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ANALYSIS OF THE PRODUCTION PROCESS IN A CLOTHING COMPANY FROM THE POINT OF VIEW OF COMPUTATIONAL SIMULATION

Agenor Sousa Santos Neto
agenor07@hotmail.com
Pontifical Catholic University of Goiás – PUC-GO, Goiás, Goiânia, Brazil

Eduardo Thomé Cunha Sales
eduardoep09@gmail.com
Pontifical Catholic University of Goiás – PUC-GO, Goiás, Goiânia, Brazil

Layara de Paula Sousa Santos
layara0912@hotmail.com
Federal University of Goiás – UFG, Goiás, Goiânia, Brazil

Valéria de Sousa Leitão
valeriaeng.amb@gmail.com
Pontifical Catholic University of Goiás – PUC-GO, Goiás, Goiânia, Brazil

ABSTRACT

One of the main concerns of organizations is the improvement of production processes. To stay on the market they need to be competitive and they must permanently improve their processes. The objective of this work was to analyze, through computer simulation techniques, the production process of a small clothing company located in the city of Aparecida de Goiânia, Goiás. The Arena® software was used to evaluate the mean time that the Skin bras remained in a queue at each production stage, as well as the average time spent performing the task at each stage. It is scientific, quantitative and qualitative research. According to its objectives, it presents a descriptive and explanatory character, aiming to deepen the knowledge of the reality, using the case study for data collection. Two scenarios were created for the company, for comparison purposes with the current scenario. The conclusion reached was that, currently, the production of bras in the company has a good flow; however, it is necessary be careful with the formation of extensive queues at the cutting and preparation sectors.

Keywords: Productive processes; Computer simulation; Clothing company; Software Arena®.

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1. INTRODUCTION

The apparel industry is one of the sectors that developed earlier in Brazil. This is due to the fact that it requires little technological level and small investment of capital. This industry has a significant participation in the country's economic growth and development, accounting for 9% of jobs in the national manufacturing industry and occupying one of the first places in the world economy, with 14% of jobs (FIEP, 2009).

In the current context, there is a great interest of customers and consumers for products and services of companies that satisfy them and meet their requirements and expectations (Silva *et* Magalhães, 2005). One of these demands is about queues.

The queuing phenomenon is already routine in today's life; it occurs in a number of applications, such as a piece waiting to be sanded or polished (in the industry), an airplane waiting to take off, a computer program waiting to be executed, and, of course, a queue waiting for service (Barbosa *et al.*, 2009).

Queues are formed due to the increase in consumers and the inability of the system to meet this demand. Thus, by means of simulation techniques, it is sought to find a balance point that satisfies the customers and is economically feasible for service providers (Arenales *et al*., 2007).

According to Banks (1998), simulation is a technique of solving a problem that occurs from the analysis of a model that describes the behavior of a system, using a digital computer. The simulation of a model allows understanding the dynamics of a system, and to analyze and predict the effect of changes that are introduced in it. It is a close representation of reality, and it will be all the more real the more significant features the system is capable of representing. On the other hand, the model must be simple, so that it does not become too complex to build, but at the same time the model must be as faithful as possible to the real system.

According to Bortuluzzi *et al.* (2014), the clothing industry participates in a very dynamic and competitive market. Therefore, efficiency is an extremely important factor for the survival of these industries. Thus, it is necessary that the productive process be organized in such a way that the losses are minimal, both in terms of time and product. To achieve such result, several techniques, tools and instruments are made available to the leaders of these processes, many of them involving information management technology. However, any change process needs to be preceded by a technical evaluation that assesses the advantages or problems that may occur. Many of these evaluations are performed through the use of simulation software.

In order to simulate the manufacturing process, the Rockwell Software Corporation's Arena® software was chosen as one of the most widely used discrete simulation software in the business and academic world.

In view of the above, this work aimed to analyze, through computer simulation techniques, the production process of a small lingerie industry located in the city of Aparecida de Goiânia, Goiás.

2. THEORETICAL REFERENCE

2.1 Simulation

According to Montevechi et al. (2010), simulation concerns the importation of reality into a controlled environment, where behavior can be studied under varying conditions, without physical risks and without high costs involved.

The use of simulation has been increasingly accepted and used as a technique that allows analysts of the most diverse segments to verify or route solutions with the desired depth to the problems they face daily. Computational simulation allows studies to be performed from systems that do not yet exist, leading to the development of efficient projects before any physical change has been established (Ryan *et* Heavey, 2006).

According to Prado (2009), there are two steps to the study of system simulation. The first concerns the construction of the model by the analyst, who must provide some data and obtain others that are similar to the system being studied. The second step is structured in the model change, since, based on the results obtained, it is possible to carry out the analyzes, generating recommendations and conclusions.

Andrade (2009) lists some of the benefits that justify the use of the simulation among them:

a) Forecasting results in the execution of a given action;

b) Reducing risk in decision making;

c) Identification of problems even before their occurrences;

d) Elimination of procedures in industrial arrangements that do not add value to production;

e) Conduct of sensitivity analyzes;

f) Reduction of costs with the use of resources (labor, energy, water and physical structure);

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g) Disclosure of the integrity and feasibility of a given project in technical and economic terms.

On the other hand, Freitas Filho (2008) lists some of the disadvantages of the use of simulation, among which stand out:

a) Special training for the construction of models;

b) Difficult interpretation of the simulation results because of the random processes included in the model;

c) Consumption of many resources, mainly time, by the modeling and experimentation associated with simulation models.

