A simulation-based multi-objective optimization approach for production and logistics considering the production layout

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Abstract

Manufacturing sectors in Sweden have a long tradition and represent a significant share of the national gross domestic product and the export values. Most of the Swedish manufacturing companies have gone through a modernization and adaptation process in order to be able to compete on a globalized market. Many plants, however, still have non-optimized shop floors as a consequence of the shop floors being adapted over time without redesigning its production and logistics flows and with a lack of an overall strategy. To support the optimization of shop floors, this paper suggests the combined use of Discrete-Event Simulation and Simulation-Based Multi-objective Optimization. The aim of the paper is to analyze a simulation methodology that supports the optimization of shop floors by considering production and logistics flows along with the shop floor layout. The methodology is intended to contribute to significantly increase the productivity and efficiency of the Swedish manufacturing industry and help companies to survive on the globalized market. Through a case study, the paper shows that the proposed methodology is useful in practice and that it provides a decision support system for manufacturing companies.

Keywords: Simulation-based optimization, mix-model production, logistics, layout.

1. Introduction

Competition in the nowadays globalized world is something really common in the manufacturing sector. There are many international companies trying to conquer a bigger share of the market and usually a key factor in this task is the efficiency in the manufacturing processes. A great effort is required to achieve the level of efficiency needed to stay present in a significant share of the market. This effort can be supported by new improvement approaches as Discrete-Event Simulation (DES) and multi-objective Simulation-Based Optimization (SBO).

Simulation is an analytical tool to design, maintain and improve different types of complex systems [1]. It has been successfully applied in many sectors by building simulation models that represent accurately different kinds of processes, systems and even organizations. With the use of DES models, system analysis and comparisons of different parts of the complex systems can be done easily with a relatively minor investment and without interrupting the production [2].

In this paper an initial attempt to find a methodology for the improvement of complex manufacturing systems with SBO considering the production and logistics flows and plant layout is presented. The research is conducted in close collaboration with a middle-sized Swedish manufacturer, Xylem Water Solutions. Xylem manufactures water pumps and has its main factory in Emmaboda, in the southern region of Småland.

In the paper, a methodology to build conceptual and detailed simulation models of production lines and logistics systems is introduced and initial results are presented. It is demonstrated that the proposed methodology that combines DES and SBO together can be really useful as a decision support system in manufacturing companies. The methodology can contribute significantly to increase the productivity and efficiency of the Swedish manufacturing industry and help them survive on a global market.

The rest of this paper is organized as follows: in Section 2 a literature review of related papers in DES, SBO and manufacturing systems (layout, production and logistics) with high product mix and low volume production is presented. Section 3 presents the main steps of the simulation methodology and how it has been applied to a real-world problem from the manufacturing industry. In Section 4 initial results are presented and finally, Section 5 presents conclusions and future work.

2. Literature review

In this chapter the related scientific literature to this paper is analysed. The chapter is divided in three main sub-chapters: discrete-event simulation, simulation-based multi-objective optimization and high product mix and low-volume production manufacturing system.

2.1. Discrete-Event Simulation

Nowadays there are different techniques for process improvement. All of them have different applications for a big variety of more specific purposes such us different process improvement and design or feasibility studies. Some examples of process improvement approaches are linear programming, Markov Chain Analysis, DES, System Dynamics, Mathematical Modelling, Montecarlo Simulation or Value Stream Mapping and some other Lean approaches. Simulation techniques can be a suitable approach in diverse applications for process improvement of complex systems with high variability [3]. This characteristic results really useful to evaluate changes or variations in processes, facilities or procedures in order to increase its efficiency in a simpler and more effective manner. Another important benefit of simulation is that it helps to identify the bottlenecks, the main limitations of the system.

Some authors study the simulation and optimization of production and logistics systems using mathematical modelling, such as Petri nets [4, 5]. Due to the high degree of complexity, variability and stochastic behaviour of the systems in consideration, this project is mainly focused on simulation and optimization with DES modelling. Nevertheless, some mathematical modelling is addressed in order to support the DES models, for example modelling the required amount and scheduling of some of the automated transports that feed the production lines.

