

Process Optimization with Simulation Modeling in a Manufacturing System

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Abstract: Computer simulation has become an important tool in modeling systems in the last ten years due to parallel improvement in computer technologies. Companies tend to computer based system modeling and simulation not to lose any extra income or time to their competitors but to make future investments while they both have the same labor force, resources and technology. This study is an implementation of a machine spare parts manufacturer factory located in city of Turkey. The purpose of the study depends on increasing the utilization rates and optimizing the manufacture process to decrease production costs via identifying the bottlenecks in manufacture system. Therefore, ProModel simulation software was used to model the production line of the factory. Production line consists of nineteen work stations and was modeled for the most manufactured two products. The manufacture in the factory is divided into two weeks of batch production time and simulation model was demonstrated and replicated for ten times to get results. Thus, statistics including existing capacity usages of work stations in the whole production line were found to identify the bottlenecks of the critical work stations and machines. With the use of the simulation model, creating scenarios while making changes of the system parameters, taking the cycle times of the work stations, total production quantity, batch sizes and the shifts of the factory in hand helped to make suggestions.

Key words: Manufacture system, simulation, ProModel, production

INTRODUCTION

Recently, companies get more and more stressed because of the technologic improvements, increasing welfare due to high salaries brought extra burden for companies, competition between homogeneous goods manufacturers. These kinds of problems force the factories to get the best out of their system. To do that, estimation has been an outstanding tool. For manufacturing systems, estimation can be done with powerful softwares with high knowledge of statistics, computer programming and observation. Analyzing the system will help the user to comment about the system parameters such as the cycle times, capacity utilization rates etc. All these parameters will lead the way to the clues that the system hiding. In this study a factory established in Izmir/Turkey was examined to uncover the bottlenecks and to improve the system for the most manufactured two products of company.

Simulation Modeling in Manufacture Systems is a very important decision-making tool for improving system flow with help of simulating the existing systems' manufacture process. Especially, this will inform about production line utilizations in order to improve the productivity in lines and also an appropriate decision to make the right choice for the investor before the investment.

The study is about a spare parts manufacturer' optimization located in city of Izmir, Turkey and the aim is to find the bottlenecks in manufacture system in order to increase the system's utilization and improve production process via lowering manufacture costs. For this purpose simulation modeling is demonstrated. With the help of the simulation model, utilization rates were found, batch sizing problem was solved in some specific areas of system and essential improvements were made to decrease manufacture costs.

LITERATURE REVIEW

Rivero (2004) shows the importance of the use of animated simulation tools in Engineering Education. Simulation is a fictitious reproduction of the behavior for real events of dynamic systems made in order to evaluate and improve systems performance in his study. Some applications frequently used in dynamic logistics systems by means of animated simulation are: layout improvements; simulation of collecting and picking operations; simulation of dock operations, rapid interchanges or cross docking; choosing of better alternatives between a set of possible paths, to simulate the flow of raw materials, human resources, physical resources, in load, unload and transportation operations; simulation of information flows of client orders, well

known as call centers and simulation of integrated dynamic logistic system in order to see the totality of information flows, transportation routes, and operation control along the supply chain and to obtain more profitable alternatives.

Yu *et al.* (2006) research focuses on productivity issue for an automotive assembly workstation involving a lift assist device. To evaluate the productivity of the assembly workstation interfered by proactive ergonomic design, a prescriptive model of the automotive assembly system is developed and simulated with ProModel. This model and its simulation can not only evaluate the productivity, but also determine the maximum conveyor speed. Furthermore, this methodology using ProModel simulation to evaluate productivity and utilization described in this paper can be extended to evaluating other human-machine systems with dynamic, stochastic, and discrete-event characteristics.

Krishnamurthy *et al.* (2004) states that using simulation experiments will help to analyze system performance under different product mixes and observe that in certain environments with advance demand information kanban-based pull strategies can lead to significant inefficiencies. In these environments MRP-type push strategies yield better performance in terms of inventories and service levels. They also studied the impact of design parameters such as safety lead time and safety stock policies on system performance and observe that for low and medium values of system loads, safety lead time policies yield better system performance than safety stock policies. As a result they found it helpful designing efficient MRP-type push strategies in multi-product environments.

DuPont has saved several million dollars by developing simulation models of their tank car operations. ProModel's Consulting Team helped DuPont by providing modeling support for several projects. According to Gates (1998), DuPont received excellent modeling assistance. And they were able to finish building a logistics model of some of their tank car operations that afforded DuPont several million dollars in cost avoidance. The simulation project was designed to evaluate fleet sizing and overall management of railroad tank car operations for transportation of chemicals to various locations in North America.

Kim *et al.* (2005) study is about call centers' becoming an important contact point and an integral part of the majority of corporations. They made an argument about managing a call centers' diversity challenge due to many complex factors. Improving performance of call centers is critical and valuable for providing better service. And in this study they applied forecasting techniques to estimate incoming calls for a couple of call centers of a mobile telecommunication company. They also developed a simulation model to enhance performance of the call centers. The simulation study

showed reduction in managing costs, and better customer satisfaction with the call centers.

Simulation: The mathematical relationships can therefore no longer represent, in a realistic manner, the problem being investigated. Such problems can, however, be investigated by experimentation, although in the workplace it is very difficult, or often impossible, to carry out experiments on the actual manufacturing systems themselves. Simulation can usefully be employed to carry out such experiments (Baldwin *et al.*, 2000). Simulation is an analytic approach used when the solution of a hugely sized and complex problem is hard or impossible (Chase and Aquilano, 1981).

Verma *et al.* (2000) described the steps taken by a major commercial bank in the USA to redesign a critical function within its check-processing operation. They animated simulation models of the current and new processes were developed to understand the relationship between process parameters, waiting times and productivity measures. They described a simulation model in detail for further use of such an approach in banking. Simulation is also a method which enables the results for purpose with the use of probability distributions of random numbers obtained by each random numbers' frequency (Lapin, 1988).

Simulation monitors the cause and effect relationship of a real or a theoretical system and also simulation defines the system behaviors under different conditions. A simulation model should be basically taken in hand as a tool to demonstrate the "what-if" analysis (Pedgen *et al.*, 1990). Simulation lets the user to find alternative strategies effects on general system performances. Besides, simulation is necessary when an experiment needs to be done with the simulation model instead of real system or to gain experience (Oren, 2006). Simulation is used to:

- Predict the consequences of certain decisions and outcomes
- Determine the cause of the observed results
- Identify the problems before investing in
- Reveal the effect of changes
- Ensure finding all the system variables
- Assess the ideas and identify inefficiencies
- Develop new ideas
- Test the integrity and feasibility of your plans

Simulation basically aims to reveal the operational aspects of a system questioning:

- What?
- When?
- Where?
- How?

Computer simulation has become a very popular tool within the system design and analysis. Simulation will

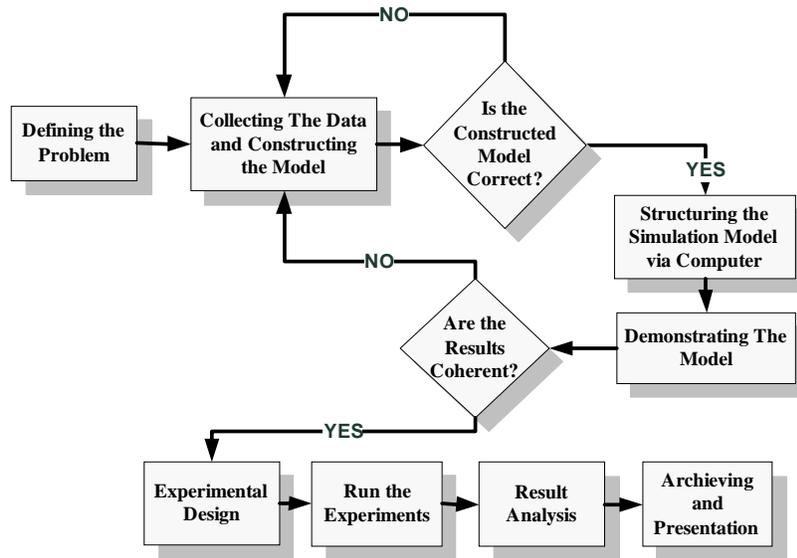


Fig. 1: Steps of a Simulation Study (Law and Kelton, 1999)

provide a timely and intelligent decision making process within the system for engineers and planners. Simulation alone cannot solve the problems but can clearly define and evaluate alternative solutions. Simulation also can do quantitative measurement and analysis to find the best alternative solution for any proposed condition. Before testing the operating policies, computer based simulation model can be demonstrated to encounter the pitfalls of a system and in advance simulation modeling can help us to see whether all these policies etc. are beneficial for the model builder. To obtain the best product or service normally may takes months, perhaps years of work but with simulation, it can be compressed into days or even hours. Today, increasing customer demands, changing technologies and accelerating global competition, companies that produce products or provide services have to find the answers for serving faster and more efficiently, producing better quality with lower costs.

In Fig. 1, steps of a simulation study is given. The hierarchy begins with defining the existing problem on hand, afterwards collecting data to construct the first model. After completing these two beginning steps, the model has to be corrected to move forward. If the answer is yes the model should be structured via computer help and then the model should be demonstrated. After this fifth step, once again the justifying question should be asked, "Are the results correct?". If no, the steps should be repeated till the desired answer. The else situation meaning "if yes", rest of 4 steps can be done as they are respectively Experimental Design, Running The Experiment, Result Analyses and Archiving.

