ANALYSIS AND IMPROVEMENT OF MANUFACTURING PROCESS USING SIMULATION: A CASE STUDY OF A COFFEE INDUSTRY

Heráclito Lopes Jaguaribe Pontes – hjpontes@sc.usp.br
Shih Yung Chin – sychin@sc.usp.br
Arthur José Vieira Porto – ajvporto@sc.usp.br
Escola de Engenharia de São Carlos – USP
Av. Trabalhador Sancarlense, 400 CEP:13566-590 – São Carlos – SP

Abstract. *The competition among the coffee industries and the customer demand for differentiated products has increased substantially. To suvirve in this market, the companies need to know very well its manufacturing capacity and its possible improvements. The company which the study took place is a manufacturer of coffee, which required an analysis of its manufacturing operations in an attempt to increase its resource utilization and to detect its bottlenecks. Therefore, the purpose of this paper is to describe the use of simulation to analyse and to improve the manufacturing process efficiency of a coffee industry. Arena software was chosen to develop the simulation. Arena is a powerful easy-to-use simulation tool for modeling of manufacturing processes. The initial model was developed to produce an accurate simulation of the existing system and later the model was used to experiment with three differents scenarios. The simulation results that were obtainded from this three scenarios gave an important support to the decision-makers and provided important knowledge to the company about how its manufacturing process works.*

***Keywords**: Simulation, Manufacturing Process, Arena.*

1. INTRODUCTION

Nowadays manufacturing industry is facing problems that have been growing in size and complexity over the last several years. Increased demands for high quality products and services, shorter lead times, reduced costs, available new technology and market globalization have encouraged manufacturing organizations to introduce changes in the processes to improve efficiency. Simulation has become a popular technique for analyzing the effects of these changes without actual implementation or assignment of resources. Many world manufacturing processes can be easily and adequately analyzed with simulation models.

The competition among the coffee industries and the customer demand for differentiated products had increased substantially in the last years. To survive in this market, the industries need to know very well its manufacturing capacity and its possible improvements. The companies need to identify the potentialities of the manufacturing process and the customer's necessities and to satisfy them fast and efficient.

The company which the study took place is a manufacturer of coffee, which required an analysis of its manufacturing operations in an attempt to increase its resource utilization and to detect its bottlenecks. Therefore, the objective of this paper is to describe the use of simulation to analyze and to improve the manufacturing process efficiency of a coffee industry. Therefore, the purpose of this work is modeling the manufacturing process to identify bottlenecks and to enhance process performance in terms of resources utilization.

Arena software was the tool chosen to develop the simulation. Arena is a powerful easy-to-use simulation tool for modeling of manufacturing processes. The simulation study with Arena provides a picture of the manufacturing process performance under different possible scenarios. First, it was developed a real simulation model that is used to observe the manufacturing process and later the model was used to experiment with three different scenarios. The three scenarios are done by changing the configuration of the manufacturing process and analyzed in terms of production capacity and resource utilization.

This paper is organized as follows: Section 2 presents a description of simulation (definition, when should be used, advantages and disadvantages, manufacturing process simulation and software Arena). Section 3 describes the case study (manufacturing process description, data and information collection, simulation model development, validation and verification, experimentation, discussion of results). The last part provides the final considerations.

2. SIMULATION

2.1. Definition of simulation

Simulation is the process of design a mathematical-logical model of a real system and experimenting with this model on a computer. Thus simulation encompasses a model building process as well as the design and implementation of an appropriate experiment involving that model (PRITSKER, 1986).

Simulation is the imitation of the operation of a real-world process or system over time. Simulation involves the generation of an artificial history of the system, and the observation of that artificial history to draw inference concerning the operating characteristics of the real system that is represented. Simulation is an indispensable problem-solving methodology for the solution of many real-world problems. Simulation is used to describe and analyze the behavior of a system, ask what if questions about the real system, and aid in the design of real systems. Both existing and conceptual systems can be modeled with simulation (BANKS, 2000).

For Harrel and Tumay (1997), simulation is an activity whereby on can draw conclusions about the behavior of a given system by studying the behavior of a corresponding model whose cause-and-effect relationships are the same as (or similar) those of the original. Simulation uses a computer program to actually mimic causal events and the consequent actions in a system.