Freitas Filho (2008) also discusses the situations for which the use of the simulation should be considered:

a) At times when there is no complete mathematical formulation for the problem;

b) When there is no analytical solution for the problem;

c) The achievement of results becomes easier to achieve through simulation than with the analytical model;

d) Personal skill should not be considered for the resolution of mathematical models by analytical or numerical techniques;

e) When it is necessary to observe the process from the beginning to the end, except for more specific details;

f) For situations of difficulty or even impossibility of experimentation in the real system;

g) When you want to observe long periods of time or alternatives not presented by real systems.

For Law et Kelton (2000), the construction of models requires training and previous experience and the variability of a system is not always well captured and modeled and can lead to the wrong results.

2.2 Queue theory

According to Cardoso *et al*. (2010), the queues are defined as systems that are directly related to the routine of the people, who see them in a rather unpleasant way. Consumers are becoming increasingly demanding because of the implications of globalization; therefore, managers consider the formation of large queues to be a competitive disadvantage, and thus rationally address this event.

Managing queues is essential, since they are directly related to customer perceptions of the service provided and the need to wait for it (Sabbadini *et al*., 2006).

Queuing theory is an analytical technique that studies the parameters of a queue of a real system, such as the average waiting time, average queue size and average server utilization rate. Queuing occurs when the demand for a service is greater than the system's ability to service it. In this way, by means of mathematical models, it becomes possible to reach a balance point that serves the client, but is economically viable for the service provider. The queue system can be viewed as shown in Figure 1:

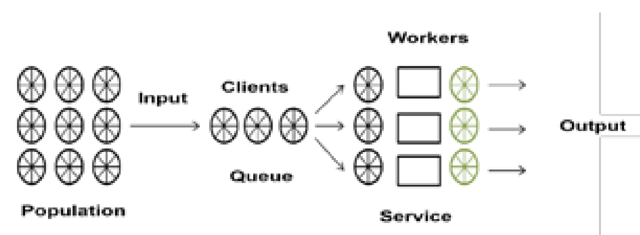

Figure 1. Queue systems
Source: Sampaio *et* Oliveira (2013)

There are six basic characteristics that properly define a queuing system, which are:

a) Process of arrival of clients: in processes of common queues, the arrival presents stochastic behavior, that is, it is described in time and space according to the laws of probability. Therefore, it is crucial to know the probability distribution that describes the times between customer arrivals. Among the most common probability distributions are Poisson, Erlang, Hyperexponential and Arbitrary distributions.

b) Distribution of service time: the time of service can be classified in: regular, in which the duration of all calls is the same; and random, the most common situation, in which each client needs his own service time.

c) Queue: definition of the method of choosing the sequence of customer service when there is queuing. The most commonly used discipline routinely is FCFS (First Come, First Served) or FIFO (First-In-First-Out), in which the first to come is the first to be served. In addition to these, there are other forms of discipline

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such as LCFS (Last Come, First Served), in which the last to enter the system is the first to be attended, most often used in inventory control systems; and SIRO (Select in Random Order), in which the priority choice is set at random.

d) System Capability: it informs the limitations to potential customers in queuing processes, whether physical, monetary, or waiting time. For example, in a bank queue there is physical space limitation, where a new client cannot enter the system until there is no queue decrease. This type of system is called finite, different from a system of queues of infinite capacity, when there is the guarantee that the service will happen, because, in theory, there are no limitations.

e) Number of servers: also called number of service channels. This characteristic indicates the number of service points of the system that can serve, in parallel, the customers. If the system has more than one server, there are two possibilities: adoption of a single queue system for all servers or one of multiple queues, where each queue is destined for a server.

e) Population size: it is measured by the number of potential users who can at some point use the system, and it can be finite or infinite.

2.3 Arena® Software

Initially, the simulation systems were developed on general purpose programming languages, such as: Fortran, Basic and Pascal. However, this required a great effort to build models, as well as professionals with deep knowledge of computer programming. Faced with this difficulty, programming languages dedicated to the simulation that could overcome this barrier began to emerge. This is the case, for example, of the languages Gpss, Siman, Slam and Simscript. Such languages were, in fact, libraries made up of sets of macro commands from general purpose languages. Some of the simulators of the following generation were developed on the platform of these languages. As an example, there is the Arena® software, implemented in Siman language (Fernandes, 2006).

According to Chwif *et* Medina (2006), in the 1980s the first software simulators appeared with their own interface to minimize programming lines. It was at this time that the simulation started to explore the potential of the personal computer, allowing the use of graphic or visual representation techniques to simulate real or projected landscapes, such as Arena®.

Launched in 1993, Rockwell Software Corporation's Software Arena® is an integrated graphical simulation environment that contains numerous features for modeling, animation, statistical analysis and results analysis. This simulation platform has the following tools (Law *et* Kelton, 2000):

- Input analyzer;
- Output analyzer;
- Process analyzer.

The input analyzer tool allows the analysis of real data that has been collected in the system, namely, the data of the operation of the process, and chooses the statistical distribution most appropriate to the process (Costa, 2009). The Output analyzer allows analyzing data collected during the simulation, and these results can be obtained by graphs and by statistical comparisons (Prado, 2010).