DEMONSTRATING THE MODEL

Problem statement: This study is an implementation of a machine spare parts manufacturer factory located in Turkey. ProModel simulation software was used to model the production line of the factory. Statistics including existing capacity usages of work stations in the whole production line, idle times, waiting times etc. were found to identify the bottlenecks of the critical work stations and machines. Production line consists of nineteen work stations and was modeled for the most manufactured two products (as their codes are P1 and P2). The simulation model was demonstrated for fifty weeks and the bottlenecks of the system were found. There are two products taken in hand to demonstrate the model. Their process flow and the layout of the factory are shown in Fig. 2 and 3.

Below, some explanations are made for the machineries:

Cupola Furnaces: The heavy mold aluminum raw material is melted.

Band-Saw: Raw materials are given the appropriate shape.

Emery-Machine: The parts are being drilled.

Vertical Machining Center (VMC): Near to exact shape is given.

Computer Numerical Control (CNC): The final unwanted burrs are cut off from the parts for exact shape.

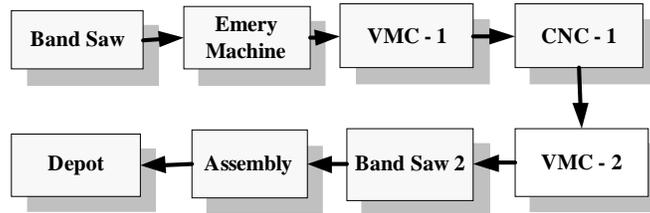


Fig. 2: Process table for P1

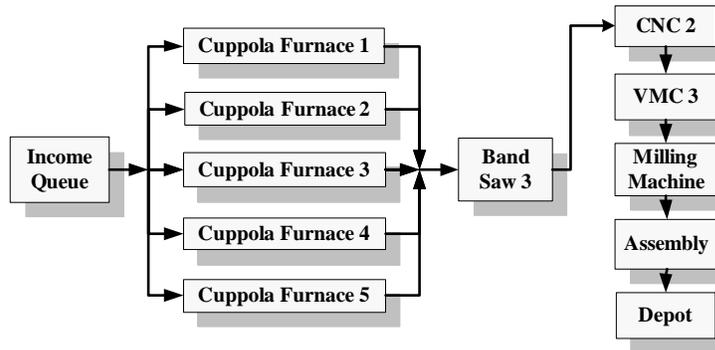


Fig. 3: Process table for P2

After raw material's arrival to income queue location, they are cut at Band Saw location after this operation they go to Emery Machine to be ready for drilling. When drilling is complete at the location VMC-1 (Vertical Machining Center), they arrive to CNC-1 to be turned, then to VMC-2 for another drilling operation. Packaging is the last operation for P1 product and 125 of them gets packed together in a box. Lastly they are shipped to depot accordingly to order policy.

In Fig. 3, aluminum raw materials arrive to income queue, and then they are taken to the Cupola Furnaces firstly to get the designated form of the product P2. The workers get rid of the burrs that the parts have after they are ready at the location Band Saw 3. These parts come to CNC-2 to be turned. They are drilled at VMC-3. P2 products take the last form at Milling Machine then they are batched in groups of 55 products. They complete the processes arriving to depot.

The Company was founded in 1978 as a machinery and spare parts manufacturer in second plant site of Kemalpassa Region in Izmir. The company is a leading star in automotive sector as well as known as manufacturing several types of products. In 2004 the company went for restructuring and completed a move to 5000 m² open and 1500 m² closed space location very near where it was located earlier.

After collecting the data and examining the existing system, we need a bird's eye view to draw the factory layout. As the steps that the products follow, we mentioned about the system and its workflow. The drawing of the layout is in Fig. 4. Figure 4 is the real model of the system created in MS Visio. The machineries are located in their original positions in this preview compared to the real system.

Constraints: The Company's aim is to make the system better without investing much money due to crisis around the world. Redesigning the facility is an expensive way for restructuring but optimizing the system is the most adequate way for them. So finding bottlenecks of the working system will be quite enough to increase the income so in long term they will be able to invest much more.

Per P1 product costs 2.95€ and P2 costs 2.75€. Average cost of a CNC machine per hour is nearly 16€, 24€ for VMC's, 32€ for Cupola Furnace and other machineries about 21 level. These machinery costs include electricity consumption and fixed costs like amortized and rental values.

Statistical distribution of the collected data: When conducting an experiment, questionnaires, interviews,

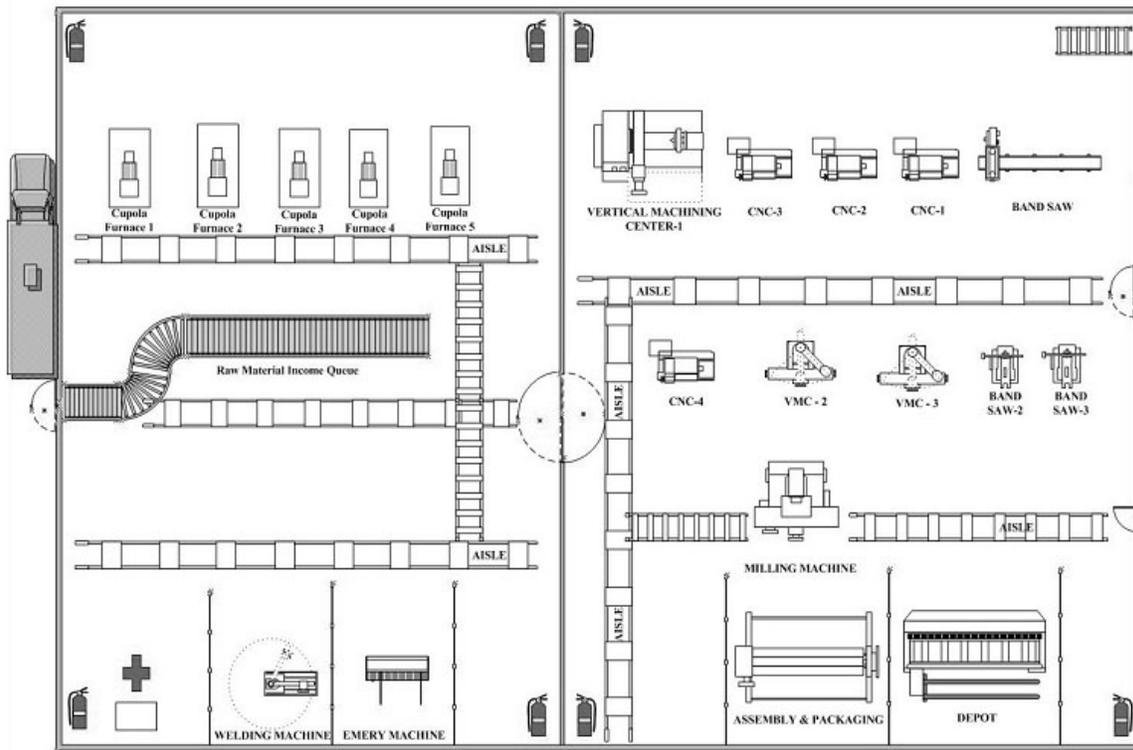


Fig. 4: Layout view of the factory

Table 1: Statistical distributions of machines for P1

Machine	Statistical distribution	Test statistics
Band Saw	Uniform	a = 14,513, b = 20,647
Emery machine	Uniform	a = 43,461, b = 56,319
Vertical machining center -1	Uniform	a = 8,5336, b = 12,546
CNC 1	Normal	$\mu = 120,29, \sigma = 5,9752$
Vertical machining center -1	Uniform	a = 111,08, b = 130,68
Band saw 2	Uniform	a = 26,49, b = 32,27
Assembly	Uniform	a = 273,75, b = 319,61

Table 2: Statistical distributions of machines for P2

Machine	Statistical distribution	Test statistics
Cupola furnace (5)	Normal	$\mu = 26, \sigma = 5$
Band saw - 3	Uniform	a = 12,614, b = 17,614
CNC 2	Lognormal	$\mu = 4.0072, \sigma = 0.06188$
Vertical machining center -3	Uniform	a = 56.235, b = 65.485
Milling machine	Uniform	a = 8,1216, b = 12,542
Assembly	Uniform	a = 275,08, b = 317,04

observations, documentation, surveys or different types of quantitative measurement methods can be used. In this paper, cycle times of the system were measured with a stopwatch to record the statistics and the collected data was fit for an appropriate distribution. For the distribution and test statistics per machine for the product P1 (Table 1) and for the product P2 (Table 2).

The depot is seen on the right top of Fig. 4 although it is at the down right of the system; it is just to fit the

visuality. The variables (boxes) including “Total Products Manufactured, Products in Queue and Total Boxes in Depot” trace the number of the products to see the workflow clearly. As we said before product type of P1’s are grouped together as 125 and products P2 as 55 at the Assembly and Packaging location routing to depot. A figure of the simulation model is below and shows the routs that the products follow with arrows during production process (Fig. 5).

