THE USE OF SIMULATION AS A TOOL TO SUPPORT DECISION-MAKING IN A PISTON MANUFACTURING SYSTEM

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ABSTRACT
The business scenario is characterized by a high complexity, which influences various aspects of the organizations, such as the decision-making. In this way, companies can use several techniques to reduce the risks and uncertainties of this process; among them is the computer simulation. Considering that, this article aims to demonstrate the effectiveness of this technique. In order to do so, it will simulate several situations of a piston manufacturing system linked with the expansion of the manufacturing cell. In summary, the method will be used as a support for the manager to decide which is the best option to expand the manufactory cell.

Keywords: Computer Simulation; Decision-making; Manufacturing System

1. INTRODUCTION

This work presents the use of simulation as a tool for decision support in manufacturing environments, to evaluate different alternatives for improving productivity and therefore, various situations that can occur in a manufacturing system are simulated. These conditions, in turn, were based on a manufacturing cell of a piston factory located in the state of São Paulo - Brazil.

In this sense, it is the perception that the business setting faced by organizations in recent decades is characterized by increasing complexity, so that companies are dealing with situations that make decision making increasingly difficult in their daily routines, such as: the time available for making the decision, the risks and uncertainties inherent in the organizational environment (BATEMAN, SNELL, 2008), the decision-makers and conflicts of interests (LACHTERMACHER, 2002).

Given this context, organizations can use several techniques that assist in the decision making, including computer simulation, a tool of Operational Research that has been gaining prominence in recent years due to the improvement of hardware and software and awareness among companies about the applicability tool, which allows a process of decision making wider, in which managers can simulate various scenarios representing different market variables (SARGENT, 2004).

In its most basic definition, computer simulation can be considered to be a technique based on queuing theory, which reproduces a real system by means of equations or a mathematical model to evaluate and improve performance. Thus, trials of predefined scenarios can be made from its use, verifying how they affect system performance (HARRELL; GHOSH; BOWDEN, 2000; ANDRADE, 2004; HILLIER; LIEBERMAN, 2005). It is still necessary to emphasize that the trials only occur in a controlled environment allowing a substantial reduction of costs, since working in this environment is cheaper than a real system (LAW; KELTON, 2000).

In this sense, one can say that the simulation is a tool that can assist in decision making in different situations, enabling a reduction of the time of the decision process (BARTON, 2004). Furthermore, through it, it is possible to analyze the situation faced in more detail, exploring all possibilities for its resolution thus reducing uncertainty and risk decisions (LIMA; BARBOSA; BEAL, 2003; SLACK et al., 2002).

In this study, the simulation will be used to represent a piston manufacturing system. In this sense, it is understood that the car market has shown a steady growth in the last decade, reaching in 2012 a total of 3,415,486 million vehicles produced, twice the amount produced in 2000 - 1,691,240 million (ANFAVEA, 2013). This increase resulted in an expansion in the amounts of parts made, thereby manufacturing systems have to be expanded or optimized to meet the growing demand.

Thus, the simulation will be used to assist in decision making regarding the expansion of the manufacturing system of pistons. Three different scenarios are simulated using the software Promodel, which involve: increasing the amount and better distribution of inputs received, the increase in the number of employees, and the purchase of new machinery.

In general, the goal is to demonstrate the operational and financial results of these scenarios, facilitating the process of decision making of those responsible for this manufacturing system, since they can both design costs, as the results and consequences of each action.

2. LITERATURE REVIEW

2.1. Organization Decisions

A decision is the act of choosing one alternative among all possible. This option is, according to the decision maker, the best way to achieve the goal, already pondering the consequences and risks (ANDRADE, 2004). Thus, the act of deciding involves at least six elements: the decision maker, the goals the decision maker seeks to achieve; preferences; strategy, the situation, and the result (SIMON, 1997).

When analyzed under the organizational scope, decisions become even more important. That happens because they become more frequent and the majority of cases, more complex having characteristics such as risk and uncertainty. In general, most of the decisions in a company have different characteristics from personal ones. They are complex and extensive, they lack information about the problem faced and involve situations where one can't predict and evaluate the results of the alternatives, thus hindering the taking of decision.

Accordingly, Bateman and Snell (2008) reported that the majority of decisions within an organization lacks structure and entails risk, uncertainty and conflict, which can slow decision making, as decision makers hesitate to act because there are certain difficulties to be faced.