The Process Analyzer, in turn, helps in the evaluation of alternatives presented in the execution of the simulation of different scenarios for the system model studied. It focuses on the comparison of scenarios after the system has been completely translated into a "virtual model". At this stage, such a model is already complete, properly validated and configured for the use of Process Analyzer. The role of this tool is then to allow the comparison between the results obtained from the model, from different input data (Lima *et al.*, 2006).

To describe a real application in Arena®, a set of blocks (modules) is used. These blocks are configured to generate data from schedules made by the operator. As they were designed for simulation, they are easy to program in the modules. As in most simulation software, it is possible to visualize the system to be modeled as consisting of a set of workstations that provide services to entities that move through the system. The available modules are presented below (Costa, 2009):

- Basic Process
- Advanced Process
- Advanced Transfer
- Elements
- Blocks
- ContactData
- CSUtil

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- Packing
- Elements

Arena® is directed to the Discrete Event Simulation (DES), which is used to model systems that change their state in discrete moments in time, from the occurrence of events, that is, in situations in which each event occurs in moments determined in time (Chwif *et* Medina, 2006). It also has the capacity to model rework, probabilistic events and decision processes (Leal *et* Oliveira, 2011).

2.4 Clothing industry and trade

Brazil is not among the largest exporters in the garment industry, accounting for just under 3% of world trade; however, it still has great potential in the apparel business (ABRAVEST, 2014).

In Brazil, the garment industry has a significant participation in the country's economic growth and development, accounting for 9% of the national manufacturing industry and occupying one of the first places in the world economy, with 14% of jobs (FIEP, 2009).

According to ABRAVEST (2014), the clothing industry is made up of seventeen groups: beach line, children's and babies' clothing, professional uniforms, school uniforms, shirts, knitting, men's social clothing, boutique fashion, men's and women's underwear, socks, embroidery, day lingerie and night lingerie.

The clothing industries are formed by medium and small companies. These companies manufacture products with low added value, using, in large scale, cheap labor. The chain of this branch is very extensive and can provide gains of scale in the stages of the productive process. The main features are: production technologies, innovative raw materials and design, trade and distribution strategies (IEL, 2003).

In the 1970s and 1980s the clothing industry underwent significant transformations from competition between European and Asian suppliers, supported by the development of modern machinery and equipment and the creation of new textile materials. These transformations also include the implementation of new advanced management techniques (IEL, 2003).

China, the United States and India concentrate the world production of the garment industry (ABRAVEST, 2014). These countries have invested heavily in technology, reflecting increased production and productivity, consequently reducing costs and the final price of the product, as can be seen in Table 1.

Table 1. World production of textiles and clothing 2010 (in 1,000 tonnes)

Textiles			Clothing		
Countries	**Production**	**%**	**Countries**	**Production**	**%**
1. China	38.561	51%	1. China	21.175	46,40%
2. India	5.793	7,60%	2. índia	3.119	6,80%
3. United States	4.021	5,30%	3. Pakistan	1.523	3,30%
4. Pakistan	2.820	3,70%	4. Brazil	1.271	2,80%
5. Brazil	2.249	3%	5. Turkey	1.145	2,50%
6. Indonesia	1.899	2,50%	6. South Korea	990	2,20%
7. Taiwan	1.815	2,40%	7. Mexico	973	2,10%
8. Turkey	1.447	1,90%	8. Italy	935	2%
9. South Korea	1.401	1,80%	9. Malaysia	692	1,50%
10. Thailand	902	1,20%	10. Poland	664	1,50%
11. Mexico	748	1%	11. Taiwan	638	1,40%
12. Bangladesh	686	0,90%	12. Romania	549	1,20%
13. Italy	660	0,90%	13. Indonesia	505	1,10%
14. Russia	516	0,7%	14. Thailand	467	1%
15. Germany	456	0,60%	15. Bangladesh	466	1%
Subtotal	63.974	84,20%	Subtotal	35.112	76,90%
Others	12.105	15,80%	Others	10.535	23,10%
Total	76.079	100%	Total	45.647	100%

Source: IEMI (2012)

The garment industry plays an important role in the global economy. In international trade, it is ranked third in most industrialized countries. In developing countries, it represents the gateway to the international market. First, the products with the lowest added value are exported. Subsequently, they internalize new production processes and seek to compete in large market countries (IEL, 2003).

3. MATERIALS AND METHODS

According to Santos (2000), three criteria are usually used to identify the methodological nature of the research. They are: objectives, collection procedure and sources used during data collection.

This quantitative and qualitative scientific research, according to its objectives, is descriptive and explanatory. Santos (2000) defines descriptive research as a survey of the components of the fact/problem, and the explanatory research for creating an acceptable theory

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about a fact or phenomenon, aiming to deepen the knowledge of reality.

According to the collection procedures, this research is experimental, used when a fact or phenomenon of reality is reproduced with the objective of discovering the factors that produce it or that are caused by it (Santos, 2000). Still according to the collection procedures, Yin (2005) presents the case studies as a strategy to control the events inserted in some context of reality.

3.1 Characterization of the research scenario

The business name of the company being studied is Le Pink Monde Lingerie. It was founded in 1986 and is located in Aparecida de Goiânia, Goiás.

For 26 years, Le Pink has offered its customers lines of products composed of lingerie, basic line (skin) with panties and bras, comfortable line pajamas (Confort) and romantic line (Romantique). It should be noted that the basic line (Skin) of bras is the focus of this research.