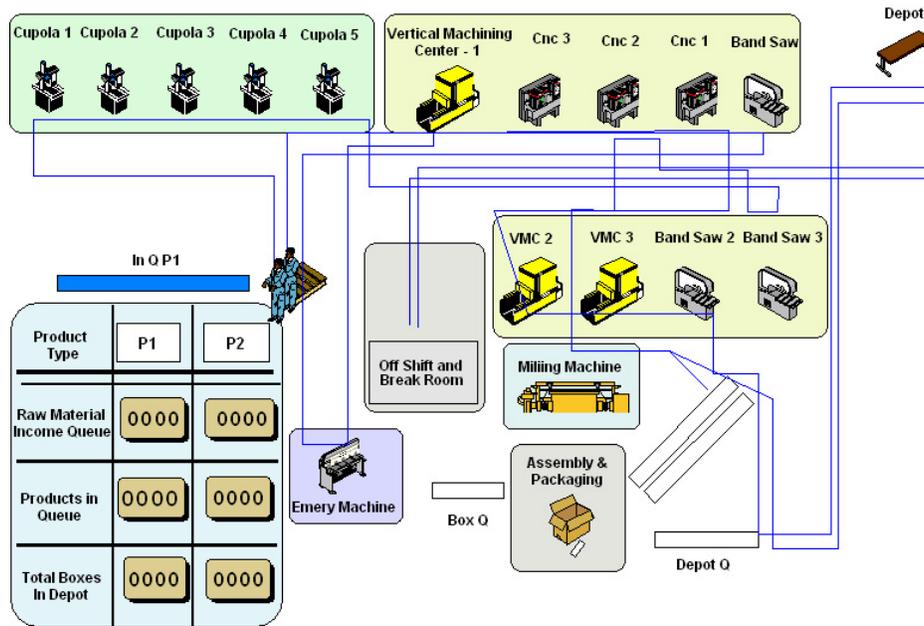


Fig. 5: Layout view of the system in ProModel software

Verification: Collecting the data was the first basis to create the basics for this simulation model. Like every statistical approach, this type of data has to be verified if it represents the real system or not. The simulation model was validated intuitively by the production engineer and the workers. The outcome numbers for the system were adequate; the key question was if it is sufficient cause to perform the system. So the system had to be statistically verified. After running the simulation model for two weeks and fifty replications and using SPSS software to find out descriptive statistics and the data we got with the simulation model.

The Mean for the simulation model came up as 1483,94 and Standard Error Mean as 11,77494. These two model output values are statistically compared to the real systems manufactured products number as it is 1500 for two weeks of time. The hypothesis is given below:

$$H_0 : \mu = 1500 \text{ (The mean production of the system is equal to 1500)}$$

Result for Z statistic is found as -1364 and H_0 hypothesis $p = 0.00 < 0.05$ is validated at 5% level of significance. Therefore, now it is appropriate to find the bottlenecks and different scenarios can be analyzed.

Demonstrating the simulation model: As the creators of the software ProModel and the authors Harrell and Ghosh recommended, it is chosen ten repeats. Besides, with the help of *Shift Editor*, the work time of the facility was assigned to the workers and machines in the factory. After that the model was demonstrated.

Experimental results are provided to show that their model provides comparable computational and managerial advantages (Meng *et al.*, 2009). Spedding and Chan (2001) used simulation as a platform to conduct the control chart system design because different scenarios can be tested off-line so that statistical process control can be performed effectively without making costly mistakes.

Below in Table 3, some codes of the simulation model are given. The first column represents Entities that are used in the system. In the second column, the locations are given which they will process the entities. The last column consists of operations that the locations will process. In this part of the model, the logic for the whole processes is given to the software as it will calculate the times when the simulation model runs.

First of all, the raw materials for P1 get in the system (entity name as P1_Raw) and these materials arrive In_Q_P1 as they have no operations because they are stored. After that these materials come to Band_Saw location named machinery to be processed about Uniformly Distributed (17.58, 3.067) seconds. After the process is completed, now these parts are able to head to Emery_Machine location with their new entity names as P1_T1. They are again processed for Uniformly Distributed seconds as given in Operation columns till the CNC_1 queue. They wait and accumulate here in the number of 200 because the CNC machinery will process them as batches of 200 and then let them to continue their processes. After their process in Band_Saw_2, they are headed to Box_Q to join 125 of them together and get into the same box to be shipped after their transportation to the Depot location.

Table 3: A part of the simulation model's code

Entity	Location	Operation
P1_Raw	In_Q_P1	
P1_Raw	Band_Saw	WAIT U (17.58, 3.067) sec
P1_T1	Emery Machine	WAIT U (49.89, 6.429) sec
P1_Z	VMC_1	WAIT U (10.54, 2.006) sec
P1_IM_1	Block_DIM1	
P1_IM_1	CNC_1	Accum 200
P1_CNC_1	Block_CNC1_DIM2	
P1_CNC_1	VMC_2	WAIT U (120.29, 10.35) sec
P1_IM_2	DIM2_CIK	
P1_IM_2	Band_Saw_2	WAIT U (29.38, 2.89) sec
P1	Product_Q_P1	INC Pack_Q_P1
B_K_P1	Box_Q	
B_K_P1	Packaging	JOIN 125 P1
D_K_P1	Depot_Q	
D_K_P1	Depot	INC DEPOT_P1
Raw_P2	Giris_P2	
Raw_P2	Cupolo_1	WAIT U (26, 5) min
Raw_P2	Cupolo_2	WAIT U (26, 5) min
Raw_P2	Cupolo_3	WAIT U (26, 5) min
Raw_P2	Cupolo_4	WAIT U (26, 5) min
Raw_P2	Cupolo_5	WAIT U (26, 5) min
P2_O	T_G_K	
P2_O	Band_Saw_3	WAIT U (15.114, 2.5) sec
P2_T3	Blocktes3	
P2_T3	CNC_2	ACCUM 34
P2_CNC_2	Block_CNC2_DIM3	
P2_CNC_2	VMC_3	WAIT U (60.86, 4.625) sec
P2_DIM_3	Block_DIM3_FRE	
P2_DIM_3	Milling_Mac	WAIT U (10.332, 2.210) sec
P2_U	Product_Q_P2	INC Pack_Q_P2
B_K_P2	Box_Q	
B_K_P2	M_P2	JOIN 55 P2_U
D_K_P2	Depot_Q	INC Depot_P2
D_K_P2	Depot	
P1_Raw	Product_Q_P2	

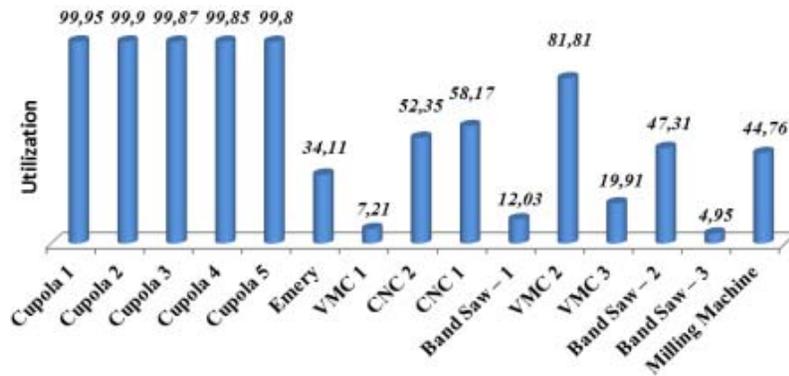


Fig. 6: Utilization Rates of the machines after the demonstration

As likely to P1, P2 products follow the same procedures and they are also transported to the Depot for their potential customers. The code Inc is "increment" as it increments the specific entity's number after their successful operation. Thus the model builder can follow the numbers of products or any other parameter given like boxes, workers or any other routine.

After the input of the given statistical data into the model and demonstration, the results are output like in the

following figure. As it can be seen from Fig. 6, the utilization rates of the machines are given. Cupola furnaces are highly productive but it can't be said the same for VMC-1, Emery Machine, VMC-3 and Bandsaw-3.

Cost of the existing system: Company's aim is to make the system better without investing much money due to crisis around the world. Redesigning the facility is an

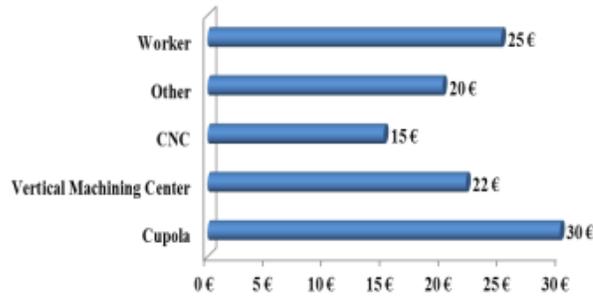


Fig. 7: Cost per hour

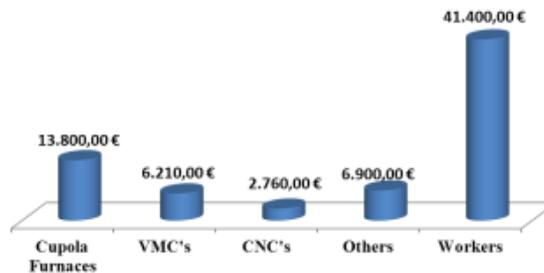


Fig. 8: Cost table for one group of production

expensive way for restructuring but optimizing the system is the most adequate way for them. Facility design problems generally solved with statistical and deterministic model approach. Facility planners must be particularly good in the areas of engineering, budget and information systems (Askin and Standridge, 1993). So finding bottlenecks of the working system will be quite enough to increase the income so in long term they will be able to invest much more. Per P1 product costs 2.95€ and P2 costs 2.75€. Average cost of a CNC machine per hour is nearly 15€, 22€ for VMC's, 30€ for Cupola Furnace and other machineries about 22€ level. These machinery costs include electricity consumption and fixed costs like amortized and rental values. The Company has 18 workers and per worker costs 25€ hourly including like lunch, severance payment and travelling expenses. The mentioned costs are shown in Fig. 7.

