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Modelling and Simulation

Modelling and simulation of production process in the field:

electrotechnical or food processing

Analysis of effective processing in the dairy company

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1 Introduction

This report presents the results of the analysis of the efficiency of machines, that are part of the **dairy company**. This company is one of the largest dairy companies in *Mexico*. A few years ago, the company had a problem, not meeting the client's requirements and demand. The *Planning department* of the company has decided to execute the analysis of equipment, in order to increase the production rate. For the company [1] was designed a model, describing the individual processing machines in detail. Subsequently, the simulation(ims:33) of designed model was executed using method *Monte Carlo* (ims:113-118). The conclusion that was drawn, claimed that the main obstacle to improving the use of production lines is the *harvesting system*. It was shown, that the installed equipment is not used at all.

Veterinarians of the company declared that it can be possible to change the *harvesting system*. The new system for raw milk harvesting will not receive milk only in the *morning* and only once a day, but tankers will arrive more often. Based on the designed model (ims:7) and simulation experiments (ims:33) there will be shown the behavior of the system under conditions, which will be represented by **increased probability distributions** for inter-arrival of tankers. The purpose of the experiments will be to analyze the utilization of individual production lines and then propose the relevant changes, in the form of addition or removal of specific production lines.

The results of this simulation study can provide the necessary information to the subsidiary in the country where the company is located. An analysis of the efficiency of all production lines can provide cost savings in the development process, but also provide information on where a company can grow to increase production if necessary.

1.1 Source of information

The methods that were used in creating the model (ims:7) were largely taken from [1]. Our designed model will be introduced in the 3, with using the formalism of *Petri net* (ims: 123). The relevant parameters of processing machines were taken from [1] and they have been verified with at **least one** other source for verification and validity of the data. More details about the selected machines and its parameters will be introduced in the 2.

All changes that were made in our model comparing with model designed in [1] were consulted with *Mária Fabuľová* who worked in the dairy company for *30* years.

1.2 Validation of the model

The experimental verification of the **validation** (ims:37) of the designed model was executed in the different period of simulation and then compared with the data from [1]. The first value, which was compared is the **summary quantity** of produced milk in *liters*, during the simulating period. Another value which was monitored at the *validation* process was an **average utilization** of the individual processing lines. The exact results of this process, that prove the *validation* of designed model, will be introduced in Section 5.

2 Analysis of the topic and used methods

The production plant is divided in three main areas: *raw milk reception* area, *fluid milk* processing area and *milk derivative processing area*. We will introduce all technical parameters of processing lines presented in all these areas sequentially. Unless otherwise stated, the correctness of the data comes from [1] or from [1].

[1] https://www.victoria.ac.nz/sef/research/pdf/2016-papers/SEF-Working-Paper18-2016.pdf

2.1 Raw Milk Reception Area

The main task of this area is receiving the raw milk, which is imported by *tanker* from dairy farms and subsequently is milk stored to relevant *silos* for its processing. The **tankers** that transport the raw milk have usually *capacity* between **3000 - 30 000** liters[2][3]. In our case we consider tankers with the capacity of **25 000** liters. Although the capacity of tankers is *25 000* liters, their actual content is different. The *exact* data about the content of tankers, in the actual month of the year, were taken from `Table 4` in [1].

On arrival to the company there is quality checking of the imported milk by *Quality Control Development*. Samples of milk are taken from the bulk milk tanker and then are send to the laboratory testing[4]. Because the quality of the milk in most dairy companies is tested by the *Resazurin test*, the period while the tanker can go to reception line is given by **12 minutes** in summary[5].

After successful check tankers can continue to **1** of **5** *reception lines* intended for the milk receiving and moreover, there is **two** *reception lines* intended for receiving the milk and cream for the developing milk derivatives. Each *reception line*, that serves for pumping the raw milk, pumps milk **40 000** liters per hour, what confirms another reception pumps too[6]. The remaining two *reception lines* pump cream **15 000** liters per hour.

The capacity of the *reception silos* ranges between **140 000** and **675 000** liters. Subsequently the total number of *reception silos* for the relevant purpose depends on that capacity. In our case, it will be **3** milk reception silos with capacity of **150 000** liters each and **2** cream reception silos with capacity of **115 000** liters each one.

2.2 Fluid Milk Processing Area

In this area is processing of milk from the *reception milk silos*. The *clarifiers* represent only processing links in this area. These machines usually have the capacity of **15 000** to **33 000** liters per hour[7]. In our model there are **4** *clarifiers*, two of them with capacity of **25 000** liters per hour, and **two** with capacity of **30 000** liters per hour. After processing by *clarifiers*, milk is pumped into *process silos*. The capacity of the*process silos* is one of the highest capacities among of all silos in the dairy companies, that usually has capacity from **1 420 000** liters to **1 700 000** liters, as well as in our case[].

2.2.1 Pasteurized Milk Lines

In order to produce *pasteurized milk*, these production lines take *fluid* milk from the *process silos*. The first machine is the *homogenization pump*, which does not require storing silos in this process. Its frequency, respectively capacity of processing is set on the value, which ensures the smooth transition of currently processed milk from this link to the packaging lines. Due to capacity of other machines the capacity is set to **30 000** litres per hour.

In the next phase milk is processed by *homogenization machine*, that has capacity of **20 000** litres per hour[8][9]. Then the milk is sent to *pasteurizer*, that prepares the milk for the packaging.

[2] https://dairyprocessinghandbook.com/chapter/collection-and-reception-milk
[3] http://www.surakhsha.in/stainless%20steel_milktankers.html
[4] https://milk.procon.org/view.resource.php?resourceID=000658
[5] http://www.fao.org/ag/againfo/resources/documents/MPGuide/mpguide2.htm
[6] https://dairyconsultant.co.uk//servicesdairyfactorydesign1.php
[7] http://ecoursesonline.iasri.res.in/mod/page/view.php?id=147908
[8] https://www.uoguelph.ca/foodscience/book/export/html/1908
[9] http://www.horiba.com/scientific/products/particle-characterization/applications/milk-homogenization/

The standardized period for the *pasteurized* milk is **15** seconds per one liter minimal[10]. After that, pasteurized milk is bottled by **3** *bottle filling machine* with a capacity of **18 000** liters per hour.

2.2.2 Ultra Pasteurized Milk Lines

The production of *ultra pasteurized milk* uses **7** lines. **Five** of them produces the milk in **one liter** presentation format, the other **two** are used to process in presentation format of **250 ml**. The usage of the production line depends on the type of demanded product. In our designed model we have focused on these types of milk, which were selected due to the highest demand: *whole* milk, *light* milk, *strawberry flavored* milk, *cholesterol free* milk, *lactose-free* milk in presentation format **one liter** and *strawberry with fruits* and *mango with fruits* milk in presentation format of **250 ml**.

Each line has between **2** or **4** bottle filling machines, with their respective capacities. *Table 1* from [1] shows the capacities of ultra pasteurized milk lines, that were also used in our model.

2.3 Milk Derivative Processing Area

In the original model, that was designed by authors of [1] is this area divided into two subareas: *cream* area and *yogurt* area. After consultation with our professional consultant, we have decided to join these two areas into common area representing the only production of cream. This is also the reason of joining reception silos in the *reception area.*

Cream stored in this silos with a capacity of **230 000** liters is pumped toward to **three** tanks used for *standardization* process. These tanks have a capacity of **9 000** liters per hour, two of them, respectively **14 000** liters per hour, the remaining one. Subsequently is the cream pumped to *pasteurization* and *homogenization* process. Whether these machines work with the same capacity, we will not differentiate in our model and we will simply work with double capacity.

In our model there are **3** *pasteurization* machines with a capacity of **4 000** liters per hour for two of them, respectively with a capacity of **4 000** liters per hour for remaining one. After that, the cream is pumped into **4** cream tanks with a capacity of **5 000** liters each one. *Table 2* in [1] show the characteristics of these bottle packaging lines.