Shannon (1998) define simulation as the process of designing a model of a real system and conducting experiments with this model for the purpose of understanding the behavior of the system and/or evaluating various strategies for the operation of the system.

According to Kelton *et al.* (1998), simulation refers to methods for studying a wide variety of models of real-world systems by numerical evaluation using software designed to imitate the system's operations or characteristics, often over time. From practical viewpoint, simulation is the process of designing and creating a computerized model of a real or proposed system for the purpose of conducting numerical experiments to give us a better understanding of the behavior of that system for a given set of conditions. Although it can be used to study simple systems, the real power of this technique is fully realized when use it to study complex systems.

For Maria (1997), simulation of a system is the operation of a model of the system. The model can be reconfigured and experimented with, usually, this is impossible, too expensive or impractical to do in the system it represents. The operation of the model can be studied, and hence, properties concerning the behavior of the actual system or its subsystem can be inferred. In its broadest sense, simulation is a tool to evaluate the performance of a system, existing or proposed, under different configurations of interest and over long periods of real time.

2.2. When should simulation be used?

According to Maria (1997), simulation is used before an existing system is altered or a new system built, to reduce the chances of failure to meet specifications, to eliminate unforeseen bottlenecks, to prevent under or over-utilization of resources, and to optimize system performance.

For Carson II (2004), simulation is most useful in the following situations:

- There is no simple analytic model, spreadsheet model or "back of the envelope" calculation that is sufficiently accurate to analyze the situation.
- The real system is regularized, that is, it is not chaotic and out of control. System components can be defined and characterized and their interaction defined.
- The real system has some level of complexity, interaction or interdependence between various components, or pure size that makes it difficult to grasp in its entirety. In particular, it is difficult or impossible to predict the effect of proposed changes.
- You are designing a new system, considering major changes in physical layout or operating rules in an existing system, or being faced with new and different demand.
- You are considering a large investment in a new or existing system, and it represents a system modification of a type for which you have little or no experience and hence face considerable risk.
- You need a tool where all the people involved can agree on a set of assumptions, and then see (both statistically and with animation) the results and effects of those assumptions. That is, the simulation process as well as the simulation model can be used to get all members of a team onto a (more) common understanding.
- Simulation with animation is an excellent training and educational device, for managers, supervisors, engineers and labor. In fact, in systems of large physical scale, the simulation animation may be the only way in which most participants can visualize how their work contributes to overall system success or problems.

In accord with Bertrand and Fransoo (2002), simulation is used in case the model or problem is too complex for formal mathematical analysis. This type of research generally leads to lower scientific quality results than research using mathematical analysis, but the scientific relevance of the process or problem studied may be much higher. This is because computer simulation can deal with a much wider variety of scientific models than can mathematical analysis.

2.3. Advantages and disadvantages of simulation

Simulation has a number of advantages over analytical or mathematical models for analyzing systems. Some simulation advantages are cited for Banks (2000), Banks (1998), Banks *et al.*(1996), Schriber (1991), Law and Kelton (2000) e Centeno and Carrillo (2001):

- The basic concept of simulation is easy to comprehend and hence often easier to justify to management or customers than some of the analytical models.
- Simulation models do not require the many simplifying assumptions of analytic methods.
- It can be used to explore new staffing policies, operating procedures, decision rules, organizational structures, information flows, etc. without disrupting the ongoing operations.
- Simulation allows identifying bottlenecks in information, material and product flows and test options for increasing the flow rates.
- It allows us to test hypothesis about how or why certain phenomena occur in the system.
- Simulation allows us to control time. Thus we can examine an entire shift in a matter of minutes or we can spend two hours examining all the events that occurred during one minute of simulated activity.
- It allows us to gain insights into how a modeled system actually works and understanding of which variables are most important to performance.
- Simulation's great strength is its ability to let us experiment with new and unfamiliar situations and to answer "what if" questions.

The disadvantages of simulation include the following:

- Simulation modeling is an art that requires specialized training and therefore skill levels of practitioners vary widely. The utility of the study depends upon the quality of the model and the skill of the modeler.
- Simulation results may be difficult to interpret.
- Simulation modeling and analysis can be time consuming and expensive.
- Gathering highly reliable input data can be time consuming and the resulting data is sometimes highly questionable. Simulation cannot compensate for inadequate data or poor management decisions.
- Simulation models are input-output models, i.e. they yield the probable output of a system for a given input. They are therefore "run" rather than solved. They do not yield an optimal solution; rather they serve as a tool for analysis of the behavior of a system under conditions specified by the experimenter.

