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MODELING AND SIMULATION OF THE FURNITURE MANUFACTURING AND ASSEMBLY PROCESS IN THE ARENA SIMULATION SOFTWARE

MODELOWANIE I SYMULACJA PROCESU WYTWARZANIA I MONTAŻU MEBLI W PROGRAMIE SYMULACYJNYM ARENA

Abstract

The article describes issues related to creating discrete simulation models for the implementation of the furniture manufacturing and assembly process in a furniture company. The methodology of the manufacturing system analysis was presented, which is aimed to support the appropriate approach to the construction of simulation models. The scope of the work includes the technological identification of the furniture manufacturing and assembly process in real production conditions, on the basis of which the appropriate simulation model was built. The course of the process was analyzed in the Arena software on the basis of a computer simulation based on reports. As a result of the simulation of the manufacturing process with the use of information from report of usage, an area for improvement was located. The re-analysis of the material flow made it possible to propose a change in the input parameters for the simulation model in the indicated area. The results of the second simulation show significant changes in the effective use of workstations and increase in the efficiency of the production line. In practice, it can be the basis for introducing simulated changes in the production system.

Keywords: manufacturing system, modeling, simulation, production, assembly, process improvement

Streszczenie

W artykule opisano zagadnienia związane z tworzeniem dyskretnych modeli symulacyjnych dla realizacji procesu wytwarzania i montażu mebli w przedsiębiorstwie branży meblarskiej. Przedstawiono metodykę analizy systemu wytwarzania, która ma za zadanie wspierać właściwe podejście dla budowy modeli symulacyjnych. Zakresem praca obejmuje identyfikację technologiczną procesu wytwarzania i montażu mebli w rzeczywistych warunkach produkcyjnych, w oparciu o którą zbudowano właściwy model symulacyjny na przykładzie procesu wytwarzania w rzeczywistych warunkach produkcyjnych. Analizę przebiegu procesu na podstawie symulacji komputerowej w oparciu o raporty przeprowadzono w oprogramowaