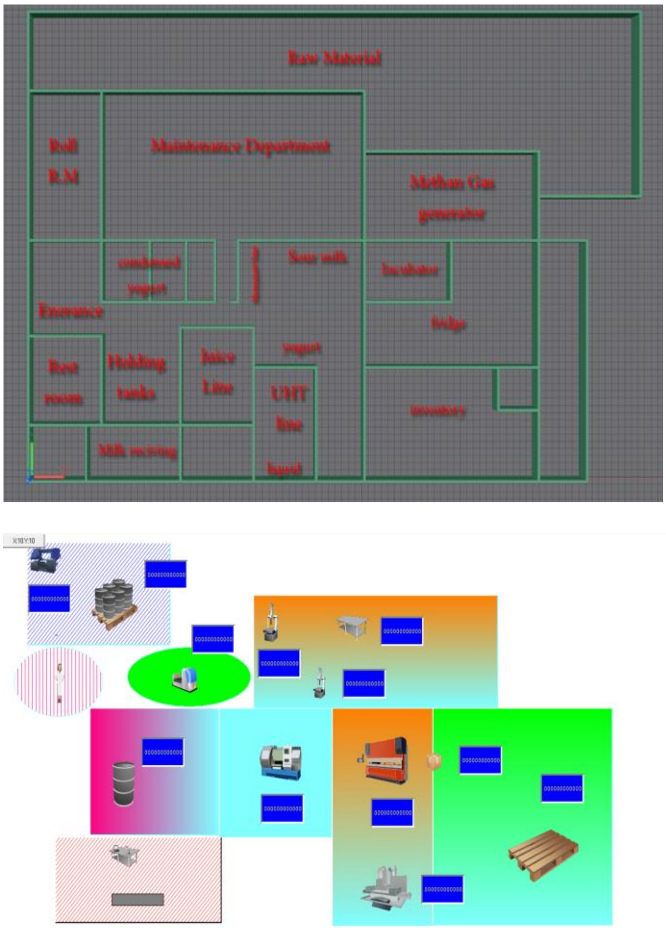
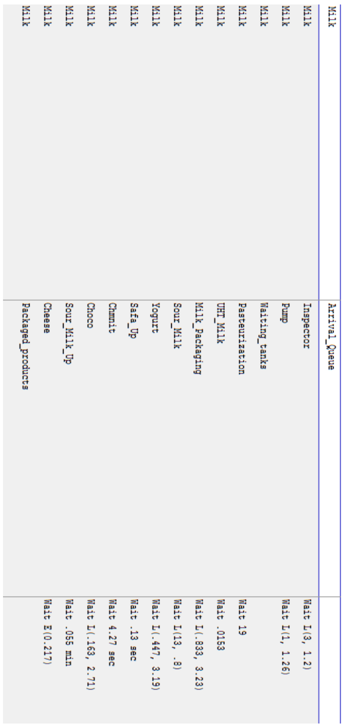


Figure 6. Layout

Processing

Processing were clearly defined and identified for each process, the following figure shows the processing as appears in ProModel:



Milk	Arrival_Queue	
Milk	Inspector	Wait L(3, 1.2)
Milk	Pump	Wait L(1, 1.26)
Milk	Waiting_tanks	
Milk	Pasteurization	Wait 19
Milk	UHT_Milk	Wait .0153
Milk	Milk_Packaging	Wait L(.833, 3.23)
Milk	Sour_Milk	Wait L(13, .8)
Milk	Yogurt	Wait L(.447, 3.19)
Milk	Safa_Up	Wait .13 sec
Milk	Chmnit	Wait 4.27 sec
Milk	Choco	Wait L(.163, 2.71)
Milk	Sour_Milk_Up	Wait .055 min
Milk	Cheese	Wait E(0.217)
Milk	Packaged_products	

Figure 7. Processing

After building the model, it has run for 2000 hours to obtain a reasonable output and observe the system at steady state values. The total produced milk during 1000 hours' time was 2,785,000 liters with 25.91 minutes' average time in system per liter. The following figure shows the sates for multiple capacity locations during 2000 hours run time:

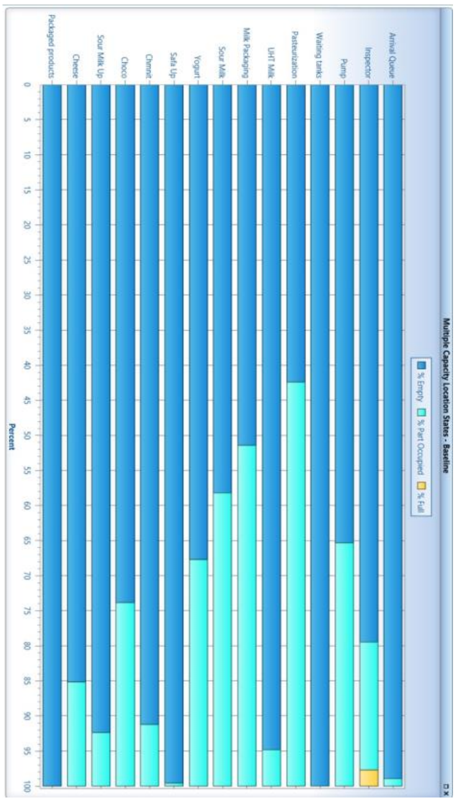


Figure 8. Locations state

The utilization for each location is shown in the following figure:

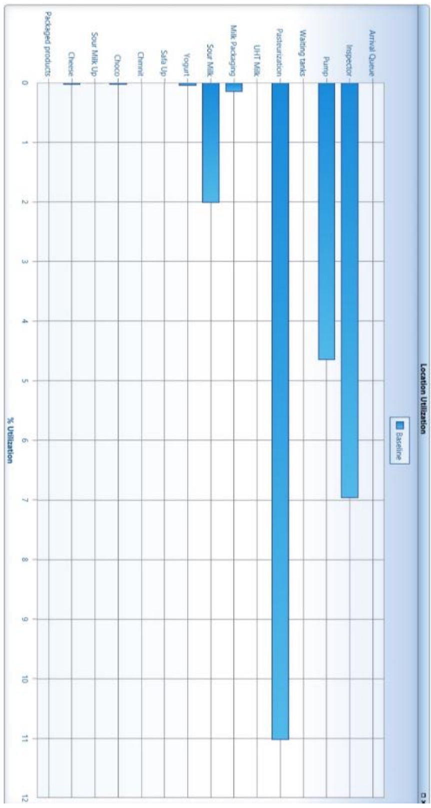


Figure 9. Locations utilization

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The following figure shows the locations summary during the simulation run time:

Location Summary

Name	Scheduled Time (Hr)	Capacity	Total Entries	Average Time Per Entry (Min)	Average Contents	Maximum Contents	Current Contents	% Utilization
Arrival Queue	2,000.00	999,999.00	2,785,000.00	0.22	5.22	2,011.00	0.00	0.00
Inspector	2,000.00	1,000.00	2,785,000.00	3.00	69.62	1,000.00	0.00	6.96
Pump	2,000.00	500.00	2,785,000.00	1.00	23.23	378.00	0.00	4.65
Waiting tanks	2,000.00	10,000.00	2,785,000.00	0.00	0.06	928.00	0.00	0.00
Pasteurization	2,000.00	4,000.00	2,785,000.00	19.00	440.96	4,000.00	0.00	11.02
UHT Milk	2,000.00	3,500.00	557,434.00	0.02	0.07	9.00	0.00	0.00
Milk Packaging	2,000.00	2,500.00	557,434.00	0.83	3.85	67.00	0.00	0.15
Sour Milk	2,000.00	1,500.00	278,169.00	13.00	30.13	420.00	0.00	2.01
Yogurt	2,000.00	2,000.00	277,941.00	0.45	1.03	25.00	0.00	0.05
Safa Up	2,000.00	2,000.00	279,226.00	0.00	0.00	4.00	0.00	0.00
Chmnit	2,000.00	4,000.00	277,443.00	0.07	0.16	14.00	0.00	0.00
Choco	2,000.00	2,000.00	419,014.00	0.17	0.59	19.00	0.00	0.03
Sour Milk Up	2,000.00	2,000.00	278,235.00	0.06	0.13	11.00	0.00	0.01
Cheese	2,000.00	2,500.00	417,538.00	0.22	0.76	27.00	0.00	0.03
Packaged products	2,000.00	999,999.00	2,785,000.00	0.00	0.00	1.00	0.00	0.00

Figure 10. Locations summary

The following figure shows the entities summary during the simulation run time:

