Application of Tecnomatix Process Simulate for optimisation of logistics flows

Peter TrebuŔa[1], ***Miriam Pekarļíková***[1] *and* ***Marián Petrik***[1]

In today's digital world, there is a need to apply advanced simulation tools in business practice in order to create value-chain within the product lifecycle. Simulation programs are important, especially in the process of design, analysis and optimisation of production and logistics systems. They enable changes to existing production systems by way of experimenting, which is it is a great advantage. One of a number of simulation applications are modules from portfolio Siemens PLM Software. The present article deals with the optimisation of logistics flow through the application of the selected module Tecnomatix Process Simulate, with an effective use especially in the automotive industry. The importance of such an application is mainly in the execution and evaluation of specific changes in production systems in a virtual environment without any impact on actual production. In the present article, the case study identifies the practical use and possibilities of the simulation tool Tecnomatix Process Simulate for material flow optimisation, inter-operational transport and material handling in company oriented in leather processing for the automotive industry. The result is a simulation of proposed changes which increase the efficiency of logistic flows, the creation of a 3D model of the proposed solution, and quantification of achieved results of optimisation. Application of applied module represents one of the first steps of transformation the selected company to a digital company.

Key words: *analysis, optimisation, material flow, modelling, simulation.*

Introduction

In today's digital world, advanced simulation software is used to design, analyse, and optimise production and logistics systems. These make it possible to implement changes in existing production systems without intervention in ongoing production. However, the simulation itself cannot solve the problem. It allows performing experiments and choosing an optimal solution for the defined conditions. For this reason, continuous interaction with the real environment is important. However, it is a key intermediate step for building a digital company (Pekarcikova et al., 2015; Negagban et al., 2014; Edl et al., 2013; Straka, 2005; Straka et al. 2009). Modelling and simulation are tools for effective verifying of the feasibility of individual production and logistics processes and procedures prior to their implementation into a real environment. The basic task of simulation is verification of spatial constraints, assembly and robotic route planning, static and dynamic collision detection (Straka, 2010; Lenort et al., 2012; Malindġák et al., 2017, Rosová, 2010).

The case study below was realised in Tecnomatix/Tx Process Simulate software from Siemens PLM Software, which constantly evolving portfolio of PLM/Product lifecycle management to meet the needs of the mechanical engineering, automotive, aerospace, defence industry, etc. In the PLM market, Siemens Industry Software belongs to the most powerful companies. In the automotive industry, more than 80% of automakers worldwide use solutions from its product portfolio (Gupta et al., 2016; Hsieh et al., 2018; TrebuŔa et al., 2015; Saniuk et al. 2014).

Material and Methods

1. Possibilities of use the Tecnomatix Process Simulate

The Tx Process Simulate software module was applied to the case study. It is one module from the Tx products package (Plant Simulation, Process Designer, RobCAD, FactoryCAD, FactoryFlow, Jack and Jill). It enables verification of virtual proposals (process, manufacturing and logistics activities) even before they are actually implemented, what significantly reduces the risk of failure. It is also a platform for the deployment of Virtual Commissioning, that allows optimising automation systems and their components in a virtual environment, enables fast system startup, and make changes in production lines without any need to stop the whole unit completely.

Another use of the Tx Process Simulate is that it is fully integrated with the Teamcenter platform, which allows engineers and designers interactively use data throughout the life cycle of a particular product/project. By using Tx Process Simulate, the creation of models is perceived as creating of 3D objects (machinery, equipment,

[1] *Peter TrebuŔa, Miriam Pekarļíková, Marián Petrik,* Technical University in Kosice, Faculty of Mechanical Engineering, Institute of Management, Industrial and Digital Engineering, Park Komenskeho 9, 04 200 Kosice, Slovakia, peter.trebuna@tuke.sk , miriam.pekarcikova@tuke.sk , marian.petrik@tuke.sk

products) in CAD software and their implementation into software environment. Logistics flows are created by definition material and information interconnection between individual workplaces and workers (Siemens, 2018; Siemens, 2017). In this context, it was understood modelling and simulation in dealing with the present case study.

The whole simulation process was carried out in the following steps, which follow in time and logically:

1. problem definition, goals formulation, system analysis,
2. collection and processing of all relevant information,
3. creation models of objects using CAD support and selection objects from the Tx Process Simulate library, resp. by 3D scanning,
4. importation the models and creation of a simulation model in the Tx Process Simulate environment (creation logistics connections between individual elements of the system),
5. verification and testing the simulation model,
6. the realisation of simulation experiments,
7. evaluation and processing of experimental results,
8. acceptation and application of simulation results to the real system.

A generalised optimisation model of logistic flows through modelling and simulation is shown in Fig. 1. For this case study, due to the fact that the company does not yet have 3D laser scanning of production halls and equipment, the lamination workplace was created by 3D modeling using CAD software and then imported into the Tx Process Simulate software environment, as well as using software library objects (Dragic et al., 2016; Xiao et al., 2017; Centobelli et al., 2016).