"Whether done by hand or on a computer, simulation involves the generation of an artificial history of a system and the observation of that artificial system to draw inferences concerning the operating characteristics of the real system" [6]. During the 21st century simulation started to be a key technology to support and improve many different kinds of systems. Hence, simulation presents a huge potential for product and manufacturing process development and improvement [7].

Each time the availability of special-purpose simulation languages, the massive computing capabilities at a decreasing cost per operation and the advances in simulation methodologies make simulation one of the most widely applied and accepted tools in operation research and system analysis [8]. Simulation models are usually analyzed by numerical methods instead of applying analytical ones; "analytical methods employ the deductive reasoning of mathematics to "solve" the model; numerical methods employ computational procedures to "solve" mathematical models" [8].

The variability and difficulty of the processes within complex systems usually demand the analytic power of DES. A discrete-event system is one in which the state of the system changes at only individual, but possibly random, set of time points, known as event times [6]. An event is a change in system state. A simulated clock, provided by the simulation software, records the time points at which events occur on a discrete-event simulation [6]. This fact makes DES a suitable tool for the analysis, modelling and improvement of complex manufacturing systems at discrete events of time.

One of the more highlighted characteristics of DES studies is the possibility to apply "what-if" questions or scenarios to the existing systems without disturbing them. Within these scenarios new alternatives, ideas, systems and work proceedings can be tried out without disturbing the real system, or be developed even before a system is constructed. When the complexity and variability of the system is increased, DES is often necessary in order to be able to model and represent the complex and stochastic flows in production lines and logistics systems.

As shown in Figure 1, a DES simulation project is usually compounded by several steps. These steps have to be carefully performed during the building process of the simulation model in order to obtain accurate models providing accurate results.

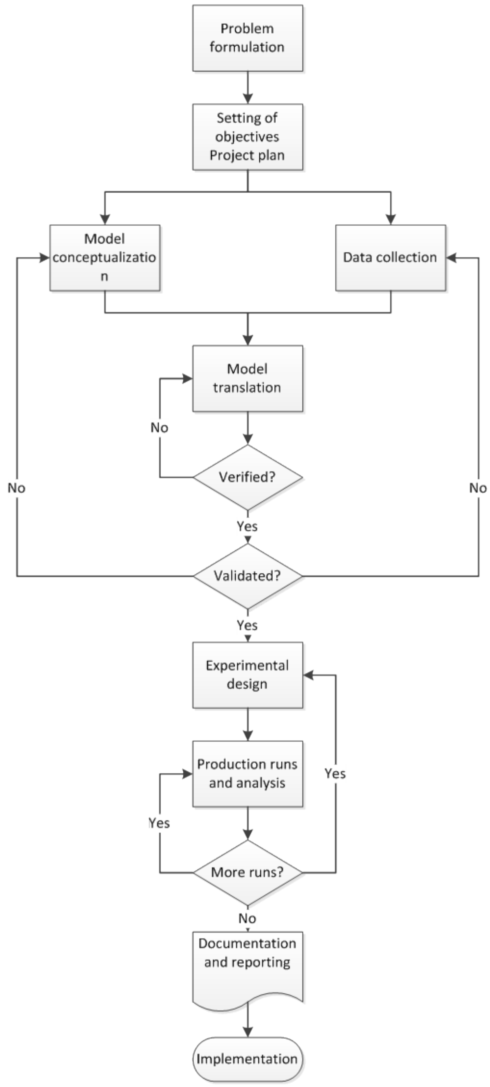

Fig. 1: *Simulation steps, Banks 2005[8]*

As it is possible to appreciate in the previous flowchart, the first step when building a simulation model is to have a clear problem formulation. The problem should be perfectly understood by the client and the simulation analyst. After this, it is possible to start with the setting of objectives and overall project plan [9]. The setting of objectives should be the answers that will be obtained by implementing a specific simulation project. Following this previous step, if simulation is the suitable approach for developing the project, an overall project plan has to be done in order to study how the project will be developed and implemented depending on the available resources and time. It should be also considered if the model will be used in the future for other specific studies in the same system; thus, maybe other processes or resources should be taken into account when developing the model.

