Application of simulation for sizing of work in process (WIP) - case study in a manufacturer company valve.

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Abstract

This paper refers to a case study where discrete event simulation was used to size the optimal amount of WIP in a Brazilian company. The data collected were used to build a simulation model that optimized the capacity of existing buffers in the manufacturing process without any problems with customer service.

Keywords: Simulation; Lean Manufacturing; Work In Process

Introduction

The increased of commercial activities, especially with Asian countries, required that Brazilian industries restructured themselves creating new manufacturing methods to reduce waste, remaining competitive in this new composition of the market.

To reduce the manufacturing costs of a firm we emphasize the philosophy of applying lean manufacturing, which consists of a set of tools with the goal of reducing or eliminating the existing seven types of waste in a production system. Vinod & Arvind (2010), Chowdary and George (2012) and Glover et al. (2013) present works in which they are applied some of the tools of lean manufacturing. The results presented show that the production system studies reduced the manufacturing costs of the product.

Emphasizing the importance of cost reduction through the development of the production system, Erjavec et al. (2012) developed a study aiming to reduce the amount of stored parts throughout the manufacturing process (WIP). In this case, a mathematical model was developed by means of simulation techniques, which helped to find the optimal size of the WIP without raising supply risks.

Used as a tool to aid decision making, simulation can be applied in manufacturing projects in order to support and sustain the decisions taken, Freitas (2001). Law & Kelton (1991) suggests the use of simulation to: develop and analyze manufacturing systems, improve and analyze attendance systems, analyze financial and economic systems; develop and analyze transportation systems, communication systems improvement; support decision making.
In another example, Aomar (2011) used simulation in a case study that aimed to apply the tools of lean manufacturing on three indicators: productivity, cycle time and WIP. In this case, Little's law was used to confirm the results obtained in future scenarios. Jeong and Phillips (2011) and Vinod and Sridharan (2011) also applied simulation studies that aimed to develop production systems.

With this information, the purpose of this paper is to demonstrate the application of simulation to reduce the amount of WIP in a Brazilian metallurgical company. Applying the optimization techniques, it was possible to scale the capacity of existing buffers during the manufacturing process in addition to reducing the capacity of pallets, thus enabling the transportation of minorsletes.

**Literature review**

The literature review of this paper was developed through research in scientific articles and books on the subjects: simulation, lean manufacturing, optimization and WIP. This survey was, mostly done in the past five years.

**Simulation**

Defined by Harrell et al. (2002), simulation is a process of experimentation with a detailed model of a real system to evaluate how this system behaves to the changes in its structure, environment or extreme system. Freitas (2001) argues that simulation is the use of mathematical techniques used in computers, which allows to copy the operation of practically of any transaction or real-world process. Law and Kelton (1991) argue that simulation is a mathematical model, usually applied by means of computers, which is a real system. Banks (1998) states that the simulation is a reproduction of a system through mathematical models.

Nomden and Zee (2008) developed a simulation model covering the following information: the processing time, fault history, time setup, layout and product flow, to represent the real system. The aim of this study was to develop routes for the flow of materials and supplies, in which the difficulties of time to deliver a product might be minimized. At the end of the work three points were evident: (1) the existence of a small number of alternative routes, (2) the utilization of fixed routes is preferable, and (3) the acquisition of new equipment are relevant only under specific conditions.

In another study, Jeong and Phillips (2011) applied simulation a manufacturer of portable fire extinguishers, in order to determine what the best layout of three different proposals. At the end of the simulation, one of them was considered the best for the system. After that the same model was used to optimize the number of pallets needed to supply the plant.

Aiming to improve the programming method of the production system, Vinod and Sridharan (2011) use simulation taking into account the total time of manufacture of the product. Seven different production scales were tested in the digital model and the simulation results were subjected to statistical tests to validate the data. At the end of the work it was concluded that the model met the expected research goals.

