Int j simul model 23 (2024) 2, 215-226
Original scientific paper

SIMULATION-BASED ALGORITHM FOR CONTINUOUS IMPROVEMENT OF ENTERPRISES PERFORMANCE

Pervaz, J.[*]; Sremcev, N.[*,#]; Stevanov, B.[*] & Gusel, L.[**]
[*] University of Novi Sad, Faculty of Technical Sciences, Trg Dositeja Obradovica 6, Novi Sad, Serbia
[**] University of Maribor, Faculty of Mechanical Engineering, Smetanova 17, 2000 Maribor, Slovenia
E-Mail: pervaz.di13.2017@uns.ac.rs, nextesla@uns.ac.rs ([#] Corresponding author), branisha@uns.ac.rs, leo.gusel@um.si

Abstract
The printing company's process performance depends on the possibility of providing requested products and managing the existing constraints of fixed machine layouts and high setup times between different products. Process inefficiencies caused by these factors reflect on throughput, production times, and resource utilization. The changes that improve one part of the production system usually affect other parts, needing additional optimization, and it is very useful to test the feasibility of proposed solutions with simulation before implementation. This paper presents a new algorithm for continuous improvement of enterprises performance, combining the lean approach with cellular manufacturing, and simulation. The performance is observed in a way that a certain setup influences the system in its entirety, rather than on a specific part of that system. The results are presented through models developed within the production optimization phase, representing various ways in which the continuous improvement algorithm can unfold. Each of them comes with its advantages and disadvantages, all intending to create more efficient production processes that generate less production waste.
(Received in August 2023, accepted in February 2024. This paper was with the authors 1 month for 1 revision.)

Key Words: Printing Process, Lean Management, Product Groups, Manufacturing Cells, Simulation, Continuous Improvement

1. INTRODUCTION

The production process in the printing industry includes the preparation of files for printing, product printing, finishing (which may contain several stages depending on the product), the final stage (taking out the excess cardboard around the box and gluing), and packaging. The complexity of production planning in the printing industry primarily stems from the fact that companies produce for a well-known customer, according to given specifications and within short deadlines. This categorises the printing processes almost as a service [1].

Each product has specifications and limitations. The specifications refer to the number of colours of the product, the type of varnish and the place of varnishing, the dimensions of the product, the format of the material, special finishes (blind printing and gold printing), and the method of gluing the product. Limitations are mainly related to the number of colours or the format of the material. All this affects the setup time of the machines. The setup time parameter is the main factor that affects the realization of the production operations, because it takes a lot of time to replace the tools and prepare the machines for production. Precisely for this reason, the possibility of producing semi-finished products does not exist (it is not profitable to stop the production of one product and start the production of another).

Also, the printing machines are large and cannot change their position within the factory. Some products can be made in several passes on the machine, i.e. large boxes from two parts in order to overcome the limitations, and this requires a significantly longer production time. It is necessary to take into account all the specifications and limitations so that the utilization of the equipment and the productivity of the entire system are at a sustainable level.

1.1 Lean tools and printing production processes

By grouping products, determining the optimal flow of materials and the production schedule, and with the implementation of lean tools, it is possible to maximally reduce the setup times. Simplified production flows in printing company contribute to better production process performances [2]. As a way of achieving better and more efficient material flows, group technology and cellular manufacturing can be combined with lean implementation practices and tools, but as noted in [3], the lean manufacturing system implementation must be planned and comprehensive. As in any other production, from the manufacturing of ultrasonic sensors [4] to influencing wastes in the banking industry [5], the lean philosophy can also be applied in the production systems of the printing industry [6, 7], because the arrangement of workplaces, the introduction of continuous improvements, and the prevention of errors and the elimination of losses are not affected by the type of production system. The application of lean techniques and tools often requires getting into details of all elements that represent the production process and identifying wastes. As reported in [1], a printing company implemented lean tools and for two years tackled all waste types, with a reported reduction of setup time, employee absence, and paper scrap. Many lean tools were implemented such as 5S, value-stream mapping (VSM), single-minute exchange of die (SMED), Poka-Yoke, etc. The authors reported that lean tools are applicable to the printing industry, but more important than the selection of the tools is the long-term approach to change in the right direction. In [8] the usage of SMED tools is reported, for a flexographic printing process where non-value-added time significantly influenced the printing press availability. The implementation of SMED reduced the downtime of the printing press during changeovers between different products and positively affected the overall equipment efficiency (*OEE*) performance indicator. Another research for the same type of printing process was shown in [9], where waste was idle machine time, consuming energy and not producing anything. The authors report that the application of tools such as why-why, Kaizen and root-cause analysis reduced the idle time of printing machines by 30 %.

1.2 Continuous improvement and group technology

Continuous improvement has become a highly sought-after concept for the functioning of organizations in the twenty-first century to ensure not only a competitive advantage but also the survival of the company in the market. The business environment in recent decades has faced numerous challenges, such as globalization, a more informed and demanding customer, dramatic technological advancements, increased awareness of the importance of the environment and ethics at work, and quality as a key concept in business, among others. Furthermore, lean management is a philosophy that has led to the accelerated development and progress of continuous improvement as it is one of the fundamental pillars of the Japanese philosophy [10]. Continuous improvement, as part of the Lean philosophy, finds its application in all industries, including the printing industry [11].