Once the problem, objectives and project plan are clear, it is possible to start with the next steps: model conceptualization and data collection. These both steps are the "key steps" to perform a good model in order to obtain accurate results. "The art of modelling is enhanced by an ability to abstract the essential features of a problem, to select and modify basic assumptions that characterize the system, and then enrich and elaborate the model until a useful approximation results" [8]. The data collection step is usually one of the tasks which need more time to be performed. Time studies may be needed and time standards applied in different processes to obtain accurate data from the real system.

When the required data is collected and the conceptual model of the system to study it is clear, it is possible to start with the model construction. This step means translating the conceptual model into a computer language with the help of a simulation software tool. This model has to represent all the key factors that are considered for the improvement approach. Then when the models are built and working properly they have to be verified and validated. Verification and validation are two processes to ensure a simulation model represents the system in an accurate manner. Verifying the models means to check that everything represented in the model is done properly and validation is to check that the behavior of the model represents the reality in an accurate way.

Once the model is verified and validated it can be analyzed and possible weaknesses of the system and potential improvement areas can be found. Finally, when the obtained results are satisfactory they can be presented to decision makers and stakeholders in order to serve as a decision support system.

2.2. Simulation-based multi-objective optimization

DES provides the results of specific what-if experiment scenarios. That is a really convenient tool when a limited amount of different possibilities of system configurations are considered. However, in order to analyse several scenarios, a large amount of modelling time is usually required and although an improved scenario can be found, optimal solutions are not guaranteed. Since simulation is not an optimization tool by itself, a step that combines simulation and optimization is required when several possible combinations of the system want to be analysed. Traditionally, simulation and optimization have been considered as different approaches in the operational research domain, but they have developed together and finally the idea is to use the great detail of simulation together with the ability of optimization to give optimal solutions [10]. Combining optimization and simulation tools allow decision-makers to quickly determine optimal system configurations, even for complex integrated facilities.

Depending on the type of problem to analyse, there are different optimization methods that can be used in combination with simulation, of which several are presented by Figueira and Almada-Lobo [10]. Meta-heuristic optimization is a flexible approach to examine any solution space and it is characterized by quickly achieving good quality solutions, therefore it has usually been used in combination with DES [10]. Consequently, the integration of meta-heuristic optimization together with simulation is necessary if the optimum range of solutions for the given input is followed. Moreover, if there are multiple objectives to be analysed at the same time then SBO is the correct approach to be applied. SBO facilitates the search for trade-offs between several conflicting objectives [10].

Different authors have analysed how simulation combined with optimization techniques can improve production or material handling systems [7, 11-13]. Nevertheless, there are not many cases in the literature where DES and SMO applied together to support the design and development of production and logistics systems of high product mix and low volume production.

2.3. High product mix and low-volume production manufacturing systems

In this subchapter the related literature to this kind of high product mix and low-volume production regarding the layout, production lines and logistics is addressed. Common problems that characterize this kind of systems are the large amount of manual processes and process steps, the high variability of process times, the buffers and space constrains, the needed specialized resources and the amount of external suppliers. In most of the analyzed papers some of the problems mentioned above are addressed specifically, sometimes analyzed from an overall perspective but few of them including the layout, logistics and production lines of these high product low-volume production systems. Most of the relevant papers analyzed are related to the automotive sector. Due to the specific case study of this paper, it is not easy to find related papers on similar production systems, hence the ones found related to the automotive sector have been utilized as a guide due to the similarities in high product mix and low-volume production.