Working in the intimate clothing industry, the company always values its products innovation, never leaving aside sensuality and comfort. Currently, Le Pink has approximately 110 employees, of which 70 are on the factory floor, working from Monday to Friday, from 07:15 to 17:15, with lunch and rest interval of 1:30 am.

The company counts on equipment, technology and professionals capable of providing superior quality, besides a diversified grid of models accompanied by excellent design and finishes.

The products are made with different fabrics. Among them are lace, microfibers, satin, bindings, cotton, polyamide and tulis. The catalog is divided into separate collections in autumn-winter and spring-summer.

Both collections have products for routine use, others more sophisticated, and a third line, with different details, intended for a more judicious and determined public.

The process of making lingerie is characterized by the following steps:

Fabric input into the cutting sector, where the fabric is cut according to the molds;

Sewing process, where the cut pieces are joined;

Preparation stage, which consists of the insertion of the metallic arch in the buckle of the bra;

Completion stage, where the quality check of the product and bartacking is performed;

Packing the parts that are then sent to the stock.

Le Pink's production flow chart shows the production process, which encompasses six major areas: Planning and Production Control (PPC), cutting, sewing, preparation, finishing, and shipping. Each of these areas is responsible for one or several parts of the production process. Starting with the PPC, which has several stages that range from the receipt of the customer's order to the issuance of the production order, which goes to the next phase or awaits the arrival of the raw material demanded. Next, the cutting sector receives the production order and performs the procedure of indentation, separating it by size. Next, the seam will check whether the pieces are in the standard size required to then sew the pieces. In the preparation arch and fin are placed in the underwear. The next step is to pack the pieces and verify that the product meets the quality standard to move forward. Finally, on shipment, the pieces are packed and stored so the order can be sent to the customer.

Figure 2 shows a flowchart depicting the operating model of Le Pink.

3.2 Problem description

The average time the pieces were queued at each production stage and the average time spent to perform the task at each stage.

Gianesi et Corrêa (1994) affirm that the queues and the way they are managed are very sensitive and important aspects in the client's perception of the quality of the service provided, which justifies a special concern with their management.

It can be seen from Table 2 that the stages where the largest row formation occurs are in the cutting and preparation sectors. This shows that these are the most requested sectors and have a higher workload than the others.

Table 2. Queue Report

Queue Details Summary	
Others	**Number of Entities in Queue**
Process Cut.Queue	9,93
Process Sewing.Queue	3,43
Process Preparation.Queue	13,55
Process Finalization.Queue	0,00
Process Packaging.Queue	0,20
Total	27,11

Source: The Authors (2015)

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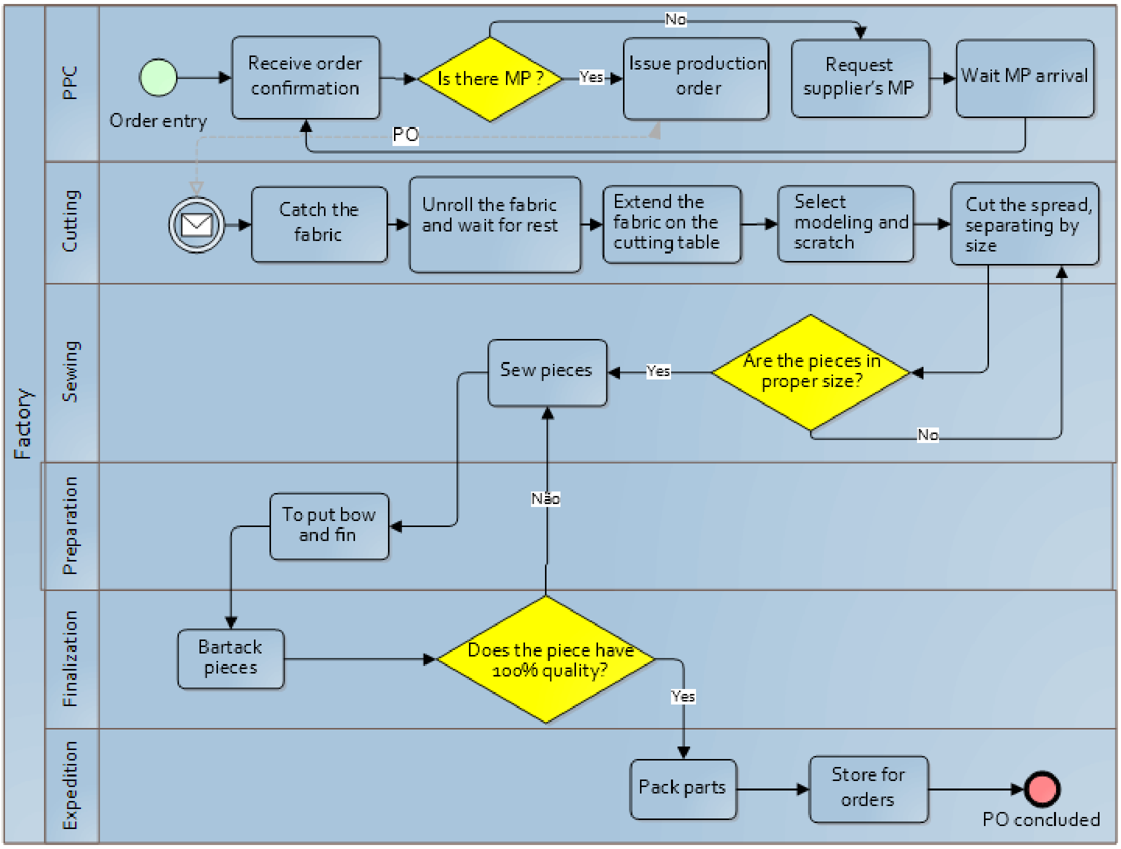

Figure 2. Le Pink production flowchart
Source: The Authors (2015)

For a productive process to be efficient, one of the goals of a company is to reduce its queuing time. Therefore, through computer simulations different scenarios will be drawn in the Arena® to indicate what improvements can be made in relation to the production of lingerie.