The effective implementation of a flexible manufacturing system requires the categorization of parts based on similarities in design and manufacturing attributes. This categorization enhances the adaptability of production planning and manufacturing processes. By grouping parts with similar processing requirements, dissimilar machines are organized into cell concepts, aligning with Lean principles. The formation of cells is inherently dependent on the specific characteristics of the processes, varying across different organizations [3].

1.3 Introducing simulation into the lean transformation of printing processes

Since waste reduction through lean tools implementation will change how the process is organized, executed, and managed, it is useful to model the process or multiple processes and simulate the effects of designed changes introduced by lean technology [12]. This enables experimentation with different process scenarios [13-16], and a combination of lean mapping tools and simulation for reviewing the as-is and to-be states (mostly a combination of VSM and simulation software) [17-20], to avoid inefficiencies and give support to better decisions [21].

Looking at the printing industry specifically the simulation was used for the needs of process optimization. In [22], simulation is used to evaluate lean implementation in packaging production processes which in one phase includes printing. The application of four lean tools was estimated against work in process, cycle time, and workers utilization. In [23] the lean and simulation were combined to reduce the product return rate for a garment printing company. Proposed improvement measures like 5S and visual control were validated through the use of simulation software, thus enabling the company to optimize the production process.

Although lean technology and tools are present in the printing industry, the implementation process of a lean tool could be costly [1]. Successful implementation of lean tools needs to be oriented towards reducing lead time, sustainable resource utilization [24], and enhancing manufacturing excellence with a lean management principles and Industry 4.0 [25]. As can be seen from previous research, simulation was used as support of lean transformation, not only to see the advantages of planned introduced changes but also to evaluate whether the benefits of the certain lean tool implementation are justified. To contribute to existing research, this paper introduces a new algorithm that is developed for the needs of better integration of the lean approach and simulation when used in the specific field of printing process optimization. The algorithm phases and its steps were developed to simplify the lean tools implementation and to compare the process performances in the light of implementation decisions, in the continuous improvement cycle which the lean approach carries with itself.

The next section describes the algorithm. After that the case study setup for simulation experimentation is explained, followed by the discussion of experimental results and concluding observations.

2. MATERIALS AND METHODS

Year after year, the number of requests for the production of various products that companies receive is steadily increasing. This leads to an increase in the time companies spend on preparation, while simultaneously being required to manufacture products in a shorter timeframe. In addition to reducing the preparation time for production at individual workstations, it is crucial to release products into production in an appropriate sequence, ensuring that machines are utilized more efficiently, adding value to the product.

The algorithm emerged due to the author's practical experience in manufacturing facilities, intending to develop a high-quality procedure focused on optimizing and improving production systems. As the algorithm's name suggests, the authors have integrated their practical knowledge in group technology, lean management, process optimization, and continuous improvement, aimed at addressing the growing challenges that companies face. The algorithm for continuous improvement through the application of lean philosophy and group technology consists of eight phases, explained below (Fig. 1).

In the first phase, requirements and information are collected. This includes the collection of requirements for the production of certain products from the market, but also the collection of information from the market after delivery, to improve existing products and/or develop new ones based on customer satisfaction.

In the second phase requirements are analysed, because some requirements are related to products that have already been made before and it is not a problem to make the product again, but also there are new requirements for the production of products that have not been made before and it must be considered whether it is feasible to produce them. There are products that the company cannot produce for a number of reasons, namely if it is financially unprofitable if there is currently no available production capacity, or if the company does not have the ability to produce the requested product.