Different automation, production and logistics methods in the manufacturing sector, their main characteristics and limitations have been deeply analyzed by Groover [14]. A complete study in the automotive sector of a mixed-model assembly line focused in the logistics including an optimization is presented by Wenping [15]. Battini [12] defines an interesting integrated approach to parts and components management to optimize the centralization degree of warehouses to minimize storage costs and to choose the right feeding policies. Ende and Boysen [16] summarized the problem of locating the logistics areas optimally to facilitate just-in-time supply of mixed-model assembly lines. According to these authors, in modern-day production systems there is an increasing challenge to feed mixed-models production lines due to the ever rising product variety. They propose a mathematical model with an exact dynamic algorithm to discuss the pros and cons of the supermarket-concept.

The concept of supermarket can be defined as a decentralized in-house logistics area close to the assembly lines that serves as immediate storage for parts delivered with a just-in-time approach [16]. [17] provides a framework to design the supermarket and feeding system to automotive mixed-model assembly lines. In this case the decision of choosing a central kitting area to supply all the production lines was based on the amount of required place on the shop floor. Both possibilities of having the storage areas needed to feed the lines located in a dispersed manner by every production line or having a central storage supermarket area were analysed. It was demonstrated that the second option, the central area supermarket, would free much more space especially by the production lines and would reduce drastically the traffic around the production lines where usually operators have to walk around. Many manufactures around the globe are adopting this supermarket concept to supply parts to the assembly lines.

In the field of the line feeding problem including the proper in-house transportation method and route as well as considering different types of production lines (with different automation levels) not much literature has been found. One of the closest papers involving these three principles is presented by Battini [12], who introduces the line feeding problem and analyses different solutions of optimally locating in house logistics areas to facilitate Just-In-Time supply of mixed-model assembly lines but without considering different production methods for different lines neither the shop floor layout.

3. Proposed methodology

The proposed methodology of this research is based on the Design and Creation research strategy [18]. The election of this research strategy is based on the creation aspect of the aim of this project, to create a guideline to support the improvement and optimization of middle size manufacturing systems with high product mix and a low-volume of customized products, addressing different kinds of production and logistics systems and considering the configuration of the shop floor layout. The need of a methodical documentation of the procedures implemented in the different steps of this project reinforces the election of this research strategy.

For showing the industrial applicability of the methodology, several main steps based on the simulation methodology by Banks [8] are described with an application on real-world problems. In this project 3D models of the system to analyze and improve are created to visualize all the processes at the factory in Emmaboda in a realistic way, being able to involve the different staff in the improvement process. In the following sub-chapters the main steps are explained in detail based on some of the developed simulation models of the industrial case study:

3.1. Step 1: Define objectives

The first step in the methodology is the definition of the objectives. In the case study, these have been defined based on the requested goals and tasks of the project according to the necessities of the company. The overall goal is to support the development and optimization of the production logistics, including modifications of production flow and shop floor layout of the factory in Emmaboda, Sweden. The work involves, among other things, to find improvement parameters of the production and logistics flows considering the layout in the optimization approach. The effective working area / volume of the shop floor must be taken into account when optimizing the production flow. Furthermore, the company wants to find the optimal combination of production and logistics systems for each product family and also which combination of production and logistics systems that is optimal from an overall perspective regarding the layout and the throughput. Answering these questions will support decision makers at Xylem to increase the production and efficiency of the system.

3.2. Step 2: Data collection

One of the most critical tasks to construct accurate models is how to get high quality data. High quality data is necessary and often time studies and time standards have to be applied. The needed data can be obtained by using historical records, work measurement procedures or estimations from subject matter experts [19]. Data collection can be a really time consuming process in this kind of projects. The main problem of the data collection procedure has been the lack of some specific data which was not available. When collecting data to build a simulation model, it usually happens that some data are missing, are too expensive to gather or the data are based in a process that does not exist [6].

In this case there was a lot of available data for the new technologically adapted production lines but on the other hand there was an important lack of data in the manual and old production lines, for example there was no available operators' interruption data, hence it had to be collected manually by performing times studies for the different processes. Sometimes data estimation of the needed times if they are not available in the system can be defined with the help of experts in the matter [19]. In this project the needed data was obtained by the logging devices of some processors when available, by time studies for most of the manual processes and with the help of the operators, expert matters and managers in some cases in which the data was not directly available. Several visits to the facilities were organized to meet the installations, resources and staff. Documentation and meetings with the personal working with logistics and production were deeply analyzed. The literature review and state of the art of previous work, research and developments in simulation and optimizations of manufacturing systems were at the same time studied to be applied to build the simulation models.