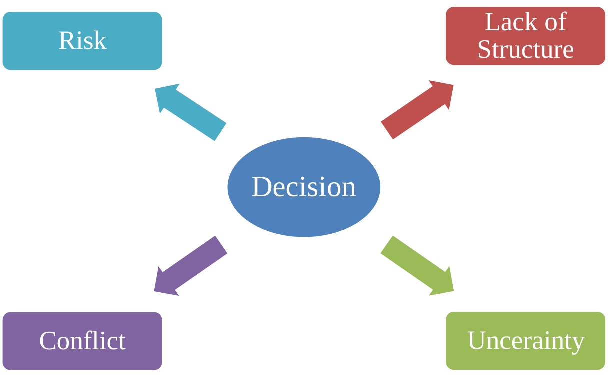

Figure 1: Characteristics of administrative decisions

Risk and uncertainty are present situations in decision-making of any modern organization, involving both the difficulty of predicting the outcome of a particular decision, and the difficulty to estimate and quantify the consequences of the decision. This situation tends to be avoided by decision makers who try to act to anticipate, minimize and control risk (SHIMIZU, 2001; BATEMAN, SNELL, 2008).

The decisions made in organizations can be classified in two types of criteria: the decision level and the degree of structuring of the problem (ANDRADE, 2004; SHIMIZU, 2001).

According to the first criterion, the decisions made within an organization are not restricted to an organizational level and can occur at three different levels: the strategic, the tactical and the operational. The second criterion divides decisions into scheduled and non-scheduled. The routine scheduled are those that are taken in an environment of certainty and have easy solutions. However those unscheduled refer to those natural and difficult to solve (SIMON, 1997; SHIMIZU, 2001).

The organizational decision-making process has evolved over the last century due to the emergence of new management techniques and assimilation of quantitative techniques such as computer simulation, which can minimize the risk and uncertainty inherent in the decisions. Through it, the decision maker can experience different situations, so as to find the optimal solution for the situation, which is against the process of rational decision (SIMON, 1997).

2.2 Computer Simulation

Computer simulation is a technique of Operational Research, which seeks to represent a real system by a computer model (VIEIRA, 2006; HARRELL; GHOSH; BOWDEN, 2000). Mathematical models are developed in order to realize these representations. They are abstractions of reality trying to imitate the main features of it (TURBAN, 1995). From the use of these models it is possible to experiment on the system without major encumbrances (HARRELL; GHOSH; BOWDEN, 2000; ANDRADE, 2004).

Therefore the use of models can provide several benefits for organizations such as: a decrease in the expenditures made in the analysis, a reduction in expenses for research and development, a reduction in analysis time, the use of a large amount of variables, ease of handling models, etc. (TURBAN, 1995; RASGDALE, 2004).

These benefits inherent in modeling and, consequently, the simulation started to draw the attention of companies. It was realized that they could play an important role in the business world, being used by organizations to support the process of decision making (HILLIER; LIEBERMAN, 2005).

In this sense, computer simulation has become a management tool that has gained prominence in recent years. This is because these days most organizations are involved in projects, large or small, which in turn encompass the use of resource-machines, persons, tools, and equipment to be optimized, since they involve considerable investment needs that need to be optimized (VIEIRA, 2006). In this sense, the simulation has gained prominence since it allows companies to represent a real situation in a controlled system, in which it is possible to experiment, in order to find the best alternative to solve the situation without adding cost to the project (VIEIRA, 2006; HARRELL; GHOSH; BOWDEN, 2000).

In this sense, briefly, we can say that the simulation is a tool that can assist in decision making in different situations, enabling a reduction of the uncertainty of decisions. For this, it seeks: to represent a real system; hypotheses and scenarios to be tested, and; to reproduce and analyze the results derived from such conjecture (LIMA; BARBOSA; BEAL, 2003). However, it should be emphasized that the simulation does not replace the decision maker. It only helps him find alternatives to solve the situation faced (DUARTE, 2003).

Even as to its basic objectives, the simulation has four distinct purposes: a) to evaluate the behavior of a system over time, b) to predict how the system simulated will perform under certain circumstances; c) to investigate and understand the system dynamics, and d) to compare the results obtained (VACCARO, 1999).

The computer simulation is an ancient technique, since the first models emerged in the 1950s to assist in solving problems, improving the utilization of business resources. However, only with the improvement of the hardware, which now supports more complex models, and software development, with more friendly interfaces to decision makers (VIEIRA, 2006).

