Improving the Productivity of Industrial Systems: A Simulation-Based Case Study

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Abstract. The modern Industrial Engineering deals with complex engineering systems which require a holistic approach to reinforce their efficiency, flexibility, and sustainability. Deliver high-quality customized products is mandatory while maintaining high levels of productivity so, the operations managers are continuously evaluating their systems in order to improve them. These improvements are usually action based and rely on decision processes with inherent trade-offs. So, methods and tools to support these decision-making processes are essential to operations managers in order to help them to choose the best course of action. This paper reports a real-world industry case study illustrating the advantages of using simulation to analyze the current systems and to evaluate different scenarios regarding productivity improvements.

Introduction

As widely known, simulation is probably one of the best engineering tools to analyze the performance of complex industrial systems, enabling the development of a computer-based replica of the system-in-analysis with the incorporation of complex interdependencies and uncertainties [1]. In fact, simulation is the best way to analyze the performance of manufacturing systems [2]. Since the main task of industrial engineers is to analyze, design, evaluate, and control those systems regarding lean and sustainability principles, simulation tools enable them to capture the dynamic nature of their systems and to test and evaluate different scenarios through the analysis of a wide set of performance measures. This dynamic evaluation supports decision-making helping the operations managers to choose the best course of action.

This work presents a real-world industry case study illustrating the advantages of using simulation to analyze the current system and to evaluate different scenarios regarding productivity improvements. This industrial engineering tool helps the operations managers to test different actions and to estimate their impact on the system-in-analysis.

Simulation

A Valuable Tool for Industrial Engineering

In the context of industrial engineering, simulation is usually defined as a technique used to develop computer-based models of complex systems for dynamic behavior analysis and/or to run what-if scenarios. The formal definitions in the literature are numerous. As [3] states, “simulation is the imitation of the operation of the real-world process or system over time (…) to draw inferences concerning the operating characteristics of the real system that is represented”. According to [4], “simulation is an important tool to make design and operation decisions to enhance the performance of manufacturing processes and systems”. [5] refers to the increasing importance of simulation in recent decades to improve the performance of the manufacturing system and mention that “modelling
and simulation help visualize, assess, implement, change and improve complex production processes by using computer animations within a reasonable time and investment”.

Analytical models impose some limitations when the systems-in-analysis are complex, highly dynamic, and require a considerable set of performance measures to perform a proper evaluation (e.g., number of parts produced, throughput times, machines and workers’ utilization rates, work-in-process inventory levels, number and time of setup operations, queue times, orders tardiness, scrap levels, as well as a set of cost indicators such as material handling costs, labor costs, lateness costs, machine setup costs, inventory carrying costs). Therefore, simulation models are usually the technique elected to analyze and predict the dynamic behavior and complex interactions of modern industrial systems. In addition, the modern simulators provide an integrated user-friendly development environment along with major input analysis, verification & validation (V&V), design of experiments, output analysis, and 2D/3D realistic animation capabilities that facilitate the development of accurate simulation models [6].

The classical industrial engineering problems usually described in the literature as manufacturing simulation applications involve, from the cell workstation to the entire supply chain: the identification of process bottlenecks, the design/redesign of layouts, the analysis of productivity rates and setup operations, the dimensioning of work-in-process inventories, the balancing of assembly lines, the evaluation of scheduling algorithms and dispatching rules, the analysis of material handling routes, the introduction of new working methods and the related ergonomic analysis, etc. The simulation models can be used for the daily control of the operations or to plan future scenarios without disrupting the existing systems. The covered business sectors are endless (e.g., electronics, automotive, high-tech, molds, steel, furniture, beverage, retailing, construction, call centers, and education). In general, all these applications embrace concerns related with productivity improvements since their main objective is to evaluate (and increase) the efficiency of a given system, when converting inputs into valuable outputs.

Based Case Study

This case study describes a real-world case study which is a simulation-based applied project carried out during the internship experience of the Management and Industrial Engineering master Programme of University of Aveiro (Portugal), in a company that produces visual communication boards. The system-in-analysis was the wood section. This section was facing some problems related to changeover times and general productivity levels. So, it was decided to model and simulate the wood section in order to evaluate its performance and to test the impact of some improvements regarding machines’ downtimes. The general objective was to increase the productivity of the section.

The simulation study followed the well-known major steps: problem formulation, conceptual modelling and data collection, operational modelling, verification & validation, experimentation, and output analysis [7]. The logical model was implemented in software Arena®. Ideally, the results should be credible enough to convince decision-makers to use them in the real system.

Wood Section

Current Situation and Simulation Analysis

The simulation study was developed for the wood section of the factory. The wood section is dedicated to a communication boards’ product line for family house environments. The section has five operators and one supervisor. For the purpose of this simulation were only considered five operators, since the work of the supervisor is not relevant for the study. In addition there are four machines (one called Multiserra and three called Molderadoras). The Multiserra cuts the boards made of pine, beech and MDF into wooden slats. The Molderadoras create wooden profiles for the structure of the boards.