In all the cases the data was verified by expert matters and managers to ensure that no errors or non-reliable data was included. Non-reliable data is generated automatically by the system when the data of a product or process is not introduced correctly by the staff or when some activities are missing or interrupted (for example when failures or lack of materials occur, the lead time can be much higher than the maximum sum of process times, but failures and lack of materials are modeled by interruptions at the production line, not at individual processes). Therefore, some boundaries, previously specified by the expert matters and managers were established in the different processes and classifications of products.

3.3. Step 3: Conceptual model

The next step is the construction of simplified process maps to be used as conceptual models of the system. The simulation models will be based on these conceptual models; they require important consideration in order to try to avoid possible future changes in the models afterwards. Applying changes in the construction of the models at this level is usually much easier than doing it in later steps.

All the processes represented in the first version of the conceptual models were revised by going through the flow of the system as a product. In the same way, irrelevant processes for the purpose of this project were rejected from the process maps represented in the conceptual models. In order to explain why and which processes were rejected from the conceptual models, a list of assumptions was discussed with the stakeholders of the project. Some of them are simplifications or considerations made to simplify the simulation models without compromising the results. Usually they have a lack of relevance for the purpose of the simulation models. They also contain those cases in which the flow of products or materials and the activities involved in the system were modified or these unnecessary data or processes simplified in order to avoid unnecessary processes that would not affect the simulation results and would make the simulation extremely complex without adding a considerable accuracy. Some example are the grouping of variants with similar characteristics and processing times (for example variants with the only difference of the color in the painting, a different performance curve or a different configuration of the cables usually have not impact in changing the processing times).

When the conceptual models are carefully studied, built and checked, it is possible to continue with the general purpose and go to the next step: to build the simulation models.

3.4. Step 4: Simulation models

In order to be able to support decision makers to increase the production and efficiency of this factory through simulation, virtual models of the different parts of the real system have to be designed and built according to the defined objectives and considering important requirements. These requirements can for example be the lack of enough free space on the shop floor, the excessive amount of traffic inside the factory and extensive amount of manpower needed to produce different models. The simulation models should be based on previously designed conceptual models that reflect the behavior, steps and processes of the system in a piece of paper. To construct the simulation models of a system, an analytical tool as DES is necessary due to the high complexity and variability of manufacturing processes. When building the simulation model, all the relevant necessary processes should be represented to understand the system.

In the case study, a main simulation model was constructed for the production and logistics flows of the main shop floor at Emmaboda. This model is compound by several 3D models of the different production lines and their respective feeding systems. In these models, statistical distributions and probabilities have been used to model the different processing times in order to achieve in the simulation model the same stochastic behavior of the production, staff and resources as in the real factory.

This part involves converting the conceptual models into a computer-recognizable format. In this case were *FACTS Analyzer* [6, 11, 20] and *Flexsim* the simulation software tools selected to make the translation to a computer program. At the beginning, simple production lines were built with *FACTS*. With this more user-friendly software, generic 2D simulation models are easily built. The models were built with the simplest flow of pumps and processes to analyze the level of detail required to obtain accurate results. When the model was working properly, it was time to use *Flexsim* to introduce, when needed, 3D visuals, more detailed processes, staff and interruptions that are usually involved in the real system, additional tasks depending on probabilities and the classification of different models and variants of products. In this way more generic concepts can be analyzed with *FACTS* easily and those cases with a higher level of detail required were analyzed using *Flexsim* (with the correspondent significant increase of programming time). Four main different kinds of product models in eight different production lines were considered to model. Different alternatives of this layout were one of the main improvement possibilities of the main shop floor at Xylem Emmaboda. This combination of lines is shown in Figure 2.

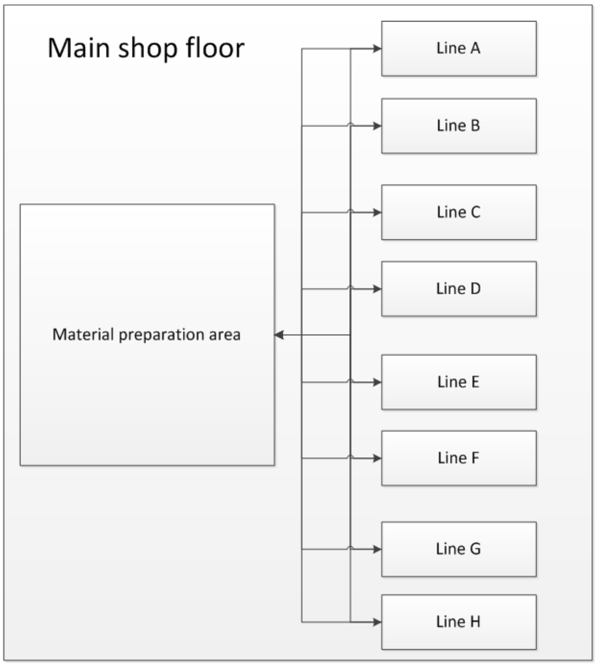

Fig. 2: *Main shop floor. Production lines*

The simulation models built as part of this study are based on the different production lines the factory has in their main shop floor represented in Figure 2. An ongoing study of the old and mostly manual production lines compared with the new adapted ones with a higher level of automation is being carried out. In the same way, the different possibilities to feed those combinations of production lines with different methods are also being analysed with simulation and stated as ongoing work. These logistics methods being considered to transport the material between a material preparation area and the different production lines are forklifts, conveyors, Automated Guided Vehicles (AGVs) and tow-trains. Stakeholders are wondering about transforming all the old production lines to the new system and about joining some of them together or not. In the following Figures 3 and 4 the detailed simulation models of both production systems are presented:

Fig.3: *Simulation model of a manual production line*

Figure 3 presents the simulation models built with *Flexsim* of one of the old production lines where most of the processes are manual. In this production system the same operator works with the same pump during the entire production line; all the operators know how to perform all the manufacturing tasks and the material is fed to the line by forklifts. The following Figure 4 presents another simulation model, also built with *Flexsim*, of one of the new adapted production lines with a higher level of automation, specialised operators, using kitting and an AGV to transport the material from the kitting area to the production line.

Fig.4: *Simulation model of a new adapted production line*

Another type of simulation model is presented in Figure 5. This is a simplified model of the same line shown in Figure 4 but built with the simulation software *FACTS Analyser*. As mentioned before less detailed simulation models can be built with this software saving a lot of time when high level of customization and detail is not required.

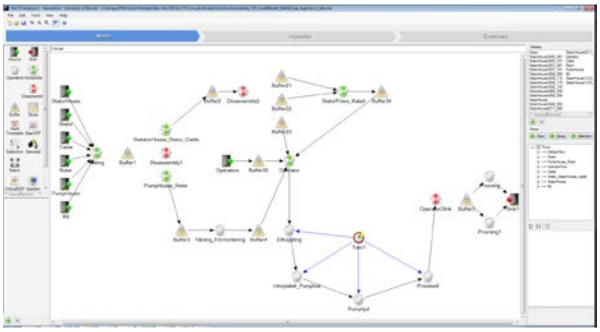

Fig.5: *Simulation conceptual model of a new adapted production line*

Once these simulation models were built it was necessary to verify and validate them in order to ensure they represent the real system in an accurate manner. This is explained in the following sub-chapter.

3.5. Step 5: Verification and validation

The developed simulations models have to be verified and validated in order to design and test some improved scenarios with the aim to improve the system. Verification and validation are necessary to ensure that the model properly represents the real system as it is, without any failure and with all the aspects needed to build up new scenarios to increase the service level of the system.

