A Simulation-Based Analysis of a Gas Filling Process

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Abstract. Simulation models are a powerful engineering tool to analyze the performance of complex systems enabling the comparison of different scenarios and the evaluation of a considerable set of dynamic key performance indicators. This dynamic evaluation supports decision-making by helping operations managers to compare options and 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 evaluate different scenarios of operation. The case study refers to a gas filling process which combines a continuous part (gas tanks’ operation) with a discrete one (filling of gas into the cylinders). The mishmash of continuous and discrete operations is a challenge for modelling & simulation, involving a combined approach not always easy to accomplish. Results lead to the conclusion that the company is able to keep the production levels while reducing the number of dedicated tanks, thus opening up the possibility of exploring other business opportunities.

Introduction

According to the Institute of Industrial Engineers (IIE), Industrial Engineering is the branch of engineering “concerned with the design, improvement and installation of integrated systems of people, materials, information, equipment and energy. It draws upon specialized knowledge and skill in the mathematical, physical, and social sciences together with the principles and methods of engineering analysis and design, to specify, predict, and evaluate the results to be obtained from such systems”. This interdisciplinary branch of engineering involves solid competences on foundational sciences as well as skills on modern themes such as smart factories, lean operations, energy, ergonomics, client-based information systems, multidimensional data analysis, among others. Additionally, sustainability concerns are mandatory and require the evaluation of the proposed engineering actions’ impact on economic, environmental and societal atmospheres. So, contemporary systems are complex engineering systems which require a holistic approach to reinforce their efficiency, flexibility, and sustainability.

Simulation models are a powerful engineering tool to analyze the performance of complex industrial systems, enabling the comparison of different scenarios and the evaluation of a considerable set of dynamic key performance indicators. This dynamic evaluation supports decision-making by helping operations managers to compare and choose the best course of action out of several options. This work presents a real-world industry case study illustrating the advantages of using simulation to analyze the current system and evaluate different scenarios of operation. The case study refers to a gas filling process which combines continuous with discrete processes, respectively, gas tanks’ operation and filling of gas into cylinders. The mishmash of continuous and discrete operations is a challenge for modelling & simulation involving a combined approach not always easy to accomplish. In this study, this hybrid process was modelled using the integration of continuous simulation in Discrete-Event Simulation (DES) through Arena® software. In the computational
simulation field, the term “hybrid simulation” refers to the combination of discrete and continuous simulation methodologies [1].

The system-in-analysis is a gas filling facility which encloses: i) four tanks that are refilled whenever a given gas level is reached (continuous process), and ii) a line of gas filling into cylinders (discrete process). The main objective of the study was to evaluate the current filling process and find out if the throughput level (pallets of filled gas cylinders) could be preserved reducing the dedicated tanks. The company wants to use some tanks to other production lines and it was necessary to evaluate the installed capacity taking into account the required time to replenish the tank levels. Results suggest that the company is able to keep the production levels while reducing the number of dedicated tanks, thus opening up the possibility of exploring other business opportunities.

**Simulation for Dynamic Analysis**

As [2] state, simulation is the second most widely used technique in operations management (after Modelling) and its appropriateness for practical real-world applications is remarkable as there is a growing need to address the complexities of the whole and to deal with different layers of decision making within a system. Often, analytical models impose some limitations such as the utilization of deterministic variables and the utilization of a restricted set of performance measures, which make some tasks (e.g., inventory buffers dimensioning) difficult to accomplish. Furthermore, most comprehensive analytical models often require large computation times to obtain solutions for medium/large sized problems [3].

With simulation it is possible to evaluate different scenarios (existent or nonexistent) and experiment several variable designs, which can be complemented with powerful and realistic 2D/3D animations. Modern simulators provide an integrated user-friendly development environment along with major input analysis, verification & validation, design of experiments, output analysis, and animation capabilities. Due to the exponential growth of computing capabilities, “simulation has transformed from its beginnings as a brute-force numerical integration method into an attractive and sophisticated option for decision makers” [4].

The modern industrial engineering challenges require: i) holistic and integrative thinking, ii) multifaceted concerns (e.g., sustainability, flexibility, productivity, quality), iii) lean operation methods for smart factories, iv) intricate comparative performance analysis with several key performance indicators (KPIs), and v) confident decision-making. So, the analysis and assessment of engineering actions based on a wide set of performance measures is one of the most important tasks of industrial engineers and, for this reason, simulation has become a popular tool in industrial engineering all over the world.