The Factory is manufacturing products in batches of products and one batch is completed in two weeks. And this two week of time consists of 1500 parts of P1 and 1000 parts of P2. After the completion of one batch manufacturing, the costs of production factors can be seen in Fig. 8. There are 5 different manufacturing factors as they effect the total cost highly. The highest cost is the workers' as they cost about 40k€ . Cupolas' are also a heavy burden as they cost about 14k€ . Vertical Machining Center, Cnc and others like Emery Machine, Band-Saw and Milling Machine cost about 6, 3 and 7 k, respectively. As the existing simulation model is done,

now it is time to optimize the model with the help of different scenarios.

Scenario 1: Cutting the low utilization rated machines off the system:

As mentioned before VMC-1, Bandsaw-1 and Bandsaw-3's utilization rates are low. So this scenario will be about cutting these machines off the system. And the same machines will be used for the low utilized machines. For example, VMC-3 will be disabled and the job will be done in VMC-1. The same operation will be done to Bandsaw-3 and Bandsaw-1 as Bandsaw-1 will replace the pending jobs of Bandsaw-3 and due to changes, company will get rid of the fixed cost for 2 machines. After regulating the model the results will be like the following:

Disabling two machines will reduce the costs about approximately 11.500 for one batch production and two weeks of time.

Scenario 2: Optimizing the batch sizes:

The Products P1 are batched together in groups of 200 parts just before entering into the location CNC-1 and this number is 34 for P2 product. These numbers are the maximum numbers of parts that a CNC machine can process. In this scenario, the batch size of product P1 is shifted between 20 and 200 to find the best value based on utilization.

Figure 9, the effect of batch sizes over CNC-1 machine and batch sizes over cost per product are shown. The left column represents the unit cost, the right column

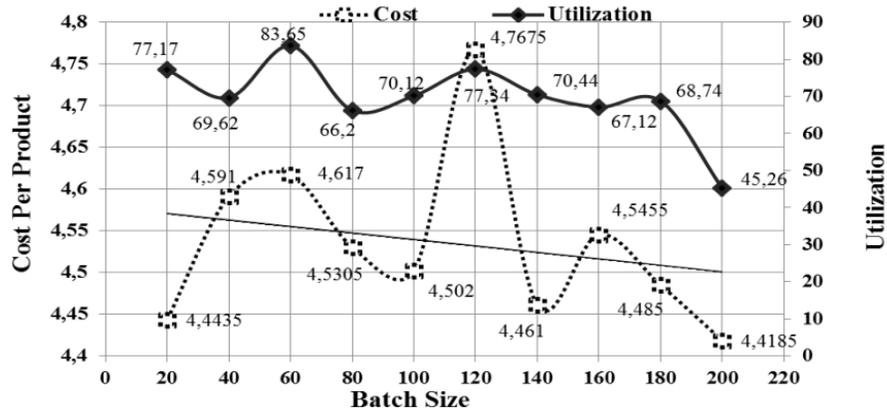


Fig. 9: Batch size change for P1 product

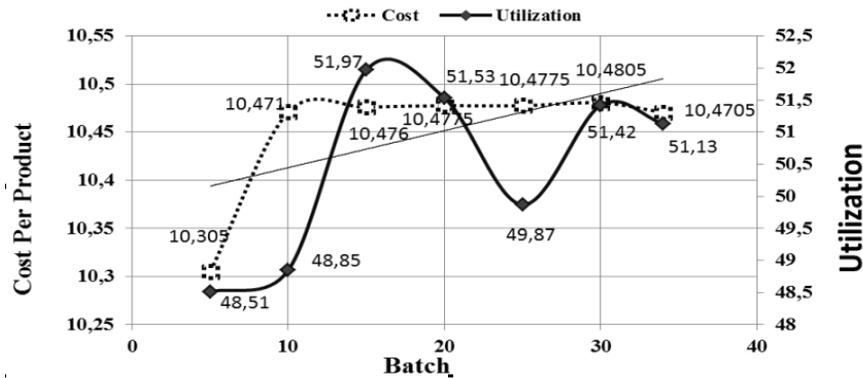


Fig. 10: Batch size change for P2 product

represents utilization and the below line represents the batch size of parts entering to CNC-1 machine. Looking into the values, it is clear that batch sizes affecting the CNC-1 utilization cost per unit. The lowest utilization is when the batch size is 200 and beside the lowest comes with it. But the optimized value between the comparison of cost per product and batch size is the group of 20's. It has the highest third utilization and the second lowest cost. Upon these constraints the batch size of 20 is the utmost expedition choice.

In Fig. 10 the results of Scenario 2 for Product P2 are given. As mentioned before P2 products are batched together in groups of 34 parts while to be processed in CNC-2 machine. In this scenario, the batch size of product P2 is shifted between 5 and 34 to find the best value based on utilization.