Although the tests performed in real environments are ideal for the evaluation of changes in a system, this practice can be costly to what concerns time and cost. Figure 1 shows the available alternatives for solving a problem in any one system. This figure is a ramification where the goal is to locate the simulation.
Figure 1: Branching types of experiments in a system by Kelton and Law (1991)

Lean Manufacturing

Lean manufacturing is described by Womack et al. (1997) as a philosophy incorporated into the production system that aims to produce waste in the manufacturing process. For this, it is sketched seven types of waste existing in a production system and specific tools are utilized to reduce these wastes.

Figure 2 shows the relationship between the main tools of lean manufacturing with the seven mentioned waste.

<table>
<thead>
<tr>
<th>OVER PRODUCTION</th>
<th>VSM</th>
<th>5S</th>
<th>KANBAN</th>
<th>KAIZEN</th>
<th>POKA-YOKE</th>
<th>SWED</th>
<th>TPM</th>
<th>CONTINUOUS FLOW</th>
<th>STANDARD WORK</th>
<th>HEIJUNKA BOX</th>
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<tbody>
<tr>
<td>WAITING</td>
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<td>X</td>
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<td>REWORK</td>
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<td>TRANSPORT</td>
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<td>OPERATOR MOTION</td>
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<td>PROCESSING</td>
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<td>INVENTORY</td>
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<tr>
<td>WASTE</td>
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</table>
As noted in Figure 2, some tools of lean manufacturing are applied to more than a
problem in the production system, said that, the shift from a traditional system to a lean
manufacturing system, become necessary the implementation of a set of tools that should be
chosen taking into account the particularities of each system.

Vinod and Arvind (2010) use the VSM (value stream mapping) tool to map the
production system of an Indian company in order to identify areas for improvement. On the map
of the initial flow, opportunities for application of tools such as 5S, Kanban and improvements in
information flow were found. At the end of the work there was a reduction in lead time, cycle
time and work in process system.

In another study, Chowdary and George (2012) applied 5S, VSM continuous flow and to
improve the production system in a pharmaceutical company. The initial VSM was designed and
served as the basis for future development of VSM, which contained 5S applications and
organizing the layout in the row format. At the end of the study, there was a 50% reduction in the
amount of WIP line, reducing the total processing time from 28 minutes to 10 besides the
reduction of 37.5% of the area used in the manufacturing process.

As can be seen in the application examples above, the VSM tool is used to map the flow
for a product or family of products, which notes are made regarding the stages of information
and transformation, since the arrival of raw materials to made available to the client, passing
through the transformational processing, inventory and test operations Rother and Shook (2003).

According to Rother and Shook (2003) VSM is essential because: it helps to see the
overall flow of the production system; it helps identify sources of waste; makes visible the
decisions about the future flow, easing the deployment of new concepts in the environment
manufacturing; forms the basis of the deployment plan of lean manufacturing; shows the
relationship between information flow with the flow of value.

**Methodological procedures**

The methodology used for the development of this work is the case study. Defined by
Ellet (2008) cases are textual representations of contemporary events that put the player in the
role of participant status. Yin (2010) states that a case study should investigate a contemporary
phenomenon in depth and in a real life context, especially when the boundaries between
phenomenon and context are not clearly evident.

The particularities of this research methodology is a form of research question, which
should be "how?" and "why?", the requirement of contemporary events besides not require
control of behavioral events.

For the development of the simulation was observed that the steps are illustrated in
Figure 3, proposed by the author. This stream aims to guide the actions performed in works of
discrete event simulation in manufacturing systems.
The case study

Based on the steps illustrated in Figure 3 which were presented in the methodology will be treated all the results achieved during the development of the case, which are described below:

Description of the problem: after a set of management actions that were intended to restructure a Brazilian manufacturer, it was necessary scaling of intermediate stocks during the manufacturing process, it was due to the balancing of activities involved in the process that occurred in the previous stage to this.

Initially there were a total of 21,000 pieces throughout the process divided into four points, the unit cost is $ 58.65 totaling $ 1,231,650.00 stored in pieces throughout the process. This case was not considered stocks of raw materials or the finished product inventory.