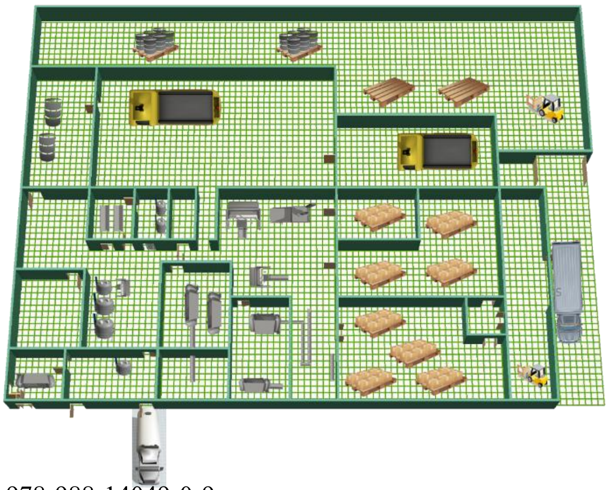
Entity Summary

Name	Total Exits	Current Quantity In System	Average Time In System (Min)	Average Time In Move Logic (Min)	Average Time Waiting (Min)	Average Time In Operation (Min)	Average Time Blocked (Min)
Milk	2,785,000.00	0.00	25.91	1.10	0.12	24.69	0.00

Figure 11. Entities summary

C. *Plant Layout*

The aim of this tool is to assess and evaluate the current layout of the Dairy factory, also trying to build new layout for the dairy through implementing layout methods of evaluating and constructing. We've measured the areas and the distances of each department in the factory to get



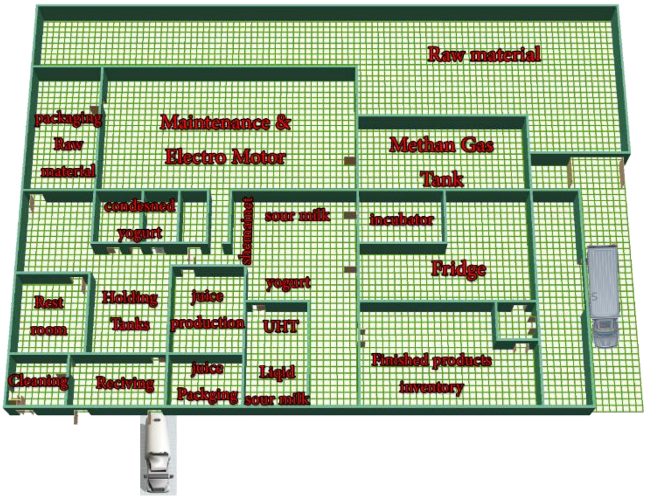


Figure 12. First floor layout

Second floor:

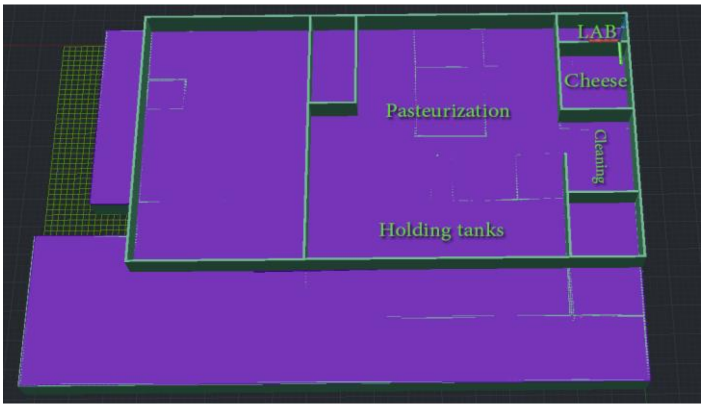


Figure 13. Second floor layout

We've tried to follow the process of the Dairy in order to measure the areas and the distances, After the observation of the flow of operators between departments we constructed a table and found that the higher flow was between incubator and fridge departments. Due to the large amount of product that must be in the incubator for hours to take the good substratum. After that we evaluate the relationship chart between departments We divided the largest number of flows by 5 and built this closeness relating ships ranges. We have only one absolutely important relationship between incubator and fridge departments and only two ordinary importance relationships between Safeno and incubator, Choco and inventory and the remaining departments have unimportant relationships.

After we constructed the relationship chart we calculated TCR (total closeness rate) for each department. And we discover that incubator has the largest TCR value.

According to the TCR value we could create the placement sequence to construct a new layout design. The placement sequence: incubator-Safeno-maintenance-condensed milk filling-receiving-cleaning-sour milk-Shemaint-roll material-holding tanks 1-electric-condensed Milk-Choco-UHT-sour milk up-inventory-lab-holding tanks 2-fridge-pasterization-raw material-cleaning2. We choose incubator as the first department to construct the new layout design because it has the higher total closeness rating (TCR) which equal 1024.

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Then we choose Safeno department which has ordinary important relationship with incubator. After that we choose maintenance, condensed, milk filling and receiving and cleaning departments because they have higher number of unimportant relationships with the already placed departments. All of holding tanks, roll materials, cement and sour milk have same number of unimportant relationship with the already placed departments and the same TCR value so we ordered them according to the value of unimportant relationship of each one. For example, the value of unimportant relationship between incubator and Shemaint is 19620. Lab, Sour milk up, inventory, holding tanks 2, condensed milk, Choco, UHT departments don't have relationship with the already placed departments so we choose them according to the value of unimportant relationship they have.

We've applied craft technique to improve current layout. At the beginning we evaluate current layout correspond to adjacency based score by multiplying flow with distance with cost per unit. Cost per trip = operator salary / (number of working hours per day) * (number of working days per week) * (average number of flow) = 2000/ (6*8*32.6) = 1.2 NIS

Table II Flow * Distance * Cost table

F*d*c	Departments
19682.4	Cleaning
95402.4	Receiving
722325	Holding Tanks
86058.6	Roll Material
2916	Condensed Milk
570307	Condensed Milk filling
17844	Electric
209604	Maintenance
167450.4	Choco
50803	UHT
89342	Sour milk up
229812	Shemaint
157941	Sour Milk
121785	Safeno
707616	Incubator
	Fridge
43312	Inventory
	Raw Material
	Cleaning 2
	Cheese
29524	Lab
5611.2	Holding Tanks 2
	Pasteurization
3307653.6	Total

By implementing the multiple method based on the relationship and the flow between charts we moved the laboratory to the receiving department to have new department "research and development"

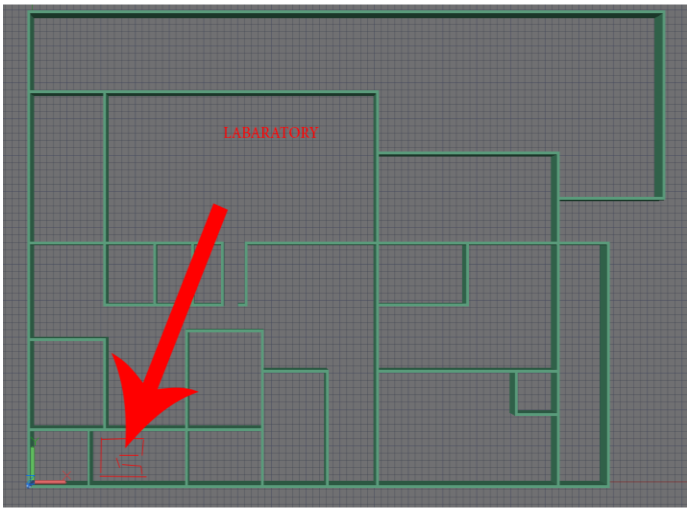

Figure 14. Multiple Method

Evaluating the new adjacency score = 175 is better than the old one of 135

IV. Conclusion

After long search, we found that the factory fulfill our improvement aims due to its pitfalls that need a lot of improvements, so that we can conclude them as follows. Firstly, the flow of materials and labors in the factory is difficult so the layout is no optimize due to that there is a time and cost waste in transportation. Secondly, the factory doesn't have neither the lean manufacturing nor the supply chain principles, so the ability of stopping the production due to the low raw material or packaging supplies. Finally, due to the supervision of human resources department, there is a deficiency in the commitment of the workers towards the working hours so that they may came late and left the work early. Moreover, most of the production lines started production lately, due to the long setup time and deficient planning. So, figuring out these problems using flow charts, simulation and plant layout will solve them.

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References

[1] Tompkins, A. J., White, A. J., Bozer, A. Y., & Tanchoco, A. M. J. (2010). Facility Planning. 4th. New York: JON Wiley & Sons,cop.
[2] Harrell,R. C. (2003). Simulation Using ProModel. 2nd. America, USA: McGraw-Hill.
[3] Benjaafar, S., Soewito, A., & Sheikhzadeh, M. (1995). Performance Evaluation and Analysis of Distributed Plant Layouts. Working Paper, Department of Mechanical Engineering, University of Minnesota. Minnesota, Minneapolis.
[4] BAIR F., LANGER Y., CAPRACE J.D., & RIGO P. (2005). Modeling Simulation and Optimization of a Shipbuilding Workshop. New York:Macmillan.
[5] Steinhauer, D. & Heinemann, M. (2004). Simulation Based Transport and Storage Planning on a Shipyard ASIM Dedicated Conf. for Simulation in Production and Logistics .113-122.

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