After the "what-if" analysis, the effect of batch sizes over utilization and cost per product are shown in Fig. 10. As in P1 product the columns places are the same. While the batch size is approximately 51%, cost per product is about 10€. Although the utilization is high, the cost is also high. But as seen in the batch size of 5, the utilization

is about 48.51% and in the cost level of 10.3€ and this is the lowest cost for desired criteria. So, selecting the batch size value as 5 for P2 and 20 for P1 will be the optimized choice.

Scenario 3: Adding shift system: In the existing system, the batch sizes for the products P1 and P2 are selected as 1500 and 1000, respectively. And this amount of production takes 2 weeks of time as said before. In this scenario it will be researched what if the shift system changes while containing the same numbers and manufacturing them quicker. If 18 more workers are hired as the company had before, the results will be like in Fig. 11:

As seen in Fig. 12, the total utilization is increased and also cost per product is decreased. There will be an extra profit of 1.5€ per product. While these values are gathered, it is based on long terms like fifty weeks as 25 batches of production.

The underlying reason for the cost per product change is the transition between shifts. Because the system now has a shift system, the machines are not

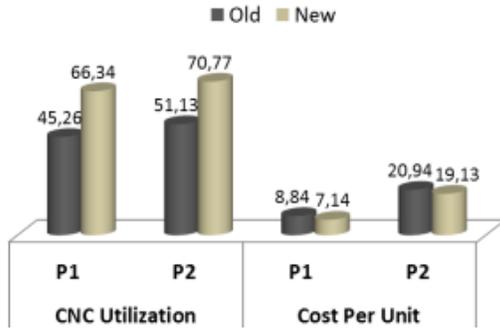


Fig. 11: The Effect of Shift Change over CNC Utilization and cost per unit

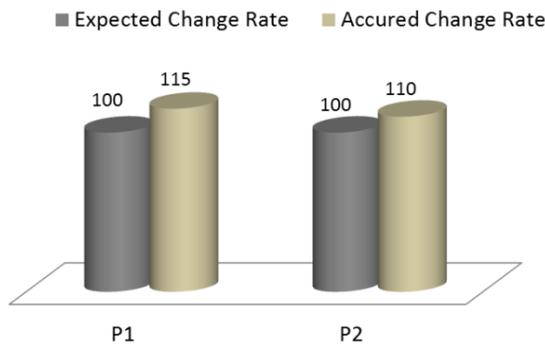


Fig. 12: The Change of Total Production for per product

turned off and the pending jobs can be processed. In long term there is significant improvement in cost per product criteria via the shift system.

In Fig. 12, total production graphic for fifty weeks is given .After simulating the third scenario, the workers of the factory are doubled, so simply the expectations are also will be doubling the numbers of production. But it does not happen as expected and the results show that while expecting a 100% increase, it happened about 115% for P2 and 110% for P1. After a deep research with comparison, it can be concluded that the estimated rate of P1 is 5% higher from P2 because the cycle time of P2 in CNC-2 takes longer time than P1.

RESULTS AND RECOMMENDATION

In Scenario 1, the low utilized machineries are cut off from the system and their jobs are transferred into other equivalent machineries. After this change, the company would be able profit approximately 11.000 in two weeks of time as can be called 1 batch production.

In Scenario 2, the batch sizes of products for P1 and P2 are changes just before entering to the desired locations in factory. The batch size for P1 product in CNC-1 machine is shifted between 20 and 200. The same

operation for P2 is done between 5 and 34. After demonstrating Scenario 2, choosing 20 to 200 made an immediate effect and let the way to find the ideal utilization rate and cost per product. The same procedure is evaluated for P2 product and selecting the batch sizes between 5 and 34 showed us that the best batch size value for this one is 5. Taking Scenario 2 in hand, these two parts made the company earn additional 1.5 including the workers cost etc. Doing simple math will lead the way as below:

In two weeks of time the factory manufactures 1500 parts of P1 and 1000 parts of P2. In 50 weeks, the total output will be about 70.000 P1 and 30.000 pieces P2 products. So:

$$1,5*(70.000+30.000) = 150.000$$

(total additional profit in fifty weeks)

In the last scenario, a shift system was integrated to the model and the results are compared. For product P1 it was expected a 100% increase but it was happened about 115% and this number was 110% for product P2. This output value showed that it will be reasonable choice to integrate a shift system in the company.

After evaluating three different scenarios it will be the best choice to integrate a mix solution including both of them. Releasing the low utilized machines from the system, changing the batch sizes of parts entering the locations and transition the shift system would give the best solution for the company.

After conducting the experiment, demonstrating all the scenarios mentioned, company's costs decreased and in contrary the productivity increased. Besides, the company decided to change the shift system and add another shift by hiring extra staff for enlarging in long term. This study enlightened the pending feasibility report and the company decided to go for a revision in factory layout.

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