The operation and the flows of the section are quite simple. The raw materials for a given production order arrive to the Multiserra area in batches. Alongside this machine is made an
inspection to the material in order to separate the defective boards. The boards that comply with the quality requirements of the company are processed in the machine with the help of an operator. On the other side of the Multiserra machine is another operator collecting the processed boards. These boards are no longer boards but wooden slats that will be inspected by another operator. This worker separates the non-conforming from the conforming materials into different handcars. In general only the pine slats are non-compliant, because the measurements of the boards vary, contrary to the MDF and beech slats that always have the same dimension. The handcar full of slats is then routed to the area of Molderadoras machines. The machine that is going to process that batch depends on the type of material and also of the availability of each Molderadora. In each machine there is an operator who is responsible for loading the slats into the machine and collect the profiles at the exit of the machine. It is important to note that these four machines of the section require cleaning, tools’ changeover and maintenance procedures during the working day. The wood section operates eight hours per day, five days per week in a single shift. The operators have a ten minutes break during the morning and a fifty minutes break at lunch time.

As already mentioned, the main objective of the company was to increase the productivity of the section (mainly by increasing its throughput) because they believed that the capacity of the section was not being used efficiently. Moreover, they need to respond to the demand and meet due dates. So, the first phase of the work was dedicated to understand the system-in-analysis and try to figure out the key flows, procedures and bottlenecks of the system. It was possible to observe that there were several problems affecting the productivity of the wood section being the downtimes one of the most significant concerns. It was found that the machine downtimes were mainly caused by exchange of dies, cleaning operations, and maintenance procedures. The type of problems found in the workplace point to the use of lean methodologies such as 5S’s (for the messy workplace), and SMED (for downtimes).

The performance measures defined for the study, in accordance to the requests of the decision-makers, were the throughput (number of completed orders) for the considered planning period, the mean waiting time of materials in queue, and the utilization rate of the resources. There was also an exhaustive process of input data modelling. Several questions were discussed with the workers (the subject matter experts) and we collected data and times from the different operations. The collected quantitative data allowed the fitting of proper statistical distributions (and also empirical distributions) to the data using the Arena’s software module Input Analyzer. For example, the time between arrivals of pine wood batches was fitted to an exponential distribution with a mean value of 85 minutes.

After validation of the conceptual model, the logic model was implemented in Arena (the simulator used in the Advanced Simulation classes). This logical model was verified and validated (V&V) using different techniques (e.g., internal validity, animation, predictive validation, structured walkthrough, traces, Turing tests) in order to ensure that the model was working as intended and was a faithful reproduction of the real system. The student who accompanied the project on site was crucial in this process, as he combined the knowledge of the simulation tool being used with the
perception gained on the process details. The decision makers were involved in the study and, as expected, the developed 3D animation model (Figure 1) was crucial for gaining their confidence in the results of the study.

It was decided to simulate a typical planning period of a working week through 10 replications (the number of replications was determined by a trial-and-error approach until confidence levels were acceptable). As it can be seen in Figure 2, the mean throughput of the simulated system is very similar to the real throughput.

In general, the attained performance measures were as expected (validation by the production supervisor and decision-makers). The results had reinforced the need to work on the downtimes. Thus, in order to help the company with this complex issue, it was decided to evaluate the impact of a reduction on downtimes. This study and the comparative results are described in the next section.

Increasing the Productivity

The operations management team decided to work on downtimes’ reduction and they believe that a lean intervention can solve some of the problems and increase the wood section productivity. They are mainly concerned with tools’ changeover, cleaning operations, and maintenance procedures. They would like to know the impact on productivity if a reduction of about 50% on downtimes occur. These reductions were reflected in a new scenario of the simulation study and the main comparative results (current scenario versus second scenario with downtimes’ reduction) can be found in the following paragraphs.

When comparing (in terms of mean values) the lead times of the different products of the wood section it was observed that all the materials stayed less time in system with a mean reduction of approximately 20% (for example, MDF wood has a mean lead time of 243 minutes in the current scenario and an improved mean lead time of 176 minutes in the second scenario).

Regarding the comparison of mean utilization rates of the machines across the different scenarios, it was observed that the utilization is higher in the improved scenario for all the machines however, these numbers are still far from the desired levels of utilization (the capacity of the machines of the section is also limited by the manual loading/unloading operations but there is some margin to increase this performance indicator).

In general, the new scenario improves the performance of the wood section leading to an increase in the productivity levels (the throughput raises about 5% with the production of more 900 profiles per week). The reduction in the lead times will help the company to meet the orders’ due date, improving the service level. Using the results provided by the simulation study it is possible to confirm that the reduction in downtimes will help to improve the productivity of the section but there are some other factors (related to work organization and layout configuration) that can also have impact on the performance of the section. Some new simulation scenarios are being studied in order to evaluate the impact of other alternative configurations of the system-in-analysis. This simulation study “forced”
the company to review its operations management procedures and to put some effort in the implementation of new manufacturing strategies and practices.

**Conclusion**

Simulation is a powerful engineering tool that enables industrial engineers to analyze the dynamic of complex systems and to support confident decision-making using a wide set of key performance indicators. In the work reported in this paper, future industrial engineering professionals use simulation models to understand a given real problem encountered during their business internship experiences. This close interaction between the academia and the industry can provide significant advantages for both parties: the academia can “feed” their courses with real engineering problems which stimulate the utilization of experiential, problem-based learning methodologies and a closer alignment with the new virtual generation; the industry/service sector can use the internship students to diagnose some internal engineering problems and to use modern tools, such as simulation, to analyze them.

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