2.4. Manufacturing process simulation

In according Korn *et al.* (1999), simulation tools for production systems have been developed focusing on various aspects and problems in modern manufacturing systems. The simulation of an entire production system, simulation of specific manufacturing processes, scheduling, grouping and resource allocation problems. In general, simulation tools often allow the user to manipulate parameters of the simulated system. This can sometimes lead to an interactive experimenting process with the simulation model which would not have been possible with the real-world system.

The realistic simulation modeling becomes very essential and effective for designing and managing of manufacturing process. Simulation has been commonly used to study behavior of real word manufacturing process to gain better understanding of underlying problems and to provide recommendations to improve the process. To observe real manufacturing process is very expensive and sometimes cumbersome. Therefore, a simulation model is an easier way to build up models for representing real life scenarios to identify bottlenecks, to enhance system performance in terms of productivity, queues, resources utilization, cycle times, lead time, etc (ALI and SEIFODDINI, 2006)

The principal benefits that the simulation can bring for manufacturing processes are the need for/and the quantity of equipment and personnel, performance evaluation and evaluation of operational procedures. The most important performance measures estimated by simulation are throughput, time in system for parts, times parts spends in queues, queues sizes, timeliness of deliveries and utilization of equipment or personnel (LAW and MACCOMAS, 1999).

According to Banks (2000), production bottlenecks give manufacturers headaches. It is easy to forget that bottlenecks are an effect rather than a cause. However, by using simulation to perform bottleneck analysis, you can discover the cause of the delays in work-in-process, information, materials, or other processes.

2.5. Software Arena

Arena is a flexible and powerful simulation software tool from Rockwell Software Corp. that allows users to create animated simulation models that accurately represent virtually any system. Designed modules are available to construct the model, and custom modules can be created for specific user needs (ALI and SEIFODDINI, 2005).

For Kelton *et al.* (1998), Arena software combines the ease of use in high-level simulators with the flexibility of simulation languages, and even all the way down to general-purpose procedural languages. It does this by providing alternative and interchangeable templates of graphical simulation modeling-and-analysis modules that user can combine to build a fairly wide variety of simulation models. For ease of display and organization, modules are typically grouped into panels to compose a template. By switching templates, user gain access to a whole different set of simulation modeling constructs and capabilities. In many cases, modules from different panels and templates can be mixed together in the same model.

3. A CASE STUDY

This paper was carried out in a middle size manufacturing coffee industry with approximately two hundred and fifty employees and demand for 2.000.000kg roaster and grinder coffee for month. The monthly production of the industry is below the market demand (approximately 1.750.000kg). With this problem, it comes up the necessity to improve the production capacity and the resources utilization of the manufacturing process, eliminating the bottlenecks and verifying the necessity of new investments.

3.1. Manufacturing process description

The manufacturing process is divided in two lines of production in accordance with the packing: coffee vacuum line and coffee bags line. In the coffee vacuum line isn't placed oxygen inside of its packing and this has a consequence: a stated period of bigger validity (1 year) and higher prices. In the coffee bags line that is placed oxygen, the validity stated period is lesser (3 months) and lower prices. The production of coffee bags line represents about 80% of the industry production. The coffee bag line has a great representation in the invoicing of the company, the detailed study and the search for improvements in its manufacturing process are of extreme importance.

In the manufacturing process of the coffee bag line are produced two types of coffees: type A and type B. The coffee type A represents about 70% of the coffee bag line production. The processes of the two types of coffees are similar. The process is divided in roasting, ground coffee hoppers, grinding, powder coffee hoppers and packaging. The daily manufacturing operation involves three shifts of eight hours each. As shown in Fig. 1 the flow chart of the manufacturing process of the coffee bag line.

The roasting process is carried out for two roasters with same production capacity. The roasting process basically consists roasting of the raw coffee for one determining time. Each roaster has an operator that determines the beginning and the ending of the roasting and monitors constantly some variation or failure in the roasting process and determines in which ground coffee hopper will go the roasting coffee. The second process is the storage in ground coffee hoppers. The ground coffee hoppers are reservoirs of storage where the coffee stay after the roasting for cooling. The manufacturing process is composed of five ground coffee hoppers with same capacity (5.000kg).