3 Conceptual model

Since the system, which we are designing has typical features and elements of *Queuing Systems* (ims: 136), was selected the formalism of *Petri Net* as suitable modelling tool. The whole designed system was divided into three smaller areas - we will describe the *Petri Net* for *Raw Milk Reception Area*, *Fluid Milk Processing Area* and *Cream Processing Area*, subsequently.

3.0.1 Raw Milk Reception Area

In the Figure 1 we can see the individual steps from the arrival of tanker to the dairy company to its pumping of imported milk. The *probability distributions* for inter-arrival times of tankers were taken from [1], in order to preserve the original problem of company. The probability of low milk quality, so-called infected milk, has been gained from experience of our expert consultant. The way of decision making about the selection of one *reception line* will be described in the next Section 4. The interesting element in this *Petri Net* is a model of progressive tank exhaustion.

[10]https://foodsafety.foodscience.cornell.edu/sites/foodsafety.foodscience.cornell.edu/files/shared/documents/CU-DFScience-Notes-Milk-Pasteurization-UltraP-10-10.pdf

In the case of a tanker obtained line, then the automatic mode of pumping solves the availability of the capacity at the target silo.

3.0.2 Fluid Milk Processing Area

The next area, in which we will focus our attention to, is the *Fluid Milk Processing* Area, which you can see in the Figure 2. The first part of this net is composed by *clarification processing.* These machines work only in the situation, when milk is in the input silos and it have the free capacity in the output silo. In practice, this activity is solved with the help of sensors.

The next part of this *Petri net* can be divided into two main parts: *Pasteurized Milk* processing and *Ultra Pasteurized Milk* processing. `Pasteurized` part is controlled by *Homogenization Pump*, which provides synchronized processing at these lines. The milk subsequently passes through individual lines and in the end will be stored. In the *Ultra Pasteurized* part was used the generalization of all machines in this area for simplification the model. The block represents the way of processing only in one step, but it does not affect our model. The individual lines differ in the number of machines, which are available on this line. Each such unit has its own equipment and therefore we can generalize to one unit too, without affecting the overall processing. Such a block would be here 7 times, but for clarity is shown only once.

Lines for processing the type of milk itself are run on generators signal, that are driven by market demand.

3.0.3 Cream Processing Area

This area is showed in the Figure 3. Its main processes are *standardization* and *pasteurization*, which run similarly like *clarification process* in the last mentioned area. In the case when the some milk is present in its input silos/tank and concurrently is the free capacity in the its output silos/tank, then the process is running. Except for these two machines there is of course also a packaging line. This *packaging bottle line* is activated by *Cream Generator* and subsequently is stored after the packaging process.

4 Programming - Implementation of Abstract Model

In this section we describe the interesting facts about implementation of *abstract model*:

- using simulation library SIMLIB, which is suitable for modeling the *Queue Systems*[11]
- the base unit of the system is represented by **1000 LITERS**
- drivers of the tankers decided at selecting the reception line according to biggest chance of the earliest leaving
- planning of production of individual product is generated by `Event`, in the common class for all types of products
- the output of the simulation is stored to the file `"milk-app.out"` where is printing the statistics collected during the simulation (ims: 197)
- the model is in the state after the last experiment (optimalized)
- user can choose the *month* from which will be starting the simulation and can choose the length of the simulation period in *hours*, *days*, *month* and *years*

[11]http://www.fit.vutbr.cz/ peringer/SIMLIB/

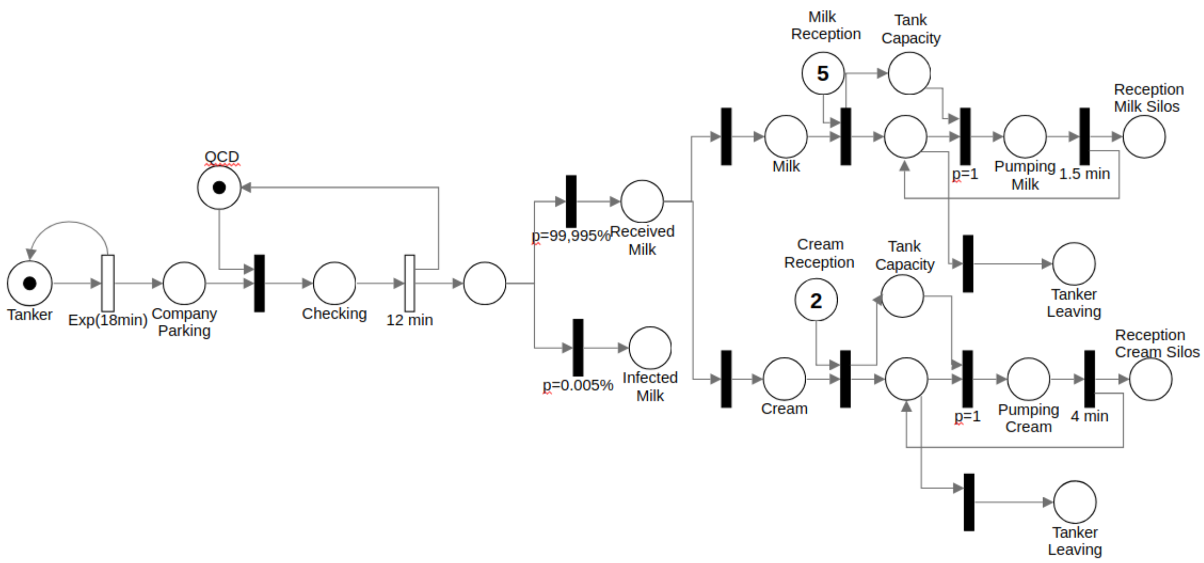

Figure 1: Raw Milk Reception Area

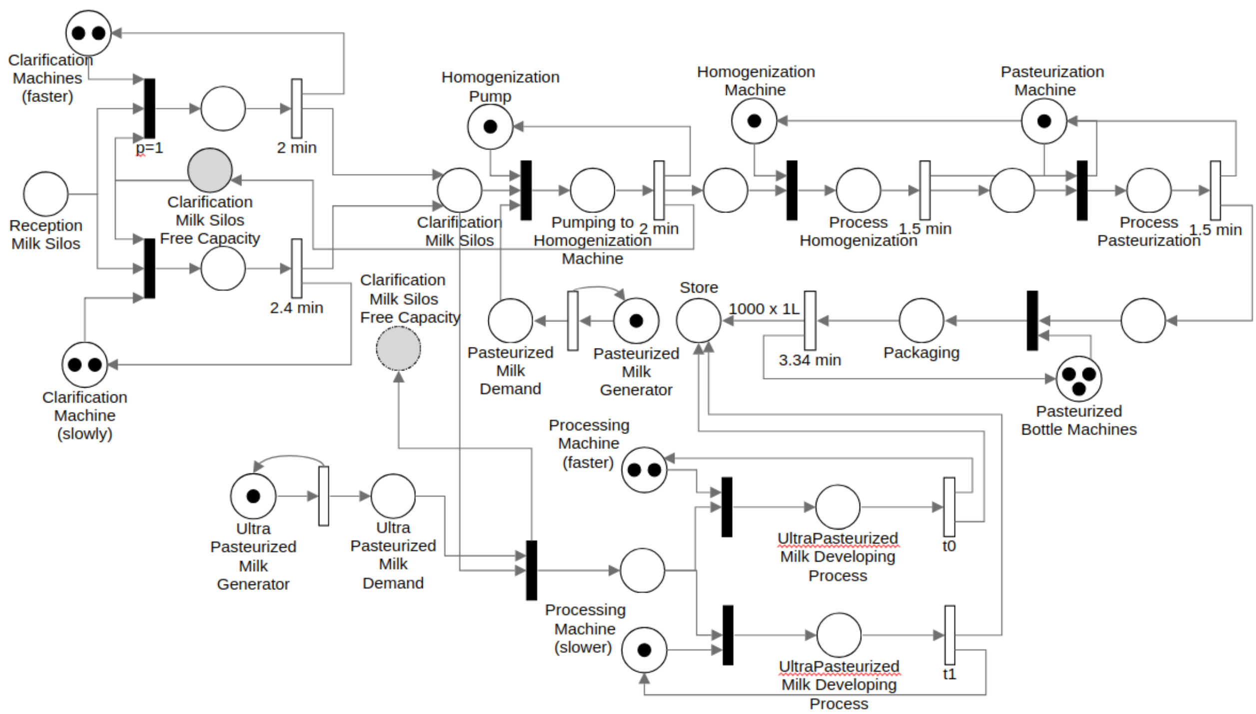

Figure 2: Fluid Milk Processing Area

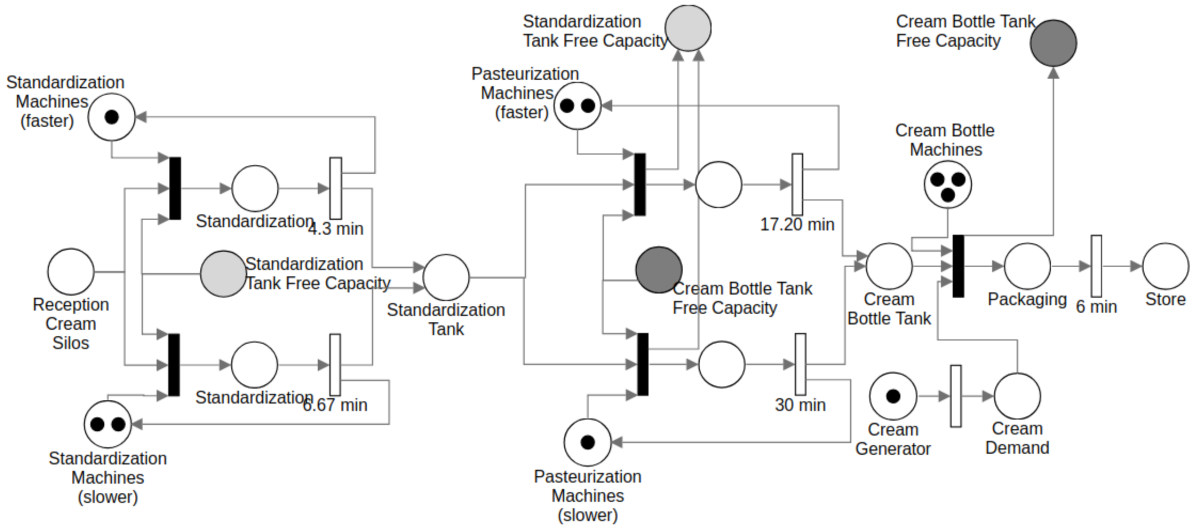

Figure 3: Cream Processing Area

5 Experiments

The purpose of these experiments is to *verify* the designed model in the first step. Consequently, there will be experimentally reduced value of the interval between the incoming tanker to the factory. The main purpose of the experiments will be to meet the market requirements for the selected products. After fulfilling these requirements we will execute the analysis of all lines in the our model.

5.1 Verification Experiment

The *verification experiment* will run above the proposed abstract model, which was based on all the obtained information. The simulation period has been determined on value of *1 year* with the start from *January*.