Despite its current reputation, before implementing the use of computer simulation a company has to weigh its advantages, as well as their disadvantages. Among the advantages, it can be noted that: a) it represents complex systems that cannot be modeled mathematically; b) it enables the creation and testing of various situations which are always under the control of the user; c) it enables the study of long term situations; and d) it is cheaper than a real system experimentation (LAW; KELTON, 2000).

The main disadvantage is related to the fact that it is a representation of reality, i.e., that it uses modeling, which is the process of representing reality in a simplified manner (TURBAN, 1995). This simplification can affect the outcome of the simulation, since the model does not accurately represent realit, the results obtained by it are useless. Besides, it is also necessary to point out other disadvantages, such as: the need to empower the decision maker to operate the software simulation, the time required to model the system, which can take months (DUARTE, 2003), and because the simulation is not an optimizing technique, it only allows the user to test various scenarios (LAW; KELTON, 2000).

Finally, it is necessary to mention as a disadvantage the initial costs involved with the implementation of the simulation in a company, which is often enhanced due to the difficulties of designing the future economic returns that will be provided by the use of this technique of Operations Research (HARRELL; GHOSH; BOWDEN, 2000).

In general, despite the potential drawbacks, there is a growing use of simulation in organizational scope, which is applied in different areas such as logistics and supply chain management, project management, systems manufacturers, among others. In this study, we intend to implement the simulation in a piston manufacturing system, which due to increased demand needs to be expanded. Thus the technique will help the manager to find an alternative that optimizes the financial and operating system returns.

3. SIMULATION OF A PISTON MANUFACTURING SYSTEM

In this work, the simulation is used to represent a piston manufacturing system of a plant located in the state of São Paulo. It should be noted that in recent years the Brazilian economy has shown considerable growth, and the auto industry follows this trend. According to the National Association of Automobile Manufacturers a total of 3,415,486 million vehicles were produced in 2012, a number that must be overcome in 2013, since this year's production, considering the first five months, exceeds the previous year by 18.6% (ANFAVEA, 2013).

This increase in production is directly related to an increase in domestic sales. In 2012, 3,802,071 million new vehicles were licensed in Brazil. This growth, in turn, can be explained both by the income improvement of the Brazilian people, and the ease of getting credit. Over the past decade the dealerships have been offering various facilities in the allocation of loans, which in addition to propelling car sales, also increased demand for accessories such as power steering, electric trio, air conditioning, among others (ANFAVEA, 2013).

Among the accessories with the highest demand is air conditioning. In 2005, 58% of the vehicles sold were equipped with factory air conditioning. It is projected that this figure will increase each year, reaching 74% of vehicles in 2012, approaching the number of European markets, where 75% of cars now have factory air conditioning (COUTTO; PROVATTI, 2005).

The piston is an essential component in the compressor used in the refrigeration circuit of the car’s HVAC system, so that the article will verify alternatives to increase production in order to meet the growing demand for the product.

The evaluated piston manufacturing cell produces 17,000 pistons daily with a 0.534 unit cost. However, about 18,000 inputs are available daily. After fabrication, the finished products are transported to another location within the factory where they are used in the production of hermetic compressors.

The manufacturing system is distributed in a space of ten feet long and seven meters wide. In the layout used, there are two part inputs and one output, the machines are positioned facing each other. Currently, there are seventeen machines with capacities and different production times: five machines of type A, eight type B, one type C, a D-type, plus a washer and quality control.

Table 1: Production times of the piston manufacturing system

Product	Machine	Units	Pçs per cycle	Time of manual labor	Time of operation (Total)
Piston	A	5	8	16	152
	C	1	4	6	86
	D	1	4	6	102
	B	8	1		30

The operation is performed by three workers, which can be divided into three distinct processes. In the first there are the five machines A, the machine C and D machine. In it, a worker takes parts of the two inputs and leads them to another machine. There he will start the setup of the machining of the parts, which are released on sequence.

The second process starts after machining. Another employee takes the initial machined parts and leads them to type B, where another machining process is initiated. In the latter case, a third employee collects the pieces from machine B and leads them to the washer and quality control, where their specifications are checked.

This production process was reproduced in this study using the software Promodel. All features of the real system were respected, such as the distances between machines, the number of employees, the amount of inputs, the lead time of the machines, among others.