Before running the simulations to obtain similar results as in the real system and before starting with the what-if scenarios, it was necessary to ensure that the model was correctly built and the results were accurate enough. The model has to be an accurate representation of the real-world system [6]. Developing a validated simulation model involves three basic entities: the real-world system under consideration, a theoretical model of the system and a computer-based representation of the model, the simulation program [6].

Verification is a determination of whether the computer implementation of the conceptual model is correct [6]. It is to ensure that the computer program works properly representing the system in the same way as the real one is. The input parameters and logical structure of the model has to be correctly represented in the model to validate it [8]. Every process had to be performed in the model properly, using just the necessary staff, resources and process times for every variant. In this case, to perform the verification, every different pump, process and staff of the model was followed during a few simulations to ensure they performed their tasks and processes as they should. The number of resources, personnel, models and variants and schedules was also revised.

The next step was to evaluate the model. The length of each simulation was established in 30 days. It was considered that running the model for 1 month would be enough to get accurate results. The data of an average month of production was considered to build the models. A replication analysis and the definition of the warm-up period were implemented, needed to avoid the excess of variability of the output of the model and to know how accurate the obtained results were. In order to determinate the warm-up period of the model, different calculations comparing the output data of the simulation models during the first simulated days were performed. The warm-up period is the time needed by the model to get the normal or usual working flow without depending on the initial conditions. In this case, the warm-up period was obtained making comparisons about the results of different simulations. Making comparisons of the first simulated days with the rest of them, it was possible to appreciate that the model was warmed-up after the 1 day of simulation (depending on the line, just a few hours were needed to fill the work in process material of the production lines but 1 whole day was chosen to obtain results for the production of entire days). Hence, to avoid this variability, a warm-up period of 1 day was established.

The replication analysis is done to determinate how many replications of the model would be necessary to obtain accurate data. In this case the data of the standard deviation and the mean of running the simulation a few times (with different number of replications) were introduced, trying to get as an output the smaller possible value of replications. Finally, an acceptable deviation of the results fort eh purpose of these studies was obtained running 5 replications of 30 days with a 1 day warm-up period. At this point that the model was verified and giving accurate results, it was time for the validation process.

Validation is a determination of whether the conceptual model can be substituted for the real system for the purposes of experimentation [6]. It can be one of the most difficult steps in a simulation project. The simulation models have to represent the real system in an accurate way. A constant communication between the modeler and the stakeholders was established. During few meetings the results of the simulation were presented and discussed in order to calibrate the model and to be able to obtain the desired accurate results which represent the behavior of the real system.

3.6. Step 6: System analysis

Once the models are verified and validated it is possible to perform a system analysis. The possible weaknesses and limitations of the real system can be found by analyzing the results of simulation models, their variability and stochastic behavior. It is done by going through the simulation models, analyzing the results and trying to find bottlenecks and shifting bottlenecks of the processes [21]. These bottlenecks create the delays on the flow of the whole system, increasing the waiting times and reducing the throughput of patients. In this part of the project "what-if" scenarios are proposed according the results of analyzing the system to check possible improvements in the existing configuration of the factory.

3.7. Step 7: What-if analysis

The most common use of simulation is to analyse what-if scenarios: new ideas, procedures and potential improvements can be evaluated without disturbing the real system or be tested even before a system is constructed. Additionally, "what-if" scenarios have been a useful tool to analyse the implementation and evaluate the results of potential improvements in the system.

With the previously presented simulation models, different production methods were analysed, a bottleneck and shifting bottleneck analysis was performed and different what-if scenarios regarding the logistics methods for the line feeding problem were designed to analyse the different improvement possibilities. Further what-if scenarios of the different logistics possibilities for the different production methods are being performed and are stated as future work.

The implementation in the system of new ideas and new behaviours of the different processes could cost a big amount of time, money, resources and even stopping the normal activity of the factory. Hence, when changes want to be applied to a real system without disturbing it, it is not possible to do it without the use of a powerful model which simulates the real system as it is.