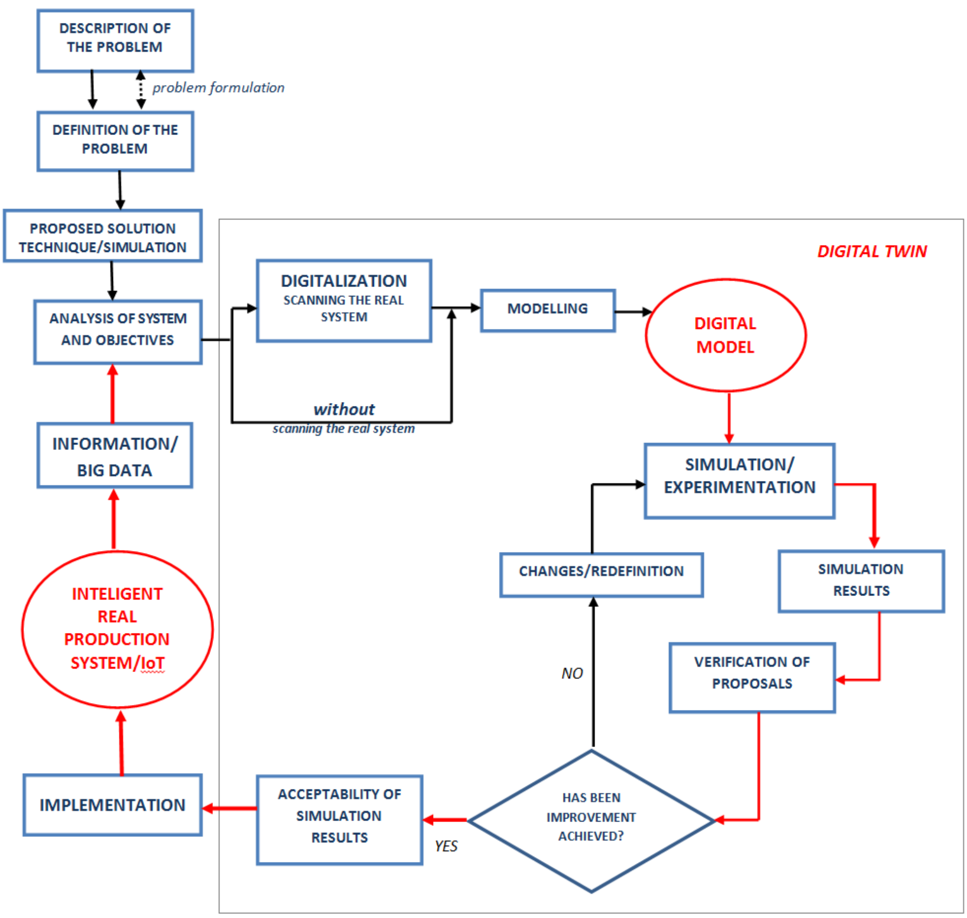
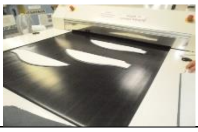


Fig. 1. Flow-chart of the methodology.

Analysis and optimisation of logistics processes took place in the leather processing company for the automotive industry at the lamination site of leather cutouts. The optimisation was focused on logistics processes - inter-operational transport, material handling and material flow. Individual suggestions for changes in logistics processes were verified on the 3D model of lamination workplace in the Tx Process Simulate software module. The process of making leather cutouts is processed in Table 1.

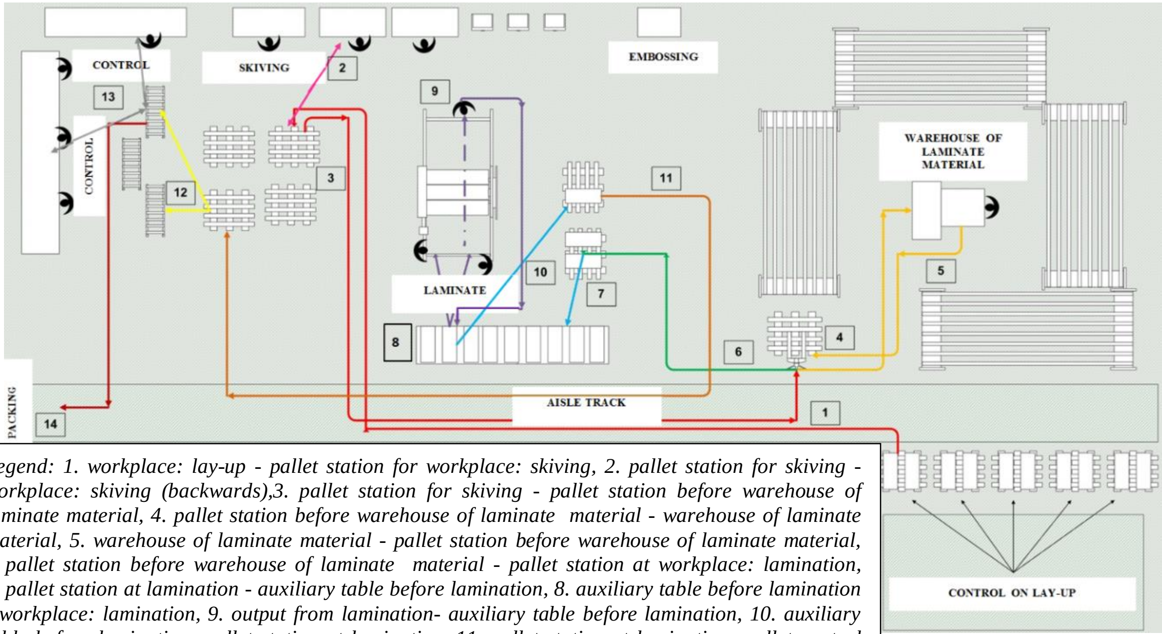
Tab. 1. Technological process of leather processing [Howe, 2016].