3.3 Modeling and implementation

According to Banks et al. (1996), the translation activity of a simulation model is basically determined by the following concepts:

- Modeling elements: any object or component of the system that requires explicit representation in the simulation model (eg, employee, client, machine, etc.);

- Attributes: entity properties (e.g. client type, order type);

- Queues: collections of entities, sorted according to some logic (eg FIFO, LIFO);

- Events: occurrences that alter the state of the considered system (e.g. arrival of a client);

- Activities: durations of specified time (e.g. time of service, interval of arrivals). They can be defined in a deterministic way; statistics; or through a function that depends on system variables or entity attributes;

- Moves: routing of entities and resources in the system.

A simulation model can be of the mathematical, descriptive, statistical, and input-output type. The most used are input-output simulation models, since they are iterative models in which the user provides input data and obtains specific responses to them. According to Chwif et Medina (2006), the input variables required to execute the model are:

- TS: Service time;

- TEC: interval between successive arrivals.

The input variables collected in Le Pink were the execution time periods of each stage of the production process, in addition to the interval between the arrivals of the production orders. The collections of these variables were car-

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ried out during two days, more precisely on a Tuesday and Wednesday, during which a normal demand was recorded, from 07:15 to 17:15. The displacement between the work sectors in order to collect the necessary time periods was considered relatively short due to the proximity of the areas in the system.

3.4 Data collection

One of the most important steps in the simulation is data collection. Hardly the data is in the exact form that can best represent the functioning of the system. Therefore, the data should be grouped carefully and consistently. The search for information must be goal-oriented, with a focus on information that contributes to achieving study goals.

The best data sources for simulation include operative modes; time studies; production and maintenance reports; factory floor personnel; among others. After collecting the data, they must be transformed into useful information. The data are rarely in a form that enables their direct use in simulation. So, what you should do is perform some analysis and conversions so that the data becomes useful as input parameters in the system.

In order to collect the time between arrivals of the production orders, it was observed the moment in which a production order leaves the PPC and arrives at the cutting sector, and this is the moment the chronometer starts.

Initially 30 data were collected (starting sample) to verify the variability of these time periods around their average.

As for the collection of the execution time of the steps of making the lingerie, the chronometer was triggered when the employee took the first piece and was stopped when he completed his task.

After the first collections, the appropriate sample size of Equation (1) was verified. The size of each of the samples, timed in this work, was obtained for a confidence level of 95% (Marôco, 2003):

$$n = \frac{Z^2 . \sigma^2}{E_0^2} \qquad (1)$$

Being:

n = sample size;

Z = normal value standardized to a confidence level of 95%;

σ = sample standard deviation around the average; and

E_0 = arbitrary tolerated sampling error, associated to the average (3%, 5% and 10%).

Considering a tolerable sample error of 5%, we reached the ideal number of collections required.

The minimum sample size was:

- 90 for time between production order arrivals;
- 49 for execution time in the cutting sector;
- 33 for execution time in the sewing sector;
- 152 for execution time in the preparation sector;
- 79 for execution time in the finishing sector;
- 53 for execution time in the quality sector;
- 20 for execution time in the packaging sector.

All units of measurement of the time periods were taken in minutes.

3.5 Data analysis by the input analyzer

Before starting to simulate the collected data, it is necessary to identify the probability distribution that best fits them. For this the Arena® Input analyzer tool was used.

One of the biggest advantages of Arena® is that it is an easy to use software with a simple interface, which guarantees user convenience for data analysis, elaboration of system logic, visualization of the system and obtaining results.

The least error distribution (square error) was adopted in preference to the possible other distributions.

Then, the adhesion tests were performed: chi-square (X^2) and p-value. The samples and distributions recommended for each process are set forth in Table 3.

3.6 Simulation time

A 95% confidence interval and an error equal to 5% were determined.

Firstly, a block diagram was constructed in Arena® to represent the logic of the system under study. Next, the current scenario was constructed using the recommended distributions obtained by submitting the data to the Input analyzer.

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The one-day workday was used as the period for simulation, that is, eight hours and 30 minutes.

4. RESULTS AND DISCUSSIONS

Three scenarios were created for the simulation of the making of the bra:

- Scenario 1: current system with four cutters, eight seamstresses, one preparer, four bartack machine operators and one packer;
- Scenario 2: One more cutter was hired, and a seamstress and three bartack machine operators were fired, resulting in a system with five cutters, seven seamstresses, one preparer, one bartack machine operator and a packer, to achieve maximum utilization of employees in each process.
- Scenario 3: The possibility of introducing a new bra model with parallel production to that of the current model, in the order of 50% on the demand under study, was evaluated. To that end, it was identified the need to hire another employee for both the cutting and preparation sectors; however, it was noticed that the company should remove two seamstresses and three employees from the travesty. Thus, the staff would be composed of five cutters, six seamstresses, two preparers, one finisher and one packer, working at maximum utilization.