The third process is the grinding that is carried out for two grinders with same production capacity. Each grinder has an operator that determines the beginning and the ending of the process and monitors constantly some variation or failure in the grinding process and determines in which powder coffee hopper will go the grinding coffee. The fourth process is the storage in powder coffee hopper. The powder coffee hoppers are reservoirs of storage where the coffee stay after the grinding for cooling. The manufacturing process is composed of four powder coffee hoppers with same capacity (4.032kg).

The last process of the coffee bag line is the packaging process. This process consists of a machine that automatically fills the package with coffee and saddle. There are three types of packing format in the packaging process: 100g, 250g and 500g. The packing format 250g represents about 60%, the packing format 100g represents about 25% and the packing format 500g represents about 15% of the coffee bag line production. The manufacturing process is composed of six packaging machines that have varied speeds in accordance with the packing format. The production of each packaging machine varies in accordance with the packaging speed and the packing format. As illustrated in Tab. 1 the production time of each resource of the coffee bag line.

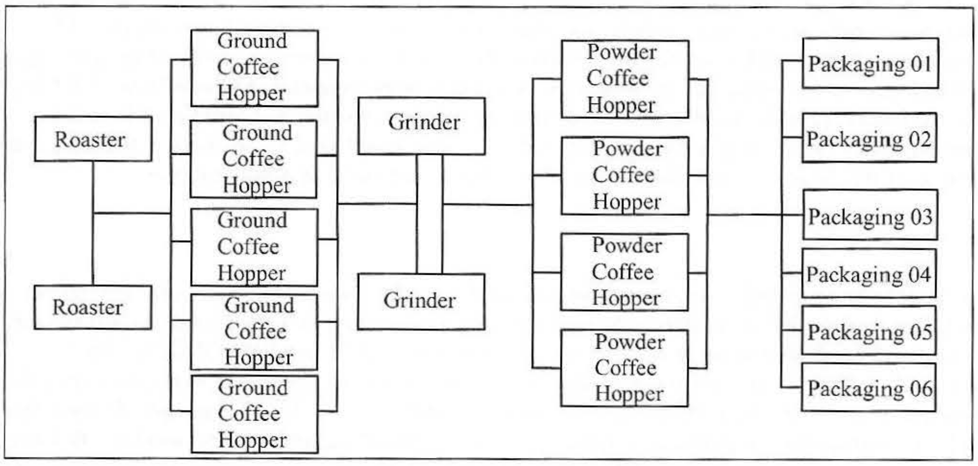

Figure 1. Flow chart of the manufacturing process of the coffee bag line

Table 1. Production time of resources in the coffee bag line

Resource	Data Parameters	Resource	Data Parameters
Roasters	21 ± 1.05 min	Packaging Machine 2	55 packages/min for 100g bags
			45 packages/min for 250g bags
Ground Coffee Hoppers	60 min	Packaging Machine 3	65 packages/min for 250g bags
			35 packages/min for 500g bags
Grinders	33 ± 1.65 min	Packaging Machine 4	75 packages/min for 100g bags
			65 packages/min for 250g bags
Powder Coffee Hoppers	60 min	Packaging Machine 5	65 packages/min for 250g bags
Packaging Machine 1	55 packages/min for 100g bags	Packaging Machine 6	65 packages/min for 250g bags
	45 packages/min for 250g bags		50 packages/min for 500g bags

3.2. Data and information collection

For the initial simulation model development, collection of data and information in the coffee industry was carried out. During the period of two months the manufacturing process of the coffee bag line was observed. Interviews with personnel at the company were also carried out, mainly among operators, maintenance personnel and industrial engineers. The main reason behind the interviews was to understand the manufacturing process and the possible problems that can occur to achieve information about failures.

The main data and information collected that were used as base for the initial simulation model development are: production capacities of the resources, monthly production for type of coffee and format of packing, resources utilization, total time of failures, time between the failures and total time of setups.