Technological process		
1.	Control the skin before cutting 	The basis of the daily production plan are required types and quantities of the leather which are moved from the warehouse to the control workplace for control the skin thickness, drawing, and colour. Damaged pieces are marked with chalk - traces of mosquito stab, lacerations on the skin and others.
2.	Cutting  	On the leather laid on the work table are stowed cut knives with maximum utilisation of the area of the skin, depending on the flaws marked with chalk. The prepared work table is moved to the press for the cutting process (the cutting tolerance is + - 0.5 mm). For the production of leather cutting for the interior of one car is used about 120 - 150 knives are needed. The individual knives are colour-coded depending on the required quality of the cut, 3 types of colours (green - highest quality, yellow - medium quality, blue - lower quality for perforation). Subsequently, the cutting are moved to the control process, where they are sorted into boxes according to the needs of the next process, resp. modifications.
3.	Grinding 	Reducing excessive skin thickness if it exceeds the customer-specified thickness tolerance.
4.	Perforation of cutting 	If the cutting has to be perforated, it proceeds to the workplace: perforation.
5.	Control cutting on lay-up 	Classification of cuttings into cardboard boxes and their control by lay-up - a paper model with the exact specification of the shape and dimensions of leather cuttings at a scale of 1:1. It is control of shape, dimensions, and notches.
6.	Skiving 	The need for skiving, i.e. reducing its thickness is illustrated by a green crosshatch on lay-up. It is realised in order to allow suturing multiple cuttings together when sewing the seat coats resp. head rests
7.	Laminate 	Then follows lamination, i.e., connection, resp. gluing the laminating material to a leather cutting.
8.	Embossing 	Stamping of the logo or other symbols and symbols as required by the customer is done on the embossing press.
9.	Output quality control of leather cutting 	Output control of shape, dimensional accuracy, precision and lamination design and control of other cuttings errors. The output of the manufacturing process is a leather part meeting the above mentioned required quality features.
10.	Product Audit	Random control of cutting, i.e. control of shape, lamination, grinding and natural characteristics of leather parts.
11.	Packaging	Store and package cuttings into boxes and calculation number of individual leather parts. Labels with prescribed data are put on the box and moved to the exit warehouse where they are waiting for export.
12.	Expedition	After the packing process, individual packages are dispatched from the exit warehouse via an external shipping company. Outputs are leather cuttings designed for sewing car covers.

2. Analysis of material flow, transport and material handling at the workplace of lamination

In the case of the analysed workplace of lamination, the input material are leather cutouts embedded in a box and mounted on a pallet. One palette with leather cutouts placed in boxes is considered to be 1 order. A standard representative was chosen for analysis of logistics processes; it means 1 order consisting of 600 pieces of leather cutouts stored in 30 boxes (stored in 20 cutouts):1 order = 1 palette = 30 boxes = 600 pieces of leather cutouts.

As shown in Fig. 2 the material flow is unnecessarily complex, and the material has to overcome unnecessarily long distances, such as in the case of moving the material between the workplace of inspection of cutouts at the lay-up and the skiving workplace, whereby there is a change to reverse the material flow. Based on the above, the table (Table II) lists all non-productive activities performed at the workplace of lamination. These values function as a representative example (1 job = 30 boxes = 600 pieces of leather cutouts).



Legend: 1. workplace: lay-up - pallet station for workplace: skiving, 2. pallet station for skiving - workplace: skiving (backwards),3. pallet station for skiving - pallet station before warehouse of laminate material, 4. pallet station before warehouse of laminate material - warehouse of laminate material, 5. warehouse of laminate material - pallet station before warehouse of laminate material, 6. pallet station before warehouse of laminate material - pallet station at workplace: lamination, 7. pallet station at lamination - auxiliary table before lamination, 8. auxiliary table before lamination - workplace: lamination, 9. output from lamination- auxiliary table before lamination, 10. auxiliary table before lamination- pallet station at lamination, 11. pallet station at lamination- pallet control station for workplace: control of cuttings, 12. cuttings control pallet station - carriage rack, 13. carriage rack - control room (backwards), 14. carriage rack - workplace: packing.

Fig. 2. Material flow on the workplace of lamination.

Tab. 2. Non-productive activities.

Activity	Measured	
	distance [meters]	**total time** [seconds]
move palettes: workplace: control of cutting on lay-up - workplace: skiving	1 x 14.5	45.23
move palettes: workplace: skiving - pallet location for a stock of laminate material	1 x 11.1	39.27
transferring of boxes: pallets location for stock of laminate material - stock of laminate material	30 x 4.3	240.0
transferring of boxes: the stock of laminate material - pallets location for stock of laminate material	30 x 4.3	240.0
transferring of pallets: pallets location for stock of laminate material - pallets location for lamination	1 x 5.2	15.21
transferring of boxes: pallets location for lamination ï table front of lamination	30 x 3.3	164.26
transferring of cutting: output from the lamination - table front of lamination	120 x 6.2	1,130.88
transferring of boxes: table front of lamination - pallets location for lamination	30 x 3.3	164.26
transferring of pallets: pallets location for lamination - pallets location for control	14.7	48.22
relocation of boxes: pallets location for control - carriage rack on workplace: control	60 x 0.82	320
summary	**1,294.7**	

All of these time values represent a non-productive time - transport, material transfer and walking. At the same time, the workers that have to process 1 contract (600 pieces of cutouts), cross with the material 1,294.7 meters. Some of the non-productive activities are performed during the manufacturing operation; it is not possible to consider them in the total processing time of one contract. It is possible to consider only activities that prolong the total processing time of one contract (Tab. 3).