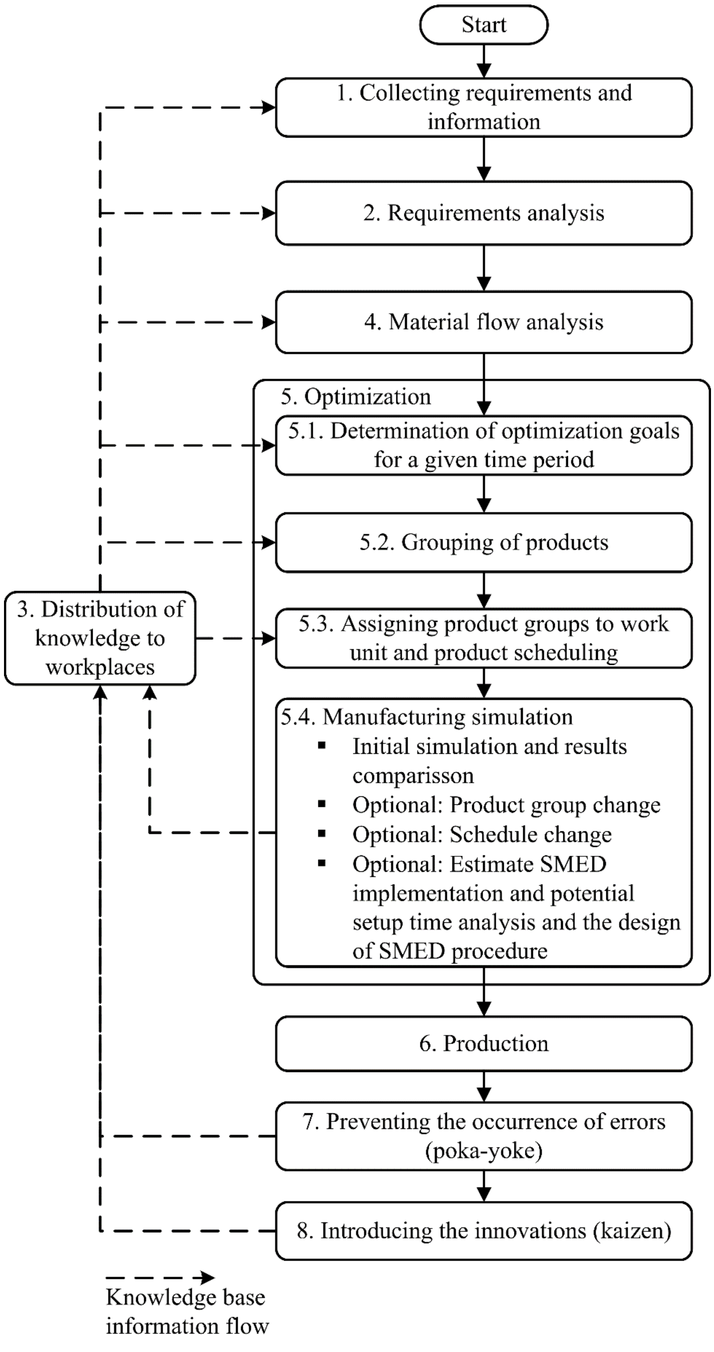

Figure 1: The phases of the algorithm for continuous improvement.

The third phase refers to the distribution of knowledge to workplaces. Knowledge from all sectors of the company is archived (knowledge about ways to solve problems, simulations results of the production schedule, innovations that are introduced in the company, kaizen maps about every implemented improvement of the work process, etc.). It is a knowledge base that is shared with all workplaces where it is needed to carry out continuous improvements in the company, and at the same time, it is easier to find a solution for the order of releasing products into production. This phase of the algorithm is connected to all other phases for continuous knowledge sharing, taking inputs from some phases and providing output information for others.

In the fourth phase the material flow analysis is performed. A routing is created for each new received request that is accepted for production. Procedures for previously performed production jobs are also checked, if there have been certain changes in technology. When the routings for the production of all products from the requirements are collected, the analysis of material flows follows, so that the products can be grouped according to the similarity of production route.

The fifth phase is optimization, which needs to be performed before the production phase, with the use of simulation, and consists of several steps. The first step is to determine the optimization goals to be achieved. The goals can be expressed in the form of production time, costs, as well as the percentage of utilization of available production resources (workers and machines). Then follows the grouping of products according to the material flow analysis, meaning that the products from the product group are released together for production through one manufacturing cell (group of machines). Manufacturing cells are predetermined, because of printing machines' dimensions and weight. Once the assignment of product groups to manufacturing cells is made, the production needs to be scheduled within the group. The schedule is determined according to the criterion of similarity of the production machine setup procedure (number and type of colours, type and position of varnish, product dimensions, etc.). Once a week, product groups are formed and assigned to manufacturing cells, which makes it possible for one product group to be produced within one cell. The next step is to simulate the production. Based on the simulation results, i.e. the percent of utilization of workers and machines, and the time required for the production of products, it is decided whether the set goals have been achieved. If the goals have been achieved, no additional improvement of the production plan is necessary.

If the goals aren't achieved, the improvement of the production plan must be examined whether it is possible to do it or not (if the improvement is not possible, the production will execute according to the current production plan). If the improvement is possible, appropriate optimization options could be investigated. The first of them is the change of product groups, in such a way that products that are similar with more product groups can change the group and thus obtain a better simulation result. If the optimization goals have now been achieved, production can start. If goals are not met, the schedule within one operation group is changed, after which the simulation is performed again. If the result is satisfactory, production can start. However, if all the changes did not lead to the desired optimization goals, then it is examined whether it is worthwhile to apply the SMED procedure. The SMED procedure realization can significantly improve the production process, but the procedure itself requires a lot of time to be implemented properly. When the requests for the products appear again in future periods, the designed SMED procedure will help to achieve a high degree of utilization of workers and production equipment, as well as a shorter production process time. If it is estimated that similar production requirements will not be repeated soon or maybe ever, then it does not make sense to go for SMED implementation, except in the case when a given SMED solution also improves the production of the standard products portfolio. If the SMED implementation pays off, the next step is the analysis of the setup times for the defined product groups. Next, the SMED procedure is designed at all workplaces where tool replacements and workplace preparations take more than 10 minutes, after which the last production simulation is carried out. Based on the obtained results, the knowledge base is updated on new production times and the degree of utilization of workers. A more detailed representation of activities within the fifth phase is provided in Fig. 2.