Characterization of the production system: this process can be considered to batch production, although all devices are configured to produce a specific product type, it is possible to manufacture similar products. The type of physical arrangement is considered by process industries since the casting, painting, machining and assembly are separated.
Survey data: to make possible the modeling of the production system, information regarding arose: process time; historical breaks, failures and scrap; setup times. For them to be reliable, thirty measurements were made of each information.

Statistical treatment of the data: After the measurements, the next step was the statistical treatment of the data. This step aimed to find the correct statistical distribution that represents the occurrence of events in the stages of the manufacturing process.

After feeding the software with information regarding the processing time and apply the tool fit, the result was a normal distribution and parameters accepted by the software. The same procedure was performed with other stages of manufacturing in which: the kiln and grinding were lognormal; mounting was normal

Development and checking the model logic: the logic development of this case was relatively simple since it is a flow without variations. The logic verification was given by accountants who certified that there was no deviation in the product flow.

Modeling and validation of the system: using the logic of the model and the data processed, the next step was the full development of the model. Model validation is given by the comparison between the amount of the real system fabricated with the virtual pieces for ten days. Figure 4 demonstrates the adhesion between the systems.

Figure 4: Validation

<table>
<thead>
<tr>
<th>Day</th>
<th>Real Production (parts)</th>
<th>Virtual Production (Parts)</th>
<th>Adherence (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1º Day</td>
<td>12.685</td>
<td>12.940</td>
<td>102,0%</td>
</tr>
<tr>
<td>2º Day</td>
<td>13.112</td>
<td>12.635</td>
<td>103,7%</td>
</tr>
<tr>
<td>3º Day</td>
<td>12.405</td>
<td>13.101</td>
<td>94,7%</td>
</tr>
<tr>
<td>4º Day</td>
<td>12.138</td>
<td>12.998</td>
<td>93,4%</td>
</tr>
<tr>
<td>5º Day</td>
<td>13.245</td>
<td>12.980</td>
<td>102,0%</td>
</tr>
<tr>
<td>6º Day</td>
<td>13.779</td>
<td>12.788</td>
<td>107,7%</td>
</tr>
<tr>
<td>7º Day</td>
<td>13.820</td>
<td>13.409</td>
<td>103,0%</td>
</tr>
<tr>
<td>8º Day</td>
<td>12.954</td>
<td>12.877</td>
<td>100,1%</td>
</tr>
<tr>
<td>9º Day</td>
<td>11.998</td>
<td>12.545</td>
<td>95,6%</td>
</tr>
<tr>
<td>10º Day</td>
<td>13.051</td>
<td>12.177</td>
<td>107,2%</td>
</tr>
<tr>
<td>TOTAL</td>
<td>129.187</td>
<td>128.450</td>
<td>100,6%</td>
</tr>
</tbody>
</table>

System optimization and analysis of results: The goal of this work is to reduce the amount of in-process inventory, for this, it was used the experiment manager tool in which the capacity values of the four stations were sized buffer was used to vary the minimum value tending not affect the amount of parts produced. Figure 5 shows the values of the variables entered in the optimization.

Figure 5: Capacity of buffers to optimize

<table>
<thead>
<tr>
<th>Buffer</th>
<th>Buffer 2</th>
<th>Buffer 3</th>
<th>Buffer 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Value</td>
<td>4600</td>
<td>3200</td>
<td>7200</td>
</tr>
<tr>
<td>Minimum Value</td>
<td>200</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>Increase</td>
<td>200</td>
<td>200</td>
<td>200</td>
</tr>
</tbody>
</table>

Data analysis and conclusion: at the end of the study, the software generated the graph, where shows the quantity of parts produced in relation to the amount of existing inventory parts.
Using this information, it is concluded that the experiment that contained the values 800, 600, 600 and 2,200 for inventory 1, 2, 3 and 4 respectively shows the best result.

**Conclusion**

With the data obtained in the optimization process performed by the software, the maximum amount of WIP was set to 4,200 pieces and the value of the inventory dropped to $246,300.00, a decrease of approximately 80% on the cost of parts stocked.

In conclusion, the simulation was important for the development of this work and contributed to determine the results obtained in this study where the goals were accomplished.

**Bibliography**


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