Tab. 3. Non-productive activities prolonging the processing of one contract.

Activity	**Measured total time** [seconds]
move palettes: workplace: control of cutting on lay-up - workplace: skiving	45.23
move palettes: workplace: skiving - pallet location for a stock of laminate material	39.27
transferring of boxes: pallets location for stock of laminate material - stock of laminate material	240.00
transferring of boxes: the stock of laminate material - pallets location for stock of laminate material	240.00
transferring of pallets: pallets location for stock of laminate material - pallets location for lamination	15.21
transferring of the first box from pallet: pallets location for lamination ï table front of lamination	5.48
transferring of the last box from pallet: pallets location for lamination ï table front of lamination	5.48
transferring of pallets: pallets location for lamination - pallets location for control	48.22
relocation of boxes: pallets location for control - carriage rack on the workplace: control	320
summary	**958.89**

Due to the duration mentioned above of non-productive activities, processing of the contract is prolonged by 958.89 seconds (15.98 minutes - non-productive activities, i.e. translating, transporting, handling and transport of material). For calculation of the total processing time of 1 order, the average measured values of the individual production operations for processing 20 pieces of cutouts (1 box) are shown in the table (Tab. 4).

Tab. 4. Duration of production activities for processing of 20 pieces of cutting.

Activity	**Time duration**
skiving of cutting (20 pieces)	4.5 minutes / 1 worker
replenishment of one box with laminating material (20 pieces)	2 minutes / 1 worker
lamination of cutting	427 pieces / 60 minutes / 4 workers
control of cutting from one box (20 pieces)	6.0 minutes / 1 worker

When calculating the duration of individual operations for a representative case (30 boxes = 600 cutouts) and taking into account the number of workers operating, the values are given in Table 5. The scheme for calculating the total processing time of 1 contract is shown in Figure 3.

Tab. 5. Duration of production activities in the processing of cutting from one contract.

Activity	**Time duration**
skiving of cutting	67.5 minutes / 2 workers
replenishment of laminating material	60 minutes / 1 worker
lamination of cutting	84.6 minutes / 4 workers
control of cutting	90 minutes / 2 workers
summary	**302.1** minutes

The main problems resulted from the analysis of logistics processes in the company (material flow, transport and material handling at the workplace of lamination):

1. large transport distances between workplaces,
2. complex material flow (reversion),
3. unnecessary walking and handling of material,
4. the performance of non-value-producing activities,
5. the absence of the possibility to enter the pallet truck into the LM warehouse,
6. poorly placed entrance to the warehouse, resulting in dangerous collisions.

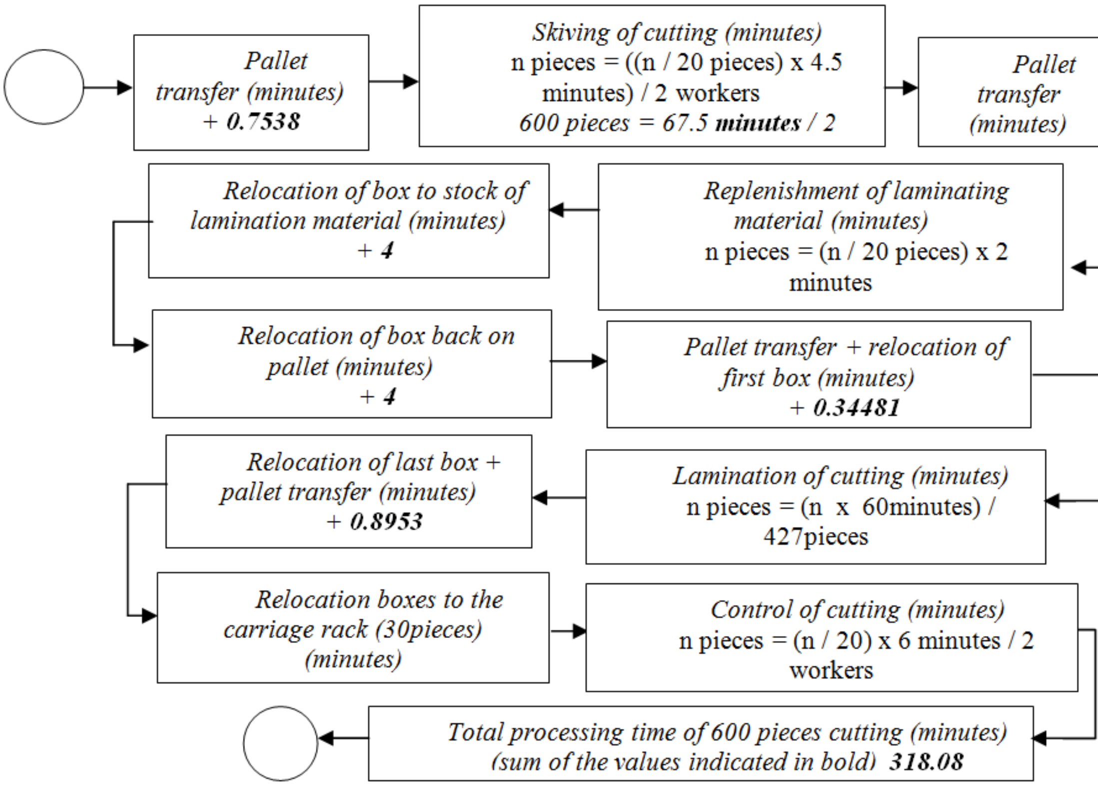


Fig. 3. The processing time of one contract - the current layout of workplaces.