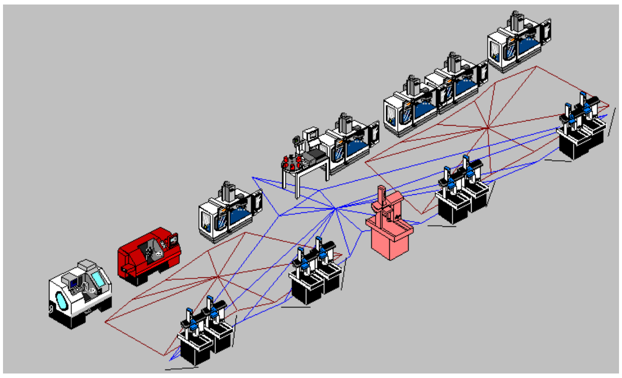

Figure 2: A representation of the piston manufacturing system

The simulation model obtained a production of 17,288 units, a value close to 17,000 pistons manufactured by the actual system. Still from the computational model it was possible to notice some system problems, such as the disparity in the level of use of machinery compared to the others.

It was also observed that employees of manufacturing cell had a major downtime. These two problems, concerning the disparity of machine utilization and idle work, were the points that initially guided the four trials made by the simulation, which involved the following changes: a) increasing the amount and the better distribution of the inputs received, b) increasing the number of employees, and c) purchasing new machinery and increased inputs.

Table 2: Machines utilization of the real system

Machines	% Utilization	% Operation
A	51,51	49,57
A	51,48	49,57
A	51,92	49,57
A	51,23	49,57
A	90,03	86,41
C	66,23	61,27
D	63,20	59,97
B	78,06	78,06
B	78,06	78,06
B	78,06	78,06
B	78,06	78,06
B	77,43	77,43
B	77,27	77,27
B	85,69	85,69
B	70,56	70,56

Table 3: Working and idle time of the workers of the real system

Workers	Number Times Used	% In Use	% Travel To Use	% Idle
1	3372	27,32	10,67	62,01
2	4844	26,51	16,98	56,51
3	8695	24,22	25,34	50,44

3.1. Simulation of Scenario I

The first simulated scenario involved two distinct strategies. Firstly, it was tried to increase the amount of incoming input from 18,000 to 20,000. It was intended to increase the level of use of machinery which, in most cases, was below 80%.

The second strategy involved modifying the number of entry pieces, from two to four. In the real system the company used only two incoming places, creating a great disparity in the level of utilization of the machines of the first process (machine A - machines C and D).

The simulation pondering these two changes had a positive result, the total number of pistons produced could grow to 19,352, an amount that would be totally absorbed by demand. Furthermore, the level of use of machinery significantly increased, exceeding 20% more than the use of other instruments used in the first process. Finally, it is noticed that there was also a considerable drop in the idleness of workers, due to the increased amount produced performing more operations related to transportation of goods and the setup of the machines. The results of this scenario are presented on tables 4 and 5.

Table 4: Machines utilization of the scenario 1

Machines	% Utilization	% Operation
A	82,64	66,15
A	82,09	66,15
A	78,97	66,15
A	78,83	66,15
A	82,75	79,38
C	64,52	59,88
D	61,52	58,67
B	99,79	99,79
B	99,76	99,76
B	99,75	99,75
B	99,71	99,71
B	71,25	71,25
B	71,25	71,25
B	83,75	83,75
B	69,03	69,03

Table 5: Working and idle time of the workers of the scenario 1

Workers	Number Times Used	% In Use	% Travel To Use	% Idle
1	4444	36,21	14,65	49,14
2	4650	25,19	16,34	58,46
3	9732	27,15	28,95	43,91

3.2. Simulation of Scenario II

The second simulation encompassed changes from the previous scenario, so the number of inputs was 20,000 pieces per day, being divided into four entries. Furthermore, it was also experienced an increase in the number of workers.

Despite the level of idleness found in previous simulations, it was intended with this trial to ascertain whether the addition of a worker influences the quantity produced. Thus, it was added another employee in C, since this worker was the one who performed most operations, a total of 9,732.

The results of this experiment were unsatisfactory, the total number of pistons produced was 19,360, only 8 more than the previous scenario. The level of machine utilization was practically not changed and the level of idleness of worker C nearly doubled from 43.91% in the previous scenario to 78.76% in the current one. Thus, it is clear that the number of employees has no influence on the total produced, so the company should consider new alternatives to manufacture more products. The results of this scenario are presented on tables 6 and 7.