Simulation modelling is used extensively in industry as a decision-support tool in numerous industrial problems, including estimation of facility capacities, identification and analysis of resource bottlenecks in production processes, testing for alternative methods of operation, defining product mix decisions, and alternative systems architectures [5]. Performance measures typically used include throughput, lead time, utilization rates of resources, and work-in-process (WIP) buffer sizes. The simulation of processes has become a field of considerable interest, allowing verifying and optimizing complex systems in virtual settings.

Simulation allows verifying the operation of systems considering different scenarios and, through the analysis of generated data, it is possible to decide on the best simulated alternative without disrupting the system. As [4] state, “for many complex real world problems requiring complex models, simulation will increasingly be the tool of first resort”.

A comprehensive review of publications concerning simulation applications in manufacturing and business over the decade 1997-2006 is presented by [6]. The analysis evidence a clear sign of maturity in the discipline (a considerable move towards empirical studies compared to methodological ones) being discrete-event simulation (DES) the most popular technique for problem-solving cases, followed by system dynamics (SD) and, more recently, agent based simulation (ABS). The most
popular applications include scheduling, process design and improvement, and supply chain design. The integration of simulation with sensing networks (e.g., RFID-generated data) is also a research topic showing an increasing interest.

**System-in-Analysis and Simulation Study**

This work describes a real-world case study which is a simulation-based applied project developed during the business internship of a student of the Management and Industrial Engineering master Programme at University of Aveiro (Portugal). It is presented a real-world industry case study illustrating the advantages of using simulation to analyze the current system and evaluate different scenarios of operation. The system-in-analysis is a gas filling facility enclosing several gas tanks and a line of gas filling into cylinders. The production line is depicted in Figure 1. The forklift brings a pallet of empty cylinders (35) to the line and, whenever 5 filled cylinders arrive to the end of the line (G), the unpalletizer (A) releases 5 empty cylinders to the process. The cylinders are verified on the RFID antenna (B) and, if the cylinder meets the requirements, it proceeds, otherwise, it is rejected. The cylinders are filled with gas (C) and after this step they are weighted (D). If the cylinder has a given weight of gas it follows to the leak test (E) and then to seal and disk assembly point (F). The filled cylinders proceed to the palletizer (G).

![Figure 1. Gas filling process.](image1)

![Figure 2. Hybrid continuous and discrete simulation model developed in Arena software for the gas filling process.](image2)
The simulation model was developed to evaluate the current filling process and find out if the throughput level (pallets of filled cylinders) could be maintained reducing the dedicated tanks. The company wants to use some tanks to other production lines and it was necessary to evaluate the installed capacity taking into account the required time to replenish the tank levels.

The model was developed using Arena software and the integrated operational model is depicted in Figure 2. The upper part regards the continuous process (gas tanks and their replenishment) and the lower part concerns the discrete process (cylinders filling line).

In the base scenario (current situation), the tanks are replenished after 24 hours (when they reach 15% of their capacity) and, with 4 available tanks, the throughput of the line was about 418 pallets per day.

Considering the new scenario (reducing the number of dedicated tanks), results suggest that the company is able to keep the production levels while reducing the number of dedicated tanks thus opening up the possibility of exploring other business opportunities. It can also be concluded that, using the 2 tanks, the replenishment interval can be adjusted in order to reduce costs and improve the process efficiency. The break-even point was settled on 35 hours.

The results of the simulation model are promising and the company is using them to improve the process-in-analysis and explore new opportunities. This study evidences the benefits of using a simulation approach to analyze complex systems and evaluate different scenarios, showing that simulation can be used as an effective decision-support tool for industrial engineering.

Conclusion

The results of the simulation model are promising and the company is using them to improve the process-in-analysis and explore new opportunities. This study evidences the benefits of using a simulation approach to analyze complex systems and evaluate different scenarios, leading to conclude that simulation can be used as an effective decision-support tool for industrial engineering.

This study is a problem-based learning experience that bridges the gap between academia and industry and reveals the advantages of using simulation to solve complex real-world problems. The authors believe that the valuable interaction between academia and industry will help to bridge the gap between the academic world and the business world, linking research, theory, and practice.

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References