3.3. Simulation model development

The initial model was developed based in the real system of the coffee bag line that is decomposed as following: initially, a production order (with predetermined production quantities) is emitted. After that, the blend of raw coffee is sent for one of the roaster that the processes the production order, the two roasters are independent between themselves. After the roasting, the roasting coffee goes to the ground coffee hopper where it stays stored during a fixed period of two hours. After the period stored in the ground coffee hopper, the coffee goes to one of the grinder where is carried out the grinding process, the two grinders are independent between themselves. After that, the coffee goes to the powder coffee hopper where it stays stored during a fixed period of two hours. The last process of the model is the packaging. The packaging is carried out after the period of storage powder coffee hopper.

The simulation model was developed using software Arena 5.0. A simulation model was generated by selecting and allocating the required modules of the template in Arena. For the initial model construction were defined: the resources, the variables (global and local) and the attributes.

In the construction of the initial model were reproduced the significant details of the real system as:

- Production Order: three types of production orders had been considered (order of 1.008kg, 2.016kg and 4.032kg). These three types of production orders represent 90% of the types of production order in coffee bag line. The production order of 4.032kg represents about 50%, the production order of 2.016kg represents about 30% and the production order of 1.008kg represents about 20% of the coffee bag line production. These production orders are processed in each resource and after it is finished the resources becomes available to process a new order.
- Setups: the setup had been considered in change of packing format in the packaging machines. The setups of the packaging machines that produce the format of 500g is longer because this format is more complicated of adjustments in the machine. As shown in Tab. 2 the setups to the three types of format.
- Failure: the failures had been considered in all the resources (roasters, ground coffee hoppers, grinders, powder coffee hoppers and packaging machines) in accordance with Tab 3. It had been determined downtime (teams frame when failure starts and until it ends) and time between downtime (TDBT). The packaging machines 1, 2 and 3 have more failure than the packaging machines 4, 5 and 6 because they are older.

Table 2. Setup Packaging Machines (min)

Packing Format	100g	250g	500g
100g	0	25	25
250g	25	0	25
500g	30	30	0

Table 3. Resources Failure

Resource	Failure (min)		Resource	Failure (min)	
	TDBT	Downtime		TDBT	Downtime
Roasters	Expo(2.880)	Expo(60)	Packaging Machine 2	Expo(2.880)	Expo(40)
Ground Coffee Hoppers	-	-	Packaging Machine 3	Expo(2.880)	Expo(30)
Grinders	Expo(4.320)	Expo(40)	Packaging Machine 4	Expo(5.760)	Expo(30)
Powder Coffee Hoppers	-	-	Packaging Machine 5	Expo(5.760)	Expo(30)
Packaging Machine 1	Expo(2.880)	Expo(40)	Packaging Machine 6	Expo(5.760)	Expo(30)

A variety of measures may be used to evaluate the performance of manufacturing processes. This simulation model has been taken into account two measures of performance:

- Production Capacity: this measure the performance of the monthly production capacity.
- Resources Utilization: this is the proportion of time that a resource is busy doing useful work. The resource utilization measures the percentage of time a resource is in its active state. Therefore a resource with the highest active percentage is the bottleneck. The above two measures of performance are in common usage for evaluating the performance of a manufacturing processes.

The following simplifications have been included in the initial model:

- That wasn't considered time between the transport from storage raw coffee to the roasters.
- The special coffees had not been considered due to small representation (2%) in the production of the coffee bag line.
- That wasn't considered setups between the two types of coffee (A and B) because the coffee types have similar compositions, not being necessary to carry out cleanness in the resources.

3.4 Verification and validation

One of the most important steps of the simulation is validation and verification. If the model does not reflect the real system, outputs of the model has badly affect on the reliability and quality of the decision. The main idea of model verification is to ensure that the conceptual model is reflected accurately. Validation is concerned with whether the proposed model is indeed an accurate representation of the real system. Some techniques are used for validating: animation, comparison to other models, degenerate tests, event validity, extreme conditions tests, face validity, fixed values, historical data validation, historical methods, internal validity, multistage validation, operational graphics, parameter variability- sensitivity analysis, predictive validation, traces, turing tests (SARGENT, 2004). In according to Kelton *et al.* (1998), the simulation software Arena is user-friendly for testing model in visual way and every step it helps to the user to controle the steps

The model was verified and validated to develop simulation model correctly reflects the manufacturing process behavior. The verification and validation of the initial model were carried out in diverse stages, having involved people made familiar to the process, historical data and the monthly production in accordance with the type of coffee and the format of packing. In the end of the model development, with all the considered factors, it was gotten an initial model very next to the real system.