From scenario 1 (which represents the real system), feasible alternatives were perceived to achieve improvements that could benefit the system and, consequently, bring greater profitability to the company.

4.1 Scenario 1 simulation

The average waiting time in the queue throughout the entire production process is approximately 32.42 minutes.

In the simulation of the current scenario it can be seen that the system is balanced; however, it is noticed that there is queuing mainly in the cutting and preparation sectors, that is, the “bottleneck” is not the privilege of only one sector. Therefore, measures must be taken to reduce the demand for these areas and to allow production to flow more quickly. Figure 3 illustrates the animation of the current scenario:

In the current scenario, with four cutters, eight seamstresses, a preparer, four bartack machine operators and a packer, the following times:

- Total waiting time = 32.42 minutes;
- Average waiting time at cut = 12.05 minutes;
- Average waiting time in the sewing = 4.08 minutes;
- Average waiting time in preparing = 16.03 minutes;
- Average waiting time at finalization = 0 minutes;
- Average waiting time on packaging = 0.26 min;
- Average time in the system = 65.64 minutes.

The queue of the cutting sector reached, at most, ten bras; the queue of the sewing sector reached a maximum of four bras; the queue of the preparation sector reached a maximum of 14 bras; in the end sector, the queue index was practically nil; and the queue of the packaging sector had at most one piece.

From the comparison of the results obtained by the simulation of the computer system with regard to the observation of the real system, the veracity and reliability of the model analyzed by the software Arena® can be perceived. Thus, the validity of this simulation is proven.

Table 3. Table of samples and distributions

Variable	Sample Collected	Minimum Sample	Square Error	X^2 Calculated	X^2 Tabulated	P-value	Recommended Distribution
TS Cut	30	49	0.012163	1.71	2.71	0.208	1 + 1 * BETA(1.24, 1.1)
TS Sewing	30	33	0.015556	2.33	3.36	0.678	UNIF(3, 5)
TS Preparation	30	152	0.002736	0.357	0	< 0.005	0.4 + 1.19 * BETA(1.56, 1.66)
TS Finishing	30	79	0.017412	2.59	4.61	0.282	0.18 + 0.22 * BETA(1.1, 1.03)
TS Quality	30	53	0.049078	1.98	0	< 0.005	0.45 + 0.55 * BETA(1.09, 0.932)
TS Packaging	30	20	0.005542	0.767	0.45	0.41	0.38 + 0.23 * BETA(1.22, 1.3)

Source: The Authors (2015)

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4.2. Scenario 2 simulation

In Scenario 2, in relation to scenario 1, the contracting of a cutter and the dismissal or repositioning of a seamstress and three bartack machine operators were proposed, giving rise to a leaner system with five cutters, seven seamstresses, a preparer, and a packer.

From the simulation, we obtained a waiting time of 34.92 minutes.

In the system of scenario 2, we noticed a worsening due to the fact that there is an increase in waiting time in relation to scenario 1. Figure 4 represents the animation of Scenario 2:

- The time periods in scenario 2 are exposed below:
- Total Average Waiting Time = 34.92 minutes;
- Average waiting time at cut = 9.48 minutes;
- Average waiting time at sewing = 7.69 minutes;
- Average waiting time in the preparation = 13.20 minutes;
- Average waiting time at finalization = 0.08 minutes;
- Average waiting time in the packaging = 0.21 minutes;
- Average time in the system = 72.60 minutes.

The queue has reached a maximum of eight, 14 and one bra in the cutting and sewing, preparation, and finishing and packaging sectors, in that order.

From the results obtained and the observations made in the real system (scenario 1), we can see a rise in the total time in the system from 65.64 minutes to 72.60 minutes, which represents an increase of 6.96 minutes or of 10.60% in relation to the real system. Therefore, when modifying the staff, the company, despite reducing its labor costs, causes the average time of the lot in the system to suffer a slight increase. Thus, we have an expansion of:

- 10,60% in the average system time;
- 88,48 % in the average waiting time at the sewing.
- On the other hand, there was a reduction of:
- 21.33% in the average waiting time at the cut;
- 17.64% in the average waiting time in the preparation;
- 19.23% in the average waiting time on the packaging.