3. The digitisation of the lamination process

The purpose is to analyse the current state of the logistics processes at the workplace of lamination, i.e., to create a digital 3D model at a 1:1 scale and simulate individual operations in Process Simulate software. On this model, it is possible to experiment and look for optimal solutions to the above-defined problems.

After inserting all objects, workers, and simulating all the activities performed, a 3D model of the present state of the lamination work is created at a scale of 1:1, shown in Figure 4.

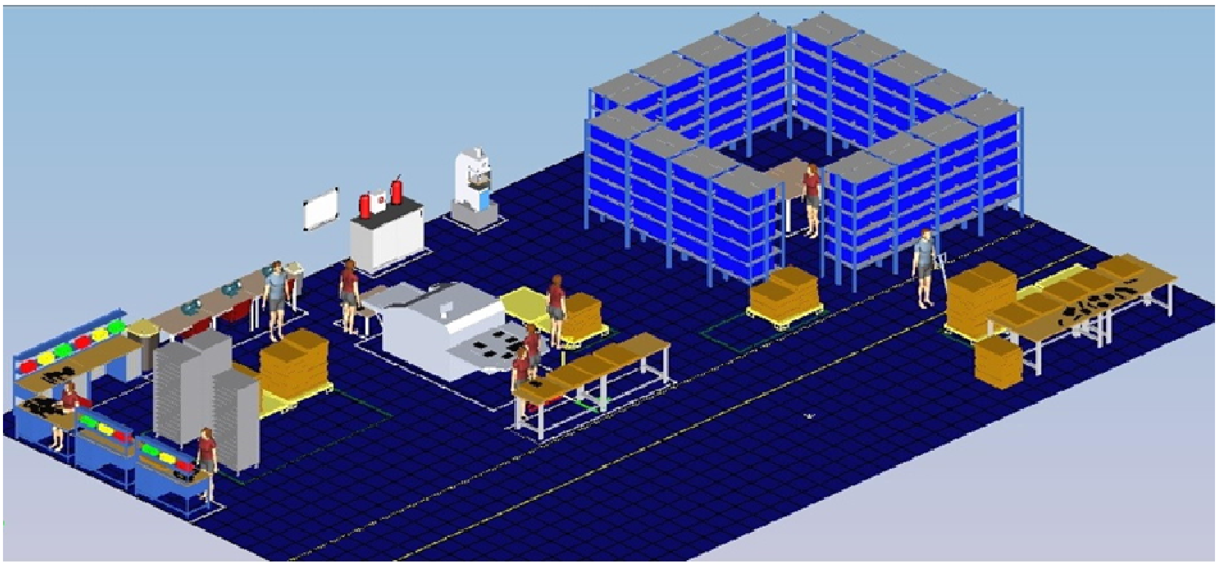


Fig. 4. 3D model of workplace lamination - current state.

Results

1. Design of new lamination workplace in Tx Process Simulate

The failings found by analysis led to the optimisation of the material flow through a new layout of the lamination workplace (Figure 5). A new 3D model of the lamination workplace was created to verify the proposed changes (Figure 6).

In the created 3D model, the proposed changes of the layout were taken into account, as well as the simulated individual activities that resulted from the new layout of the workplace.