3.5 Experimentation

Many different experiments in the case study were carried out. Experiments in the initial model indicated that resource roasters were considered the current bottleneck in the process. The bottleneck was identified by studying the simulation while it was running and it was verified the statistics from the model. Measurements and actions are then implemented to increase productivity where the bottleneck has been discovered. Changes are done gradually and the results are checked to verify improvements. The initial model and each scenario run independently for six months. It was used the average of the estimated performance measure from the individual runs to the results.

The variations carried out in the three scenarios were the following:

- In the first scenario, it was increased production capacity of the two roasters in 10%.
- In the second scenario, it was increased production capacity of the two roasters in 20%.
- In the third scenario was inserted one third roaster with the same production capacity of the other two roasters existing. The results of the three scenarios were described in the following Tab.4 and Tab.5

Table 4. Resources Utilization (%)

Resource	Initial Model	Scenario 01	Scenario 02	Scenario 03
Roaster 1	98.03	97.70	97.03	91.62
Roaster 2	97.53	97.15	96.78	90.35
Roaster 3	-	-	-	91.24
Ground Coffee Hopper 1	65.52	69.97	71.25	63.06
Ground Coffee Hopper 2	58.86	63.25	64.95	59.60
Ground Coffee Hopper 3	35.95	41.25	43.70	53.78
Ground Coffee Hopper 4	11.46	15.46	21.34	43.54
Ground Coffee Hopper 5	1.66	2.82	6.52	27.06
Grinder 1	55.84	63.53	70.42	85.91
Grinder 2	67.92	72.70	77.38	87.65
Powder Coffee Hopper 1	69.26	73.98	77.27	85.31
Powder Coffee Hopper 2	54.77	59.21	62.52	70.30
Powder Coffee Hopper 3	33.98	39.91	44.95	55.42
Powder Coffee Hopper 4	14.47	19.54	22.88	35.19
Packaging Machine 1	63.70	70.77	72.06	85.87
Packaging Machine 2	53.66	62.03	66.24	85.94
Packaging Machine 3	46.40	53.09	62.34	65.51
Packaging Machine 4	72.09	74.57	78.54	98.25
Packaging Machine 5	64.23	67.68	70.30	74.99
Packaging Machine 6	51.92	58.71	63.32	76.18

Table 5. Production Capacity (month)

Resource	Production Capacity (kg)						
	Coffee A 100g	Coffee A 250g	Coffee A 500g	Coffee B 100g	Coffee B 250g	Coffee B 500g	Total Coffee
Initial Model	324.072	750.960	197.568	112.392	300.048	74.424	1.759.464
Scenario 01	354.480	824.040	199.728	141.288	341.376	77.640	1.938.552
Scenario 02	356.832	899.472	239.736	152.208	365.232	90.048	2.103.528
Scenario 03	422.016	997.240	275.184	191.520	440.496	123.312	2.449.768

3.6 Discussion of results

The Tab. 4 and 5 show that the introduced changes in the initial model had brought important improvements for the manufacturing process in the three considered scenarios. In all the three scenarios had a significant improvement in the resources utilization and the monthly production capacity.

In the first scenario it was proposed an increased the production capacity of the two roasters in 10%. This increase of production capacity is possible with small improvements using setups techniques, more training of the operators in the resources, reduction of the failure and time between failures. This scenario results in an improvement in the production of 179.088kg, which means, the production capacity was improved in 10.17%. The percentage of the resources utilization didn't change significantly.

In the second scenario it was proposed an increased the production capacity of the two roasters in 20%. To obtain this increase of production capacity, it is a necessity to verify all possible improvements in the current bottleneck. This scenario has done an improvement in the production of 344.064kg, which means, the production capacity was improved in 19.55%. The percentage of the resources utilization in this scenario was better than the one before and it attends the present market demand.

In the third scenario was inserted one third roaster with the same production capacity of the other two roasters existing. This scenario presents an improvement of the production capacity better than others scenarios and the initial model. This scenario has done an improvement in the production of 690,304kg, which means, the production capacity was improved in 39.23%. With this scenario, the manufacturing process shows that the resources utilization were more uniform. This scenario attends the present market demand and rests 449.768kg, which means that the company can increase their sales or make stock. In this scenario, it's a need to consider an investment in a new roaster and it represents a new investment for the company.