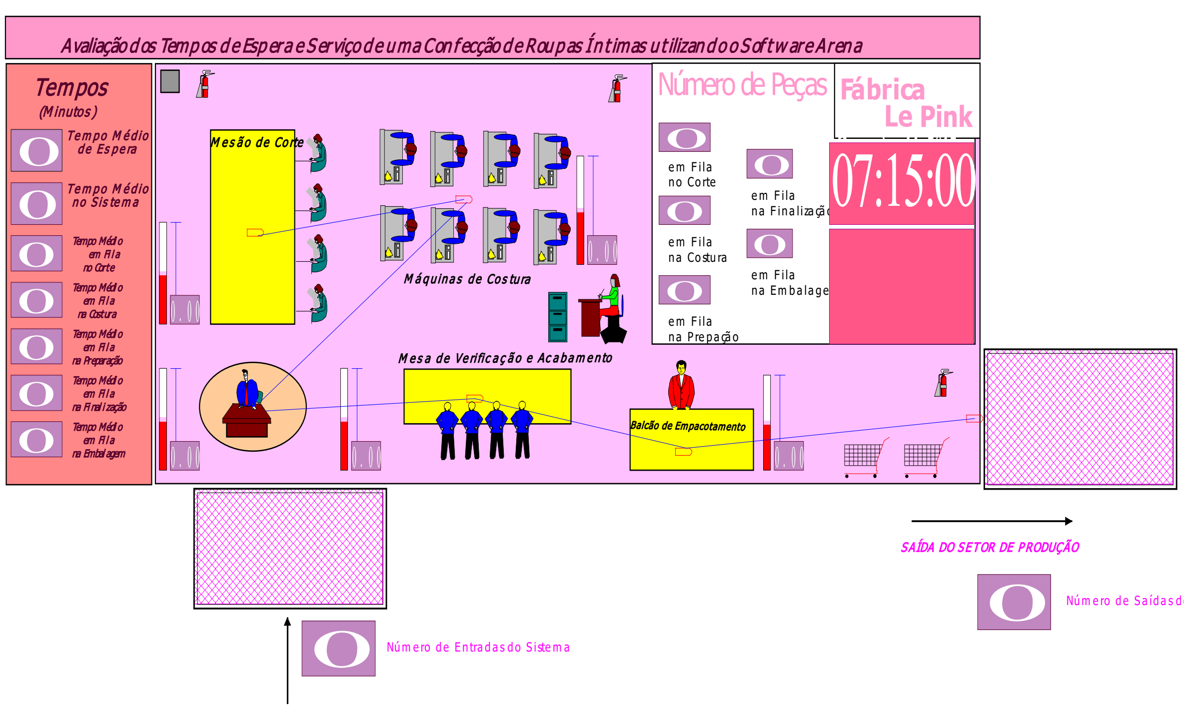

Figure 3. Scenario 1 Animation

Source: The Authors (2015)

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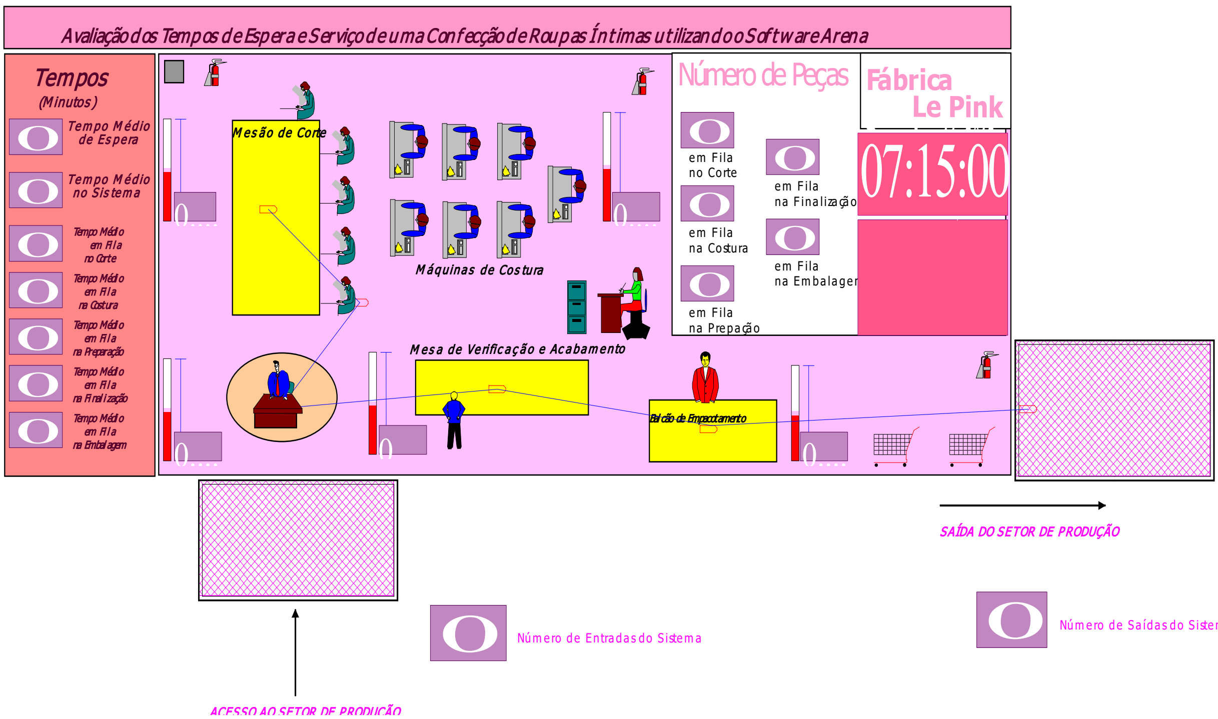

Figure 4. Scenario 2 animation
Source: The Authors (2015)

As for the completion time, they remained almost unchanged in both scenarios.

Table 4 shows a comparison between the actual scenario (1) and the proposed scenario (2).

Table 4. Comparison of the times between scenarios 1 and 2

Variable	Scenario 1 (min)	Scenario 2 (min)
Average Total Wait Time	32,42	34,92
Average Wait Time at Cutting	12,05	9,48
Average Wait Time at Sewing	4,08	7,69
Average Wait Time in Preparation	16,03	13,2
Average Wait Time at Finishing	0	0,08
Average Wait Time at Packaging	0,16	0,21
Average time in the system	65,64	72,6

Source: The Authors (2015)

4.3 Scenario 3 simulation

Scenario 3 was thought due to the possibility of a future expansion of the company. To that end, a staff was composed of five cutters, six seamstresses, two preparers, a finisher and a packer; in addition, a new bra line was established with similar characteristics and production parallel to that of the current model, with an increase of 50% on demand.