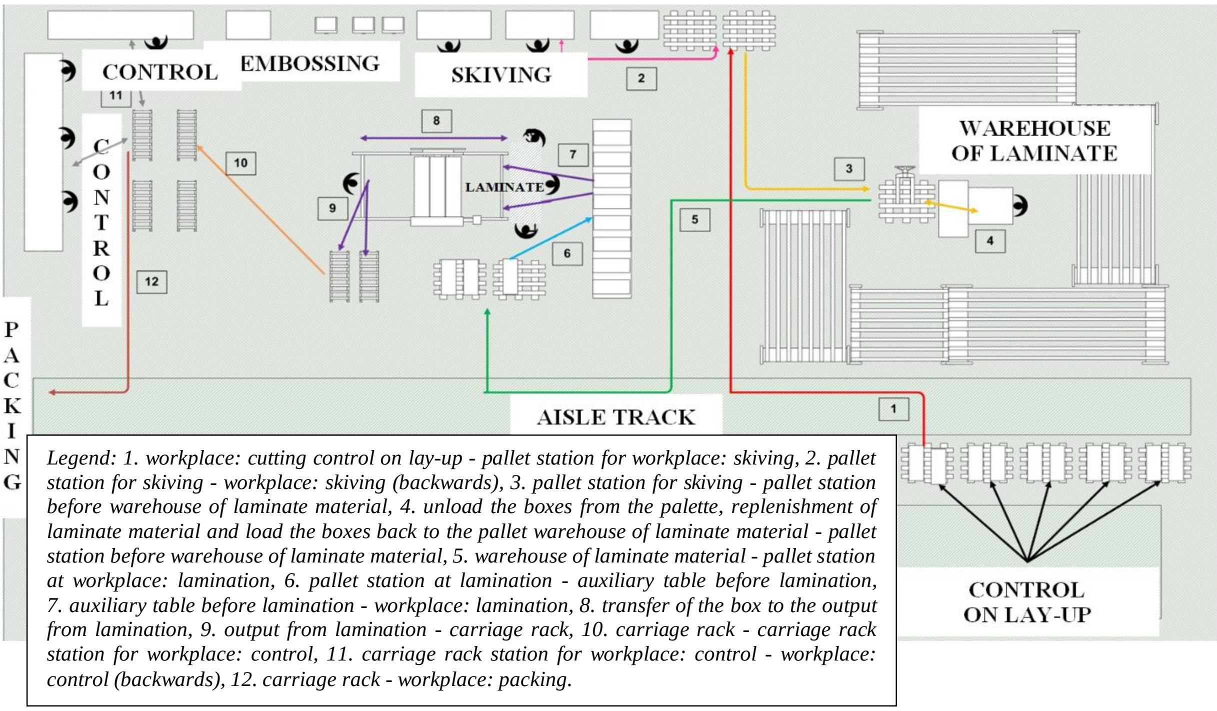


Fig. 5. Material flow for the new layout of workplace lamination.

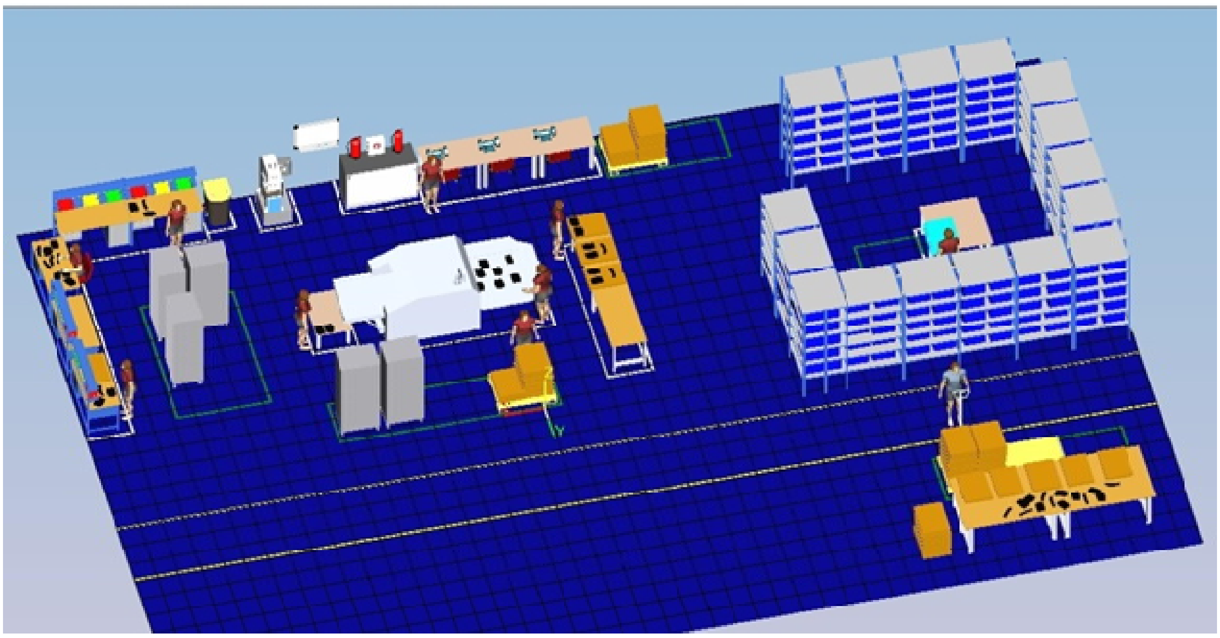


Fig. 6. 3D model of the new layout of the lamination workplace.

2. Achieved effects from simulation in Tx Process Simulate

By changing the layout of the workplace, by simplifying the material flow and by improving the activities of the organisation, the material flow has been optimised in terms of time and distance. Table 6 shows a comparison of the length and the number of repetition of distance passed by workers during their activity. By altering the layout of the lamination workplace, the trajectory was shortened from the original 1,277.37 meters to 578.52 meters. The shortening of the duration of non-productive activities resulting from the new layout was calculated on the basis of shortened transport distances. The duration of individual activities regarding shortening the length of transport distances and the complete elimination of some non-productive activities is included in Table 6.

Tab. 6. Comparison of distance travelled when performing individual activities.

Activity	**Total time** [seconds]	
	current state	proposal
move palettes: workplace: control of cutting on lay-up - workplace: skiving	45.23	34.75
move palettes: workplace: skiving - pallet location for a stock of laminate material	39.27	18.3
transferring of boxes (30ks): pallets location for stock of laminate material - stock of laminate material	240.0	0
transferring of boxes (30ks): the stock of laminate material - pallets location for stock of laminate material	240.0	0
transferring of pallets: pallets location for stock of laminate material - pallets location for lamination	15.21	34.98
transferring the first box from a pallet: pallets location for lamination ï table front of lamination	5.48	4.55
transferring the last box on a pallet: table front of lamination - pallets location for lamination	5.48	3.80
transferring of pallets (carriage rack): pallets location for lamination - pallets location for control	48.22	6.17
relocation of boxes (30ks): pallets location for control - carriage rack on the workplace: control	320	0
summary	**958.89**	**102.58**

To calculate the time savings that can be achieved; it is only necessary to consider activities that prolong the processing of one order. The duration of the activities that prolong the processing of 1 order (600 pieces of cutouts) is shown in the table (Tab. 7).

Tab. 7. Activities prolonging processing of one order.

Activity	**3D model**		
	current state	**proposal**	
	distance [meters]	**distance** [meters]	**time** [seconds]
move palettes: workplace: control of cutting on lay-up - workplace: skiving	1 x 14.02	1 x 11.14	34.75
move palettes: workplace: skiving - pallet location for a stock of laminate material	1 x 10.59	1 x 5.18	18.3
transferring of boxes: pallets location for stock of laminate material - stock of laminate material	30 x 4.42	x	0
transferring of boxes: the stock of laminate material - pallets location for stock of laminate material	30 x 4.42	x	0
transferring of pallets: pallets location for stock of laminate material - pallets location for lamination	1 x 5.18	1 x 11.96	34.98
transferring of boxes: pallets location for lamination ï table front of lamination	30 x 53.04	30 x 2.74	136.39
transferring of cutting: output from the lamination - table front of lamination	120 x 6.15	60 x 5.37	489.74
transferring of boxes: table front of lamination - pallets location for lamination	30 x 3.04	x	0
relocation of boxes: output from the lamination - carriage rack	x	60 x 2.29	227.97
transferring of pallets (carriage rack): pallets location for lamination - pallets location for control	1 x 14.58	4 x 2.11	24.68
relocation of boxes: pallets location for control - carriage rack on workplace: control	60 x 0.79	x	0
summary	**1,277.37**	**578.52**	**966.81**

A comparison of the total duration of non-productive activities at the present state and the proposed state is shown in the figure (Fig. 7).

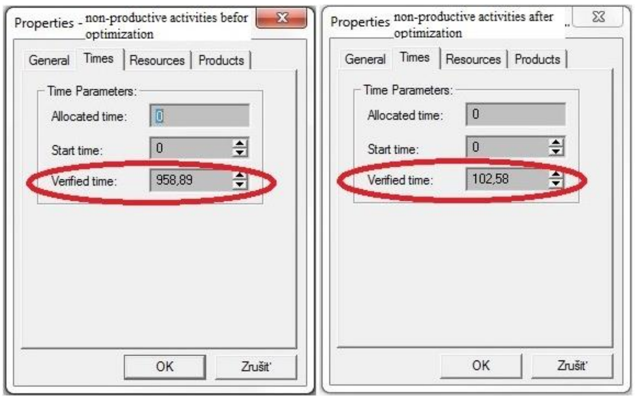


Fig. 7. A comparison of the total duration of non-productive activities.

The best time saving was achieved by removing the non-productive activities of translating boxes from the pallet into the LM warehouse and back, and also by removing the transfer of boxes from the pallet to the transport rack at the workplace of control. Another time saving was achieved by shortening the traffic distance between the workplaces. The time saving for 1 job is 14.27 minutes.

Another time saving is achieved parallel execution of activities, which requires allocation of 1 order into 2 production batches. It means that immediately after loading the rack filled with boxes with laminated blankets, this rack is moved to the station for the transport shelves at the workplace of control. Such a method is not expected to shift the entire order (1 palette) to the control site until all the blank frames have been laminated from one production batch. For comparison: The original total processing time of 1 order (600 pieces of cutouts) is 318.08 minutes. By changing the layout of lamination workplace rationalising the handling operations and dividing the production batch in the lamination process, it is possible to shorten the processing time of 1 order (600 pieces) to 261.34 minutes (Fig. 8).