3.8. Step 8: Optimization

Finally, with all the available and analyzed data form the real system, the simulation models and the what-if scenarios, the optimization engine can be designed in order to find the best possible combination of suitable solutions for the different systems and scenarios. The optimization engine is usually integrated in the simulation software or connected to it in a master-slave manner. The key improvement parameters of the systems, defined in the optimization software, are stablished as input parameters of the simulation models, then the optimization engine runs the simulation for an specific amount of simulated time and analyzes the output results. A proper evolutionary algorithm is chosen in the optimization engine usually depending on the size of the search space of the optimization and the amount of established objectives to achieve. According to the output results, new input parameters for the simulation models will be generated by the optimization; these parameters will be introduced in the model as input parameters to see if the current results can be improved. This is an iterative process that goes on until all the search space of the possible solutions has been covered. These input parameters can for example be the number and type of transporters to feed the lines, the number of processors and operators, the size of the buffers between operations… Some of the obtained results by the optimization engine integrated in the FACTS Analyzer simulation software determined the optimal size of the different buffers of one of the main new adapted production lines.

The further expected optimization results are an optimal set of solutions, different combinations of the input parameters of the system, that allow to increase its performance and efficiency, including the amount and type of different transports required for the internal logistics, the different kinds of production lines and some of their characteristics and the possible considered layouts of the main shop floor.

4. Initial results

The preliminary results obtained by the followed methodology in this project are based on the presented industrial case study. More specific results about the validation process and scenarios can be found at [22]. More generically, the main initial results obtained by going through this methodology and the introduced case study can be divided in: Firstly, the identification of the key parameters of the shop floor layout to improve the production. These parameters are obtained during the system understanding and analysis of the project as well as during the simulation models construction. In this case they are some specific processors in the specific production lines that after performing a bottleneck analysis and shifting bottleneck analysis were found out to limit the capacity of the system in a significant way. These parameters can be used as the measurement indexes and are needed for the design of the experiments and input and output values of the simulation models and optimization process stated as future work. Secondly, after analyzing the system and designing some what-if scenarios with different ideas and concepts that managers and stakeholders had in mind, refined simulation models have been built to work with the focus on specific potential areas of improvement. Different versions of the here presented simulation models have been built in other to analyze those found bottlenecks and how could they be improved in different scenarios. For example there is case study going on about line A, one of the new adapted ones, on implementing some improvements in the main bottleneck and translating that improved system to the rest of lines. Finally, with an iterative process and the results of the optimization studies of the different considered alternatives, the best combinations of production and logistics for this kind of system and layout can be found. Another case study going on has obtained the optimal capacity of the different buffers of the new adapted lines, reducing the work in progress considerably. Some of actual buffers were over dimensioned and some others were limiting the capacity of production at certain points of time.

Conclusions and future work

This paper presents a methodology that supports the optimization of shop floors by considering production and logistics flows along with the shop floor layout. The methodology is based on DES and SBO in order to tackle the complexities of real-world manufacturing problems. As far as the authors are aware, there is not much research in the related literature that uses these approaches for simultaneously optimizing production and logistics flows with consideration to the shop floor layout. Through an industrial case study, the paper shows that the methodology is useful in practice and that it provides a decision support system that aid manufacturing companies in improving their productivity and efficiency; more specific results on this case study can be found in [22]. Decision making is not an easy task when facing complex systems as several configurations and objectives, not seldom internally conflicting, need to be considered. This methodology can support managers and stakeholders in taking hard decisions and the results obtained from developed simulations models can serve as guidelines to achieve significant improvements, which is critical nowadays to stay present in a globalized world.

The industrial case study shows applicability of this methodology for solving a real-world problem found at a middle-sized water pumps manufacturer. Simulation models of the existing facilities were developed as part of the study as well as properly verified and validated. Based on the simulation models, it was possible to perform what-if analysis for the improvement of the production and logistics flows at Xylem's plant considering the layout of the shop floor. By using simulation, new automation systems, models and production and logistics methods could be tested without interrupting the real system.

In the next step of this work, additional focus will be put on the optimization step of the presented methodology considering different layout configurations. Different optimization methods will be evaluated and recommendations and guidelines on its implementation as a decision support system will be addressed.

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