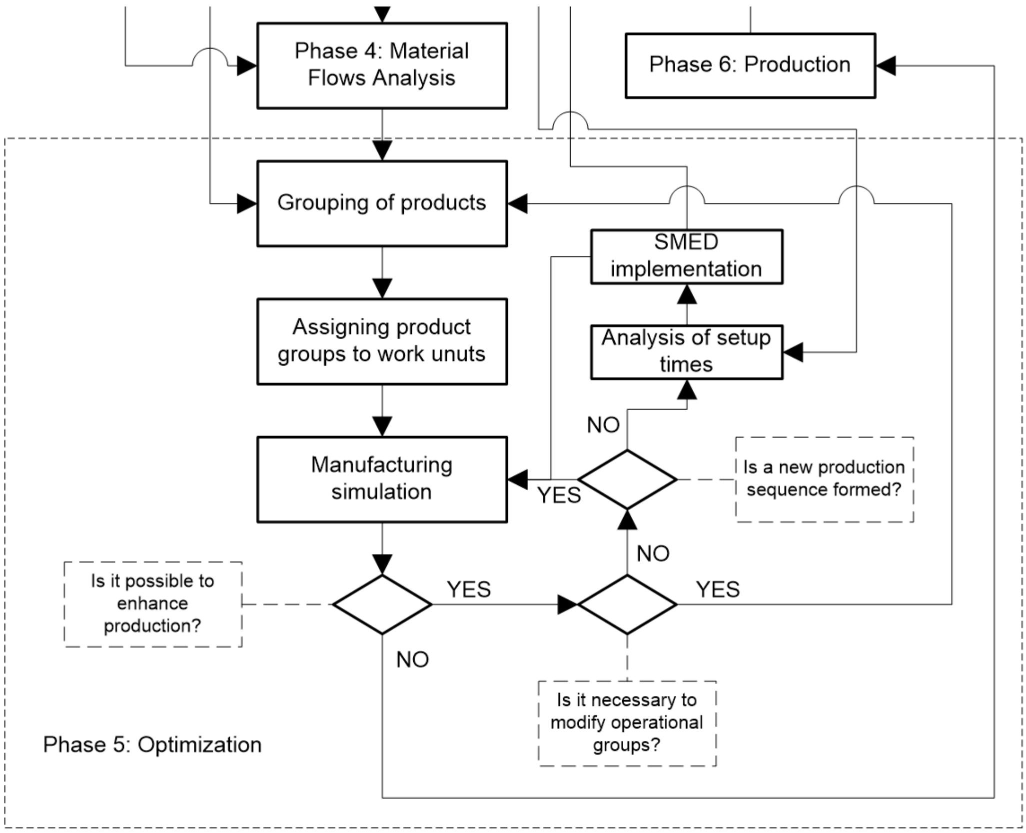

Figure 2: The fifth phase of the algorithm, optimization, is presented in detail.

In the sixth phase, the production starts, and it is based on the results from the fifth phase. Then follows the seventh phase which focuses on preventing the occurrence of errors, i.e. the implementation of the Poka-Yoke solution (it is checked whether there were problems or stoppages in production and if there were, an adequate Poka-yoke solution is applied so that the problem would never happen again, and then kaizen maps are created and archived in the knowledge base).

This is followed by the eighth phase, which refers to the introduction of innovations - kaizen. Based on received requests and collected information from the market, potential innovations are analysed and introduced in the company. If they provide a result, this information (knowledge) is also archived in the knowledge base, and if this is not the case, the analysis of failed changes and their modifications is continued until they provide the desired result. Updating the knowledge base with information from phases seven and eight makes the improvement process continuous which is useful when creating and implementing future production plans.

Also, the examples of good practices from individual workplaces are taken over by all other workplaces that have the opportunity for improvement, applying the same solution to a certain problem.

3. CASE STUDY OF PRINTING PROCESS

3.1 System description and simulation model setup

In the printing industry, where the final product is packaging, the printing company produces according to the specifications of the customer's requirements. Product specifications differ, but there are similarities (type of material, number of colours, type of operation, etc.) based on which company makes savings with proper organization.

Input parameters for the quantity of each product were based on common demand for these products. Each product has a path (specific set of machines and specific order of production operations) that needs to be followed to be produced. Each machine has a capacity based on the real-world measured data. The time horizon is seven working days in two shifts, the standard delivery period for the observed factory. Experiments were conducted 20 times in all scenarios, on the example of the printed packaging process required the production organization to be based on product groups and the creation of physical and/or virtual manufacturing cells. Simulation experiments were done in Simio software. Simio stands as a simulation modelling framework that revolves around the concept of intelligent objects. Modellers craft these objects, and they can be employed across various modelling endeavours. Simio seamlessly facilitates the incorporation of diverse modelling paradigms, encompassing event-driven, process-oriented, object-oriented, and agent-based modelling. The products produced in the system are grouped into three groups (real products representative of these three groups are illustrated in Fig. 3):

- printed packaging without gluing - marked with the letter A,
- printed packaging without gluing enhanced with gold foil - marked with the letter B and,
- glued printed box - marked with the letter C.

To carry out the production process successfully, the following machines are needed:

- printing machines with the varnishing unit – marked with R1 and R2,
- foil stamping machine – marked with a S2,
- die cutting machines – marked with S1 and S3,
- box gluing machine – marked with a letter L and,
- packing workplace – marked with a letter P.

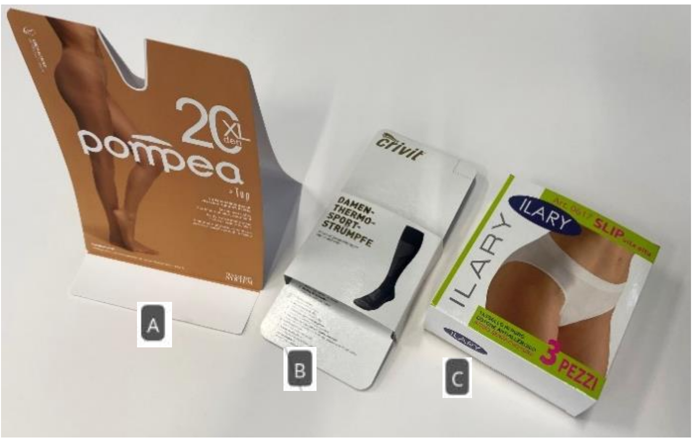

Figure 3: Product groups.

The flow of products through production is defined based on the product group to which it belongs (Fig. 4), enabling the formation of three manufacturing cells:

- for products belonging to product group A: routing R1 – S1 – P – warehouse (cell A),
- for products belonging to product group B: routing R1 – S2 – P – warehouse (cell B),
- for products belonging to product group C: routing R2 – S3 – L – warehouse (cell C).

The packaging, which is normally produced in manufacturing cell A, alternatively can also be produced through manufacturing cell B, but the foil stamping machine is then set to the die cutting operation. This is a situation in which production can be organized with a smaller number of operators but with increased setup times and losses.

The foil stamping machine needs to be heated to the appropriate temperature for carrying out the production phase, and also it needs additional time to cool after the phase is finished (so that it can execute the subsequent phases).

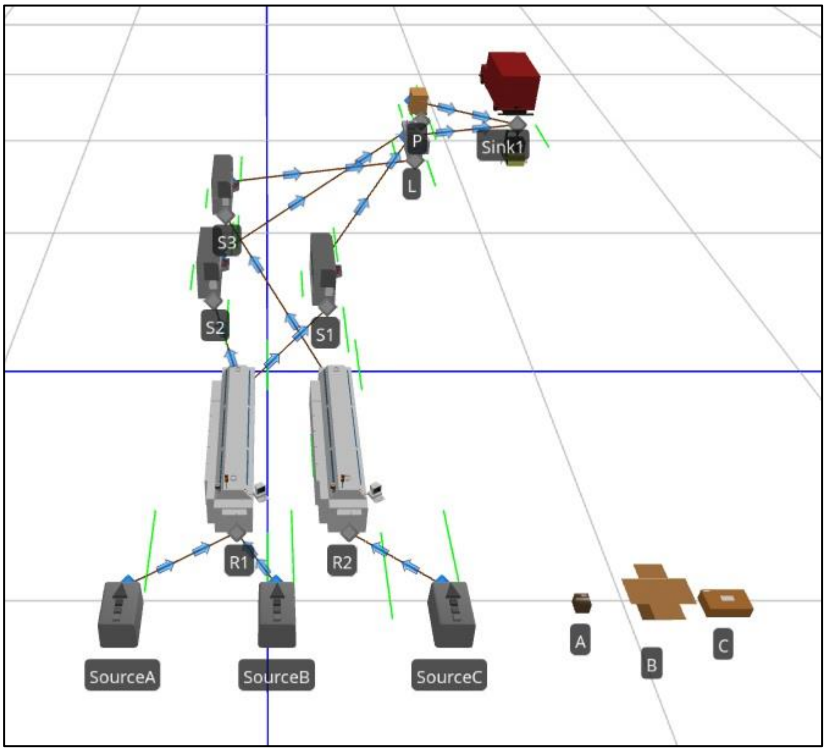

Figure 4: Manufacturing cells.

Machine setup times vary from machine to machine. Table I gives the setup time for each machine as well as the work speed per hour.

Table I: Production machines setup time and working speed.

Label	**Machine name**	**Setup time** (min)	**Optimal speed**
R1	Printing machine with varnishing unit	60	8000 sheets/h
R2	Printing machine with varnishing unit	60	8000 sheets/h
S1	Die cutting machine	30	4000 sheets/h
S2	Foil stamping machine	120	3000 sheets/h
S3	Die cutting machine	30	4000 sheets/h
L	Box gluing machine	60	10000-20000 pieces/h

When it comes to printed packaging products, there is mostly a demand for high-quality printing, and the total duration of the process cycle time has a significant portion of setup times. Savings are achieved by reducing the setup time (i.e. when switching from one job to another). To reduce losses, i.e. to make the entire business profitable on the market, it is necessary to plan production and define the production jobs at least seven days in advance. This is the period for which the market requirements were observed and the period for which the inputs for the experiment were defined. One product group organized in this way usually contains five to fifteen products and the total quantity of products for the product group is from 5000 to 200000 pieces. To be able to say that the business is successful and sustainable, the goal was set that fifteen product groups must be produced in a week, while also monitoring the utilization of the equipment and the average retention time of the product groups in the production system. Product groups should not remain in the production system for more than six days, but it is not the main goal if enough product groups are produced in the expected time. The system was tested through four simulation models, with each model introducing new changes to obtain the desired production results. The goal of fifteen product groups was to be analysed as the result of the modelled production system as a whole, and not by each manufacturing cell performance (this enables not to focus on the optimization of work for a single cell if the other cells will experience decrease in performance, and thus getting the whole production system to have a bad result).

3.2 Simulation experiments and results' discussion

The initial simulation model (Model 1) was created to simulate production with only two manufacturing cells, one for printed packaging without gluing (manufacturing cell B) enhanced with gold foil and the other one for glued printed box (manufacturing cell C). This model aimed to simulate a production scenario in which employees in production planning, based on their previous experience with similar tasks, determine the sequence of product manufacturing and the work units to be utilized for it. It engages the minimum number of work units for which employees know it can produce the products, releasing them in manufacturing according to a sequence that is experientially assumed to be the best.

The results, shown in Table II, were not satisfactory, as it was not possible to produce fifteen product groups (the throughput was 15.33 % smaller than the weekly goal quantity).

Table II: Production throughput [product groups].

Model type	Throughput cell A	Throughput cell B	Throughput cell C	Total throughput
Model 1	0	7.2	5.5	12.7
Model 2	5.15	4.2	5	14.35
Model 3	7.4	5.7	6.35	19.45
Model 4	7.85	6.7	8.3	22.85

Three manufacturing cells were needed for further simulations. The initial experiment is also important because it provides information on how much it is possible to produce with this system setup, and it indicates that with two work units, the planned quantity of product groups set for the week cannot be produced. The next simulation model (Model 2) introduced the additional third manufacturing cell for products that do not have gold foil but go through all the same other stages of the production process (manufacturing cell A). Results were better, but still, this system setting, although being close, didn't fulfil the throughput goal (the throughput was 4.33 % smaller than the weekly goal quantity). Model 2 is reached through a path where the first and second questions in phase five of the algorithm are answered with "YES" – that it is possible to enhance production and that it is necessary to modify operational groups and engage additional work units (Fig. 2). The product specifications mentioned earlier are key for production process performance, having an impact on setup time. Model 3 is reached through a path where the first and third questions in phase five of the algorithm are answered with "YES" – that it is possible to enhance production and that a new production sequence is formed. However, the second question is answered with "NO," indicating that there is no need to change operational groups (Fig. 2). Optimizing the production schedule according to product specifications (Model 3) decreased the setup times. The results in Table II show that this setting achieved the throughput goal (the throughput was 29.66 % over the weekly goal quantity). Model 4 is reached through a path where the second and third questions in phase five of the algorithm are answered with "NO" – indicating that there is no need to change operational groups and that a new production sequence is not formed. However, the first question is answered with "YES," as in each of the models, indicating that it is possible to enhance production (Fig. 2). Model 4 gives additional optimization through SMED procedure design and simulation for all workplaces. The introduction of SMED generates additional costs, which are not always justified. Because it is necessary to measure the tool changeover times at all workstations, and then, on those where these times are the longest, apply the golden rules of the SMED lean tool. This often requires physical changes and improvements to the tools, making it a sometimes expensive activity that is abandoned. In this example, simulation results show a further increase in the throughput

(52.33 % over the weekly goal quantity), which implies that SMED should be considered if the product requirements grow and implementation becomes a profitable alternative.

Table III shows the machine idle time (during seven-day period) for machines (packaging place P is not observed). Results are useful for analysing machine utilization. Model 1 has a better result than Model 2 and Model 3, but two manufacturing cells couldn't meet the demand, and the machines were busy all the time. The introduction of the third manufacturing cell in Model 2 improved the utilization of the R1 machine, but the following machines, S1 and S2, experienced a utilization decrease (because they clogged up).

Table III: Average idle time per machine (or time starved) [days].

Model type	**R1**	**R2**	**S1**	**S2**	**S3**	**L**	**Average total time starved**
Model 1	1.54	0.55	/	2.36	1.96	2.06	1.694
Model 2	0.24	0.24	3.57	3.09	2	2.49	1.938
Model 3	1.27	1.04	2.69	1.77	2.08	1.91	1.793
Model 4	0.73	0.93	2.6	1.38	2.03	1.26	1.488

Rescheduling in Model 3 improved the utilization of machines S1, S2, and L, but decreased the utilization of the R1 and R2 machines, and slightly of the S3 machine. The machine utilization can improve if SMED is applied, as shown in Model 4 simulation results.

The research experiments also explore how much time would production system need for the production of fifteen product groups (the average production time by each of the four system settings is given in Table IV).

Table IV: Average production time for product groups [days].

Model type	**Cell A**	**Cell B**	**Cell C**	**Average product time in system**
Model 1	0	6.03	11.9	8.97
Model 2	8.78	7.74	10.28	8.93
Model 3	4.61	4.22	7.76	5.53
Model 4	4.15	3.87	5.96	4.66

Data analysis shows that Model 3 and Model 4 have acceptable results, i.e. that the average time spent by product groups in the production process is less than seven days. In Model 3, the product groups created in manufacturing cell C spent in the system 7.76 days. These results are acceptable because the goal would be achieved in a sufficient number of completed work orders (product groups).

The results of Model 4 emphasize the implementation of SMED at the manufacturing cell C. The production cycle of the products was reduced to less than six days, enabling maximum produced quantity, as can be seen by comparing with results presented in Table II.

The purpose of the proposed algorithm is not only to establish a continuous improvement system within the company but also to provide the opportunity to identify the most economical sequence for introducing products into production through the application of production process simulations. This process yields information on the necessary activities to optimize production.

4. CONCLUSION

This paper has shown how important simulation is for printing companies where there is a large number of product variants, in market conditions where the customers are ordering products in an increased number of batches with smaller quantities. A larger number of batches means that the production system spends more time in the state of setup for production, which is a loss for any production system, and therefore it is necessary to reduce setup times. If we look at the waste types in the printing industry tools replacement times and products schedule make a significant impact on the system's performance.

Savings are achieved by releasing products into production according to an appropriate sequence that takes into account product routing similarity. Regardless of whether the management structure of the company has a lot of practical experience, a large number of product variants require the use of simulation software so that production is always released in the optimal arrangement. In this case, that has been achieved through the algorithm that integrates simulations, group technology, continuous improvement, and lean philosophy. Through the presented example in this paper, a solution that meets the set criteria (Model 3) was achieved without having to invest in SMED (Model 4) to reach a satisfactory solution at the given moment, and that is one of the benefits of the presented algorithm.

A good production schedule gives the greatest time savings with minimum investments. One of the prerequisites for manufacturing cells formation is that the machines' capacities and types of operations that can be performed in these cells are known exactly. This way planners can exploit all the capabilities of every machine in the cell. The experimental results obviously show improvements in system performance, but these improvements are limited by the nature of the printing process production machine's layout. The static structure of the shop floor prevents the investigation of additional layouts, constraining the optimization focus.

The implementation of SMED tools can be very expensive for the company if it is about preparing a manufacturing cell where products' future demands are uncertain (also when is not known if the customer will ever order them again). But in situations when we know that certain products will be made for some time, then investing in SMED tools certainly makes sense. Future work will include expanding the presented algorithm in certain segments, through the introduction of additional lean tools (VSM and Kanban system for example), to affect the other losses that exist in the process and thus continue the direction toward continuous improvement of the process.

REFERENCES

[1] Ainul Azyan, Z. H.; Pulakanam, V.; Pons, D. (2017). Success factors and barriers to implementing lean in the printing industry: a case study and theoretical framework, *Journal of Manufacturing Technology Management*, Vol. 28, No. 4, 458-484, doi:10.1108/JMTM-05-2016-0067

[2] Rai, S.; Duke, C. B.; Lowe, V.; Quan-Trotter, C.; Scheermesser, T. (2009). LDP lean document production–O.R.-enhanced productivity improvements for the printing industry, *Interfaces*, Vol. 39, No. 1, 69-90, doi:10.1287/inte.1080.0413

[3] Sundar, R.; Balaji, A. N.; Satheesh Kumar, R. M. (2014). A review on lean manufacturing implementation techniques, *Procedia Engineering*, Vol. 97, 1875-1885, doi:10.1016/j.proeng.2014.12.341

[4] Bucko, M.; Schindlerova, V.; Krupova, H. (2022). Application of lean manufacturing methods in the production of ultrasonic sensor, *Technical Gazette*, Vol. 29, No. 5, 1671-1677, doi:10.17559/TV-20220421141917

[5] Grozdić, V.; Demko-Rihter, J.; Benković, S. (2023). Lean management in the banking industry: a case study, *International Journal of Industrial Engineering and Management*, Vol. 14, No. 4, 336-348, doi:10.24867/IJIEM-2023-4-343

[6] Habib, M. A.; Rizvan, R.; Ahmed, S. (2023). Implementing lean manufacturing for improvement of operational performance in a labeling and packaging plant: a case study in Bangladesh, *Results in Engineering*, Vol. 17, Paper 100818, 14 pages, doi:10.1016/j.rineng.2022.100818

[7] Chan, C. O.; Tay, H. L. (2018). Combining lean tools application in kaizen: a field study on the printing industry, *International Journal of Productivity and Performance Management*, Vol. 67, No. 1, 45-65, doi:10.1108/IJPPM-09-2016-0197

[8] Lipiak, J. (2017). Methodology for assessing the factors affecting the quality and efficiency of flexographic printing process, *Procedia Engineering*, Vol. 182, 403-411, doi:10.1016/j.proeng.2017.03.122

[9] Abusaq, Z.; Zahoor, S.; Habib, M. S.; Rehman, M.; Mahmood, J.; Kanan, M.; Mushtaq, R. T. (2023). Improving energy performance in flexographic printing process through lean and AI techniques: a case study, *Energies*, Vol. 16, No. 4, Paper 1972, 15 pages, doi:10.3390/en16041972

[10] Sanchez, L.; Blanco, B. (2014). Three decades of continuous improvement, *Total Quality Management & Business Excellence*, Vol. 25, No. 9-10, 986-1001, doi:10.1080/14783363.2013.856547

[11] Getachew, F.; Kitaw, D.; Mulugeta, A.; Berhan, E. (2017). Enhancing Ethiopian printing industries competitiveness through continuous improvement approaches, *Journal of Multidisciplinary Engineering Science and Technology*, Vol. 4, No. 4, 6995-7003

[12] Pekarcikova, M.; Trebuna, P.; Kliment, M.; Mizerak, M.; Kral, S. (2021). Simulation testing of the e-kanban to increase the efficiency of logistics processes, *International Journal of Simulation Modelling*, Vol. 20, No. 1, 134-145, doi:10.2507/IJSIMM20-1-551

[13] Possik, J.; Zouggar-Amrani, A.; Vallespir, B.; Zacharewicz, G. (2022). Lean techniques impact evaluation methodology based on a co-simulation framework for manufacturing systems, *International Journal of Computer Integrated Manufacturing*, Vol. 35, No. 1, 91-111, doi:10.1080/0951192X.2021.1972468

[14] Omogbai, O.; Salonitis, K. (2016). Manufacturing system lean improvement design using discrete event simulation, *Procedia CIRP*, Vol. 57, 195-200, doi:10.1016/j.procir.2016.11.034

[15] Benmoussa, O. (2022). Improving replenishment flows using simulation results: a case study, *Logistics*, Vol. 6, No. 2, Paper 34, 26 pages, doi:10.3390/logistics6020034

[16] Attia, E.-A.; Sobhi, N.; Alarjani, A.; Karam, A. (2023). Improving electric motor assembly using one piece flow, ergonomics, and cellular layout, *International Journal of Simulation Modelling*, Vol. 22, No. 2, 255-266, doi:10.2507/IJSIMM22-2-643

[17] Villarreal, B.; Garza-Reyes, J. A.; Kumar, V. (2016). A lean thinking and simulation-based approach for the improvement of routing operations, *Industrial Management & Data Systems*, Vol. 116, No. 5, 903-925, doi:10.1108/IMDS-09-2015-0385

[18] Gurumurthy, A.; Kodali, R. (2011). Design of lean manufacturing systems using value stream mapping with simulation: a case study, *Journal of Manufacturing Technology Management*, Vol. 22, No. 4, 444-473, doi:10.1108/17410381111126409

[19] Schmidtke, D.; Heiser, U.; Hinrichsen, O. (2014). A simulation-enhanced value stream mapping approach for optimisation of complex production environments, *International Journal of Production Research*, Vol. 52, No. 20, 6146-6160, doi:10.1080/00207543.2014.917770

[20] Jordan, E.; Berlec, T.; Rihar, L.; Kušar, J. (2020). Simulation of cost driven value stream mapping, *International Journal of Simulation Modelling*, Vol. 19, No. 3, 458-469, doi:10.2507/IJSIMM19-3-527

[21] Abideen, A. Z.; Mohamad, F. B.; Fernando, Y. (2021). Lean simulations in production and operations management – a systematic literature review and bibliometric analysis, *Journal of Modelling in Management*, Vol. 16, No. 2, 623-650, doi:10.1108/JM2-05-2019-0103

[22] Mahfouz, A.; Shea, J.; Arisha, A. (2011). Simulation based optimisation model for the lean assessment in SME: a case study, *Proceedings of the 2011 Winter Simulation Conference*, 2403-2413, doi:10.1109/WSC.2011.6147950

[23] Carrasco Sayas, J. L.; Alvarado Garay, J. C. (2022). *Production Model Based on Lean Manufacturing and BPM to Reduce the Rate of Returns in SMEs of Garment Printing*, Bachelor Thesis, Universidad de Lima, Lima

[24] Debnath, B.; Shakur, M. S.; Manul Bari, A. B. M.; Karmaker, C. L. (2023). A Bayesian best–worst approach for assessing the critical success factors in sustainable lean manufacturing, *Decision Analytics Journal*, Vol. 6, Paper 100157, 14 pages, doi:10.1016/j.dajour.2022.100157

[25] Ly Duc, M.; Hlavaty, L.; Bilik, P.; Martinek, R. (2023). Enhancing manufacturing excellence with Lean Six Sigma and zero defects based on Industry 4.0, *Advances in Production Engineering & Management*, Vol. 18, No. 1, 32-48, doi:10.14743/apem2023.1.455