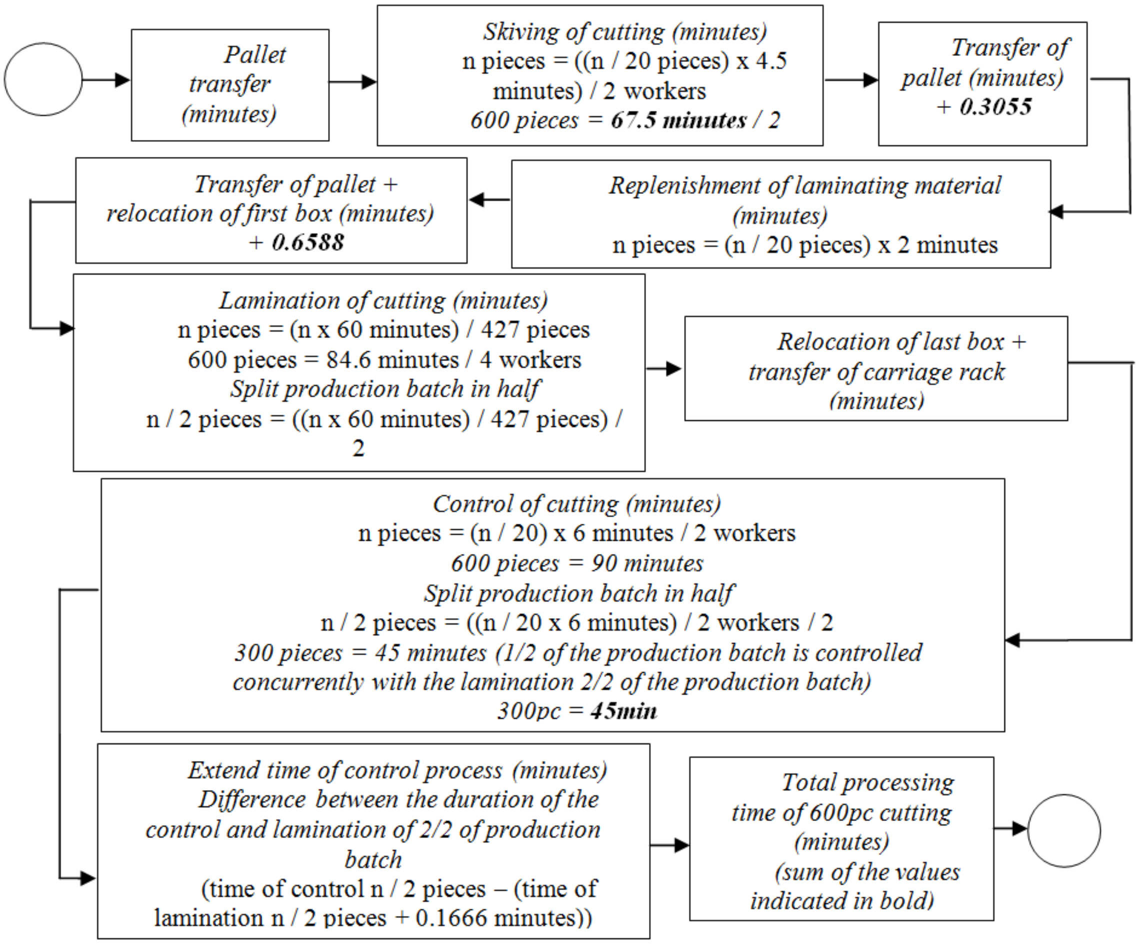


Fig. 8. The processing time of one contract - a new layout of workplaces.

In the original layout, 1 order (600 pieces) is processed in 318.08 minutes. With a duration of 7.5 hours = 450 minutes, 848 pieces are processed, it means 1.413 order. After applying the proposed changes, 1 order (600 pieces) is processed in 261.34 minutes. With a change duration of 7.5 hours = 450 minutes, 1033 pieces would be processed, it means 1722 contracts, what is an increase in productivity by about 20 %. The proposed changes in the layout of the lamination work, the rationalisation of the inter-operational transport, the manipulation activities and the division of the contract for two production batches, it is possible to increase the number of processed leather cutouts by 1 shift about 185 pieces. When considering two working shifts (7.5 hours) during one week (105 working hours) at the size of the order considered (30 boxes = 600 pieces of cutouts), then 11872 pieces would be processed (848 pieces/working shift x 14 working shifts). The same amount of cutouts 11872 pieces would be processed on the basis of the proposal for 86.20 hours. ((11.872 pieces x 7.5 hours) / 1.033 pieces). This means that 11872 pieces would be processed during the calendar week on Saturday, 3:80 p.m. before the end of the second working shift. In total, during 1 week period, there would be processed more about 2590 pieces of cutouts, totally 14462 pieces.

Discussion

Tx Process Simulate software module from Siemens was used for removal detected limitations. By proposing the changes for the layout of the lamination workplace and also by rationalisation of handling activities with the material, the following improvements were achieved:

- simplification of material flow,
- shortening transport distances between workplaces,
- eliminating unnecessary walking of workers,
- removing unproductive activities,
- reduce the total processing time of 1 job in the lamination workplace.

In the quantitative expression of the individual improvements, it was possible to shorten the distance passed by workers in the processing of one contract within the lamination workplace by 698.85 meters. By eliminating unproductive activities and a better organisation of work, the processing time of one contract was shortened from the original 318.08 minutes to 261.34 minutes. Based on the achieved time savings, it could be processed about 185 pieces of leather cutouts more during one working shift (7,5 hours).

Proposals resulting from the Tx Process Simulate application, presented in this case study, have been successfully applied in the selected company. Major importance for the company was the possibility of implementation and evaluation of proposals without interfering the ongoing production.

As the desired results were achieved at the lamination workplace, the possibility of using the module in connection with the digitisation of the entire logistics chain was created.

Hypothetically, reducing the processing time of the cutouts is also possible to achieve with any order size, which will help to increase competitiveness in the context of a flexible response to customer demands. In addition to the aforementioned improvements in the amount of processed cutouts and reducing the processing time, was achieved shortening the distance traveled by workers by handling, moving and transport of material at the intended size of the contract (600 pieces) from the initial 1277.37 m to 578.52 m, it is shortening the route by 698.85 m. Such a significant reduction in the distance travelled by workers will contribute to a decrease in their physical burden, thereby improving the working conditions of workers and it has a positive impact on productivity and work efficiency.

Conclusion

There are many reasons for the implementation of PLM systems into companies. The most important include increasing competitiveness, increasing efficiency, globalisation, innovation, the complexity of products, cost reduction, flexibility, etc. Implementation of PLM systems into companies requires the creation of new algorithms, that is needed to process on the base of experimental verification of the effectiveness by using individual PLM modules on practical examples and then generalize them for wider use in industrial practice (Micieta et al, 2016; Magvasi et al., 2013; Stanek et al., 2016).

Today's world of digitisation requires advanced modelling and simulation tools to design, analyse and optimise production and logistics systems. Modern systems no longer work on the principle of incremental improvements, but they are part of comprehensive quality management of the production system as a whole. It is necessary to ask how to react to this phenomenon and how to become a part of modern technological changes? How to prepare? New generation companies will become intelligent production systems based on the core pillars of Industry 4.0.

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