The performance improvements (production capacity and resource utilization) represent the consolidated benefits of the changes incorporated in the manufacturing process. With these three scenarios, the decision-makers can choose the best solution for eliminate the bottleneck and attend to the customer's necessities faster and efficiently.

4. FINAL CONSIDERATIONS

During the accomplishment of this work there were some difficulties as:

- At the moment of the process of observation, the machine operator had better performances than the normal one, which means that they had been influenced by the presence of the observer.
- During the collection of data it had difficulty in measure the average time between failures of the resources. To carry out this collection was developed a specific spread sheet and written down the beginnings and finishes of all the failures.

The accomplishment of the work also had positive points. The production area was compromised in improving the company and taking care of the necessities of the customers. The high administration also was compromised to the work, demanding of its commanded the biggest persistence possible, also establishing dates and knowing the systematization.

The initial model and the three scenarios are developed to compare the performances such as production capacity and resources utilization. The three scenarios show possibilities to eliminate the bottleneck and attend to the customer's necessities faster and efficiently. The simulation results that were obtained from these three scenarios gave an important support to the decision-makers and provided important knowledge to the company about how its manufacturing process works.

5. ACKNOWLEDGEMENTS

The authors would like to acknowledge the financial support from CAPES.

6. REFERENCES

Ali, S.A. and Seifoddini, H., Sun, H., 2005, "Intelligent modeling and simulation of flexible assembly systems", Proceedings of the 2005 Winter Simulation Conference. pp.1350-1358.

Ali, S.A. and Seifoddini, H., Sun, H., 2006, "Simulation intelligence and modeling for manufacturing uncertainties", Proceedings of the 2006 Winter Simulation Conference. pp.1920-1928.

Banks, J, 2000, "Introduction to simulation", Proceedings of the 2000 Winter Simulation Conference. pp.09-16.

Banks, J, 1998, "Handbook of simulation: principles, methodology, advances, applications, and practice", New York: John Wiley & Sons.

Banks, J., Carlson, J. S. and Nelson, B. L, 1996, "Discrete-event system simulation", 2.ed New Jersey: Prentice-Hall.

Bertrand, J.W.M. and Fransoo, J.C., 2002, "Modeling and Simulation: Operations management research methodologies using quantitative modeling", International Journal of Operations & Production Management, v.22, n.2, pp.241-264.

Carson II, J. S., 2004, "Introduction to modeling and simulation", Proceedings of the 2004 Winter Simulation Conference. pp.01-08.

Centeno, M.A. and Carrillo, M, 2001, "Challenges of introducing simulation as a decision making tool", Proceedings of the 2001 Winter Simulation Conference. pp.17-21.

Harrel, C. and Tumay, K., 1997, "Simulation made easy", IIE Solutions, pp.39-41.

Law, M. A. and Maccomas, M. G., 1999, "Simulation of manufacturing systems", Proceedings of the 1999 Winter Simulation Conference. pp.56-59.

Law, A.M. and Kelton, W.D., 2000, "Simulation modeling and analysis", 3.ed. New York: McGraw-Hill.

Kelton, W. D., Sadowski, R. P. and Sadowski, D. A., 1998, "Simulation with arena", WCB/McGraw-Hill, New York.

Korn, S., Burns, G.R. and Harrison, D. K., 1999, " The application of multiparadigm simulation techiniques to manufacturing processes", The International Journal of Advanced Manufacturing Technology, v.15, pp.869-875.

Maria, A. 1997, "Introduction to modeling and simulation", Proceedings of the 1997 Winter Simulation Conference. pp.07-13.

Pritsker, A. A. B., 1986, "Introduction to simulation and slam II", New York: John Wiley & Sons.

Sargent, R.G., 1998, "Verification and validation of simulation models, Proceedings of the 1998 Winter Simulation Conference. pp.121-130.

Schriber, T. J., 1991, "An introduction to simulation using GPSS/H", New York: John Wiley & Sons.

Shannon, R. E., 1998, "Introduction to the art and science of simulation", Proceedings of the 1998 Winter Simulation Conference. pp.07-14.

7. RESPONSIBILITY NOTICE

The authors are the only responsible for the printed material included in this paper.