Clarification	**HomogenizerPump**	**Homogenizer**	**Pasteurizer**
1.15 (2) – 1.08 (2)	0.43 (1)	0.32 (1)	0.09 (1)
StrawberryFlavored	**CholesterolFree**	**StrawberryFruit**	**MangoFruit**
0.62 (2)	0.96 (2)	0.67 (1) - 1.55 (3)	0.51 (2)
PasteurizationBottle	**WholeMilk**	**LightMilk**	**LactoFree**
0.71 (3)	0.83 (2) - 0.16 (1)	1.65 (4)	1.43 (4)
Standardizator	**CreamPasteurizators**	CreamBottle	**QCD**
0.23 (1) - 0.64 (2)	1.99 (2) - 0.99 (1)	0.89 (3)	0.64 (1)

Table 1: Table view the *Average Utilization* of facilities, respectively *Average Used Capacity* of Stores. In the brackets are view the summary count of individual machines on the specific line. Red color means the critical utilization, Orange color means the optimal utilization and the Green color means below average.

The behavior of the model responds to our expectations. The biggest problem, which was introduced in the introduction was confirmed. The number of unsettled bids that were generated throughout the year achieves almost half of the current production. In this experiment the number has risen to **286 646 000** of liters per year, where the production reached the **616 837 000** liters per year.

The issue of this problem is obvious. If we look at the number of liters that came to the factory during the year **616 919 000** liters, it is clear that we have generated almost the maximum of possible production. As has been said, the behavior of the system is expected, but let us go right behind to company main target. The yearly production should reach on average nearly **900** millions of liters. The validation of the remaining machines will be executed in the next step.

The first value that was tested was the decrease of the arrival interval of tanker by **one third**. Yearly income of the milk was **914 791 000** liters, what exceeds our expectation. To origin **one third** value we added one half and then the yearly income of the milk was **885 928 000** liters, What appropriately fulfilled our requirements. This knowledge provides the **first useful** information for the requester when he knows how to adjust the arrivals of the tankers during the every day, to fill client's demand. Let's take a look at the table with average utilization of machines again.

Clarification	**HomogenizerPump**	**Homogenizer**	**Pasteurizer**
+0.58 (2) – +0.53 (2)	+0.22 (1)	+0.17 (1)	+0.04 (1)
1.72 (2) – 1.61 (2)	0.64 (1)	0.48 (1)	0.13 (1)
StrawberryFlavored	**CholesterolFree**	**StrawberryFruit**	**MangoFruit**
+0.3 (2)	+0.44 (2)	+0.31 (1) – +0.87 (3)	+0.25 (2)
0.92 (2)	1.40 (2)	0.98 (1) – 2.42 (3)	0.76 (2)
PasteurizationBottle	**WholeMilk**	**LightMilk**	**LactoFree**
+0.37 (3)	+0.43 (2) – +0.01 (1)	+0.8 (4)	+0.72 (4)
1.08 (3)	1.26 (2) – 0.17 (1)	2.45 (4)	2.15 (4)
Standardizator	**CreamPasteurizators**	**CreamBottle**	**QCD**
0.00 (1) – 0.00 (2)	0.00 (2) – 0.00 (1)	0.00 (3)	*+0.28 (1)*
0.24 (1) – 0.63 (2)	1.99 (2) – 0.99 (1)	0.89 (3)	0.92 (1)

Table 2: Table view the *Average Utilization* of facilities, respectively *Average Used Capacity* of Stores. First line represents the change of utilization (used capacity) after the increasing the interval between the arrivals of tankers. Second line shows current value of *utilization*, respectively *used capacity* in the *store*. In the brackets there is view the summary count of individual machines on the specific line. Red color means the critical utilization, Orange color means the optimal utilization and the Green color means below average.

Table 2 confirms the expectation, that after the *decreasing* the interval between the arrivals of tankers to the factory will *increasing* the *Average Utilization*, respectively *Used Capacity*. Production of the company has reached expected value and the yearly production was **885 514 000** litres. Against to first experiment, where was unsettled bids that were generated throughout the year, which achieves almost half of the current production, in this experiment the value **16 343** times smaller (**17 539** litres of unsettled bids).