Table 6: Machines utilization of the scenario 2

Machines	% Utilization	% Operation
A	82,64	66,15
A	82,09	66,15
A	78,97	66,15
A	78,83	66,15
A	82,75	79,38
C	64,52	59,88
D	61,52	58,67
B	99,79	99,79
B	99,76	99,76
B	99,75	99,75
B	99,71	99,71
B	71,25	71,25
B	71,25	71,25
B	83,75	83,75
B	69,03	69,03

Table 7: Working and idle time of the workers of the scenario 2

Workers	Number Times Used	% In Use	% Travel To Use	% Idle
1	4444	36,21	14,65	49,14
2	4650	25,19	16,34	58,46
3A	4870	13,60	14,50	78,73
3B	4862	13,55	14,45	78,76
3	9732	27,15	28,95	78,76

3.3. Simulation of Scenario III

The third and final simulation involved the purchase of new machinery. Analyzing the results of the previous experiments it was noted that the level of use of certain machines B reached almost 100%.

Accordingly, in this last experiment, two more machines B were added. Despite the investments required, it was believed that the use of new machinery would increase considerably the total of products. In this sense, the amount of inputs received daily was also increased to 22,000 units.

The simulation showed that with these changes the total production of pistons would increase to 20,928 units. However, it is clear that there is a significant drop in the level of machine B use. The results of this scenario are presented on tables 8 and 9.

Table 8: Machines utilization of the scenario 3

Machines	% Utilization	% Operation
A	75,22	72,85
A	75,26	72,67
A	91,02	67,38
A	90,40	67,35
A	89,66	86,08
C	71,35	65,24
D	67,99	65,28
B	57,36	57,36
B	57,36	57,36
B	57,36	57,36
B	57,22	57,22
B	99,75	99,75
B	99,71	99,71
B	77,15	77,15
B	76,96	76,96
B	91,25	91,25
B	76,81	76,81

Table 9: Working and idle time of the workers of the scenario 3

Workers	Number Times Used	% In Use	% Travel To Use	% Idle
1	4725	38,43	16,60	44,97
2	5096	27,54	17,88	54,59
3	10525	29,57	31,37	39,07

4. DISCUSSION OF RESULTS AND FINAL CONSIDERATIONS

The aim of this study was to demonstrate that the use of simulation as a technique of Operational Research can assist the process of decision-making by businesses, which are increasingly complex due to uncertainties, risks, conflicts and lack of infrastructure decisions.

To achieve this goal we simulated a piston manufacturing cell, which represented an auto parts factory located in the state of São Paulo. Pistons are components used in air-conditioned cars, having a steady increase in demand. In this sense, the goal of the simulations was to test alternatives to increase the daily output of the production system that was 17,000 units.

The results in all scenarios were satisfactory with respect to the main objective of the trial. In all scenarios, the daily production was increased by at least 2,000 units.

However, strategies have simulated different investments, so comparing them is necessary to determine both the investment required and the unit cost of the pistons. For this, it is estimated that the unit cost is $0.534, the hourly cost of the cell is $291.98, the cost of direct labor per worker is $8.18 and the cost of labor indirectly, with the share of overhead, is $ 40.91. Table 10 presents the summary of the costs.

Table 10: Costs of the real system

Unit Cost	0.534
Cost/hour	291.88
Direct labor costs / worker	8.18
Indirect labor cost + General expenses	40.91

In the first alternative, modifications involved only a change in the input quantity and inputs received, i.e., no considerable investment. It was obtained production of 19,352 units, thus the product unit cost was $ 0.4430.

In the second scenario, the modifications involved changes experienced in the first stage, and the addition of an employee. The total production of 19,360 was obtained, so this unit cost was $ 0.4530.

Finally, in the latter scenario, the number of inputs was increased to 22,000 units. In addition, we simulated the purchase of two machines B, which required an investment of $ 200,000. The unit cost was 0.423, and the total production quantity reached 20,928 units. Table 11 presents the summary of scenarios.

Table 11: Summary of scenarios outputs

Simulation	Production	Workers	Input	Cost/piston
Scenario I	19352	3	20000	0,4430
Scenario II	19360	4	20000	0,4530
Scenario III	20928	3	22000	0,4230

It can be seen then that there are two viable options to increase daily production of pistons; Alternative 3 has a lower unit cost than the others. However, it requires an initial investment of $ 200,000. On the other hand, strategy 1 requires no investment. However, it has a unit cost of $ 0.4430.

Thus, the company should decide on the best way to face the situation, since, as mentioned earlier, the simulation is not an optimizing technique.

In general, by analyzing the results obtained by simulations and the concepts presented, it is clear that this technique can aid the decision-making process of a company making it less complex, since it allows experimentation strategies that could solve the situation faced.

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