With increased demand and consequently increased customer flow, employees will be better served and downtime will decrease.

The model of this scenario had an average waiting time of 38.80 minutes.

Figure 5 depicts the animation of scenario 3:

In scenario 3, the following time periods were found:

- Total Average waiting Time = 38.80 minutes;
- Average waiting time at cut = 14.98 minutes;
- Average waiting time at sewing = 19.41 minutes;
- Average waiting time in the preparation = 0.65 minutes;
- Average waiting time at completion = 0.27 minutes;

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- Average waiting time in the packaging = 0.44 minutes;
- Average time in the system = 75.47 minutes.

5. FINAL CONSIDERATIONS

Through the analysis of the model performed at the Arena®, it was concluded that, currently, the production of bras at Le Pink is very fluid; however, care must be taken with the formation of extensive queues in the cutting and preparation sectors. It is the company's responsibility to conduct a study on capacity analysis to determine the appropriate number of employees at each stage of production.

The total average waiting time of scenario 2 in relation to scenario 1 underwent a small increase, due to the elimination of three employees of the production process, which allowed the company to save on labor and increase the utilization rate of its employees; however, as a result, larger queues were formed in the sewing sector.

Scenario 3 was created in light of the company's ability to expand and add a new line of bras. When the simulation of the model was carried out, it was observed increases in the time and size of the queues of the cutting and sewing sectors, as well as in the utilization rates of the workstations, with the exception of the preparation.

The simulated model was faithful to the real system, proving the authenticity of the events verified during the data collection stage: medium queues and parts waiting for more time to be made in the cutting and preparation sectors, and less time in the sewing, finishing and packaging sectors.

It is recommended to carry out the timing of production steps so that a model of capacity analysis can be established for all sectors of Le Pink, which would reduce possible risks of a sudden rise in demand in certain periods.

The subject does not end with the accomplishment of this work; it should proceed from the development of a study on the behavior of the bottleneck in the system. Once there is an improvement in the bottleneck, the constraints may change place in the system.

The application of computer simulation has generated additional knowledge in terms of the process for all people involved and has also enabled the identification of improvement opportunities in the bra production process.

It should also be noted that the potential of the use of simulation is unexplored in several Brazilian contexts, especially in small and medium-sized enterprises, and that studies of this type contribute to the approximation between the university and companies.

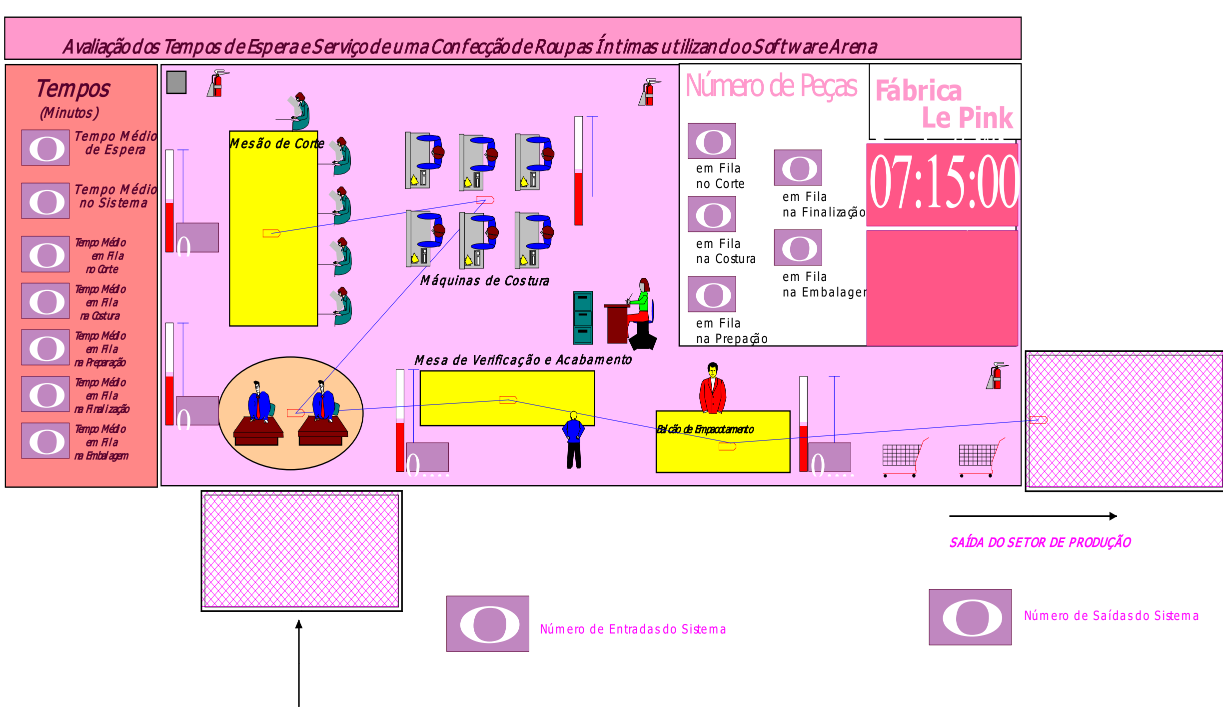

Figure 5. Scenery 3 Animation
Source: The Authors (2015)

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