The another indicator, that confirms the *validation* of the model is the *average utilization* of *Milk Reception Lines*. From Table 6 in [1] was computed the *average utilization* of *Valves 1-5* equal to **0.3178**. At *Reception Milk Lines* at this experiment was measured value **0.4607**. An *increase* of approximately one-third agreed to change of interval between the arrivals of tankers. Proof of compliance to the requirements of production is, that the *Utilization Factor* at

Pasteurized Milk Lines is **0.3368** in [1], while in our model is this factor equal to **0.3611**. Equally successfully turned a comparison of *Utilization Factor* of *Ultra Pasteurized Milk Lines* to our *Utilization Factor*, which always fell into the interval between *Utilization Factor* and *Efficiency.*

With this pair of experiments we succeeded to prove the *validation* of our model with the *real system* of modelling Dairy Company. At the same, the main target of the experiments was achieved, as defined in 1. Now, the company is able to produce almost full demand for products, based on market demands. In other experiments we will try to make the operation more efficient, we point out the unused lines, or the missing ones.

5.2 Analysis the Utilization of the Processing Lines

After reaching the main target of this *simulation study* looking at another of the sub-targets. When a relatively significant change occurred in the developing process, is necessary evaluate the *Utilization Factor* of all relevant lines. If we look at Table 2, we will focus mainly on the lines that have been marked by **green**. As has been mentioned above, the **green** color marks *under-average* use of this line and it will be assessed the possible removal of one of the lines.

5.2.1 Removing excess lines

In this section we will focus on the experimenting with *processing lines*, which has the *under-coverage* use. Our aim is always to remove the line, respectively to deactivate it from the production process. If the event that this change does not make any further changes, it will be recorded as successful.

The first such line is *Pasteurized Bottle Machine*, which have the *Average Utilization* value only at **1.08179** from the summary **3** capacity of this link. The most important indicator at this link, is the *Maximal Used Capacity*, which it values is equal to **2**, what means, that the *third* link was never used. Experiment shows, that our assumptions were correct and deactivation of this line, it was not intended to influence the developing process.

The next line, which have the value of **Average Utilization** under its efficiency boundary, its *Strawberry Flavored Milk Machines.* In the daily service are **machines**, but the 95% of time is used only one of them. Deactivation of this line has not made any further changes in production as expected. The same procedure and result was also recorded on the *Mango Fruit Milk Machines.*

The result of these experiments was the deactivation of **three** production lines that had no impact on the *production activity.* These lines have been set inactive and have been burdened with a residuals. **Recommendation** for the customer due to the use of these links will be provided in the next Section 6. The summary results of all another lines after the all executed experiments you can see in the added files `*.out`.

6 Conclusion

The main target of this simulation study was to found the relevant value, about which will be decreased the interval between arrivals of tanker to the *Dairy Company.* The company could not produce the needed amount of milk, that market demanded. It was shown that the problem is in the arrivals of tankers to the company and there was needed to decrease the period between tankers arrivals.

Through experiments, the value that needs to be changed in order to make it possible to produce milk on the basis of current market demands has been gained. Thanks to this simulation, we can provide information to the company that if they change the period obtained by us, they will be able to produce the necessary amount of milk. The company does not have to risk that its lines will be overloaded, or any other problems that may arise when changing the interval or arrivals.

Company was also provided with information about effectiveness of some lines that were not actively used. Specifically, it was deactivating of **3** lines that have never been fully utilized during the year, and so others may inactive until the increase in demand for the relevant product, which the link produced.

This simulation study builds on [1], which reveals the main problem why the company was not able to produce the necessary amount of milk. However, our simulation provides the exact results due to the necessary change in the interval of tanker arrivals to the company and adding the information in view of the streamlining of the manufacturing process.

References

[1] Medina, J.; Perez-Lechuga, G.; Seck Tuoh Mora, J.; et al.: Plant capacity analysis in a dairy company, applying montecarlo simulation. *23rd European Modeling and Simulation Symposium, EMSS 2011*. 01 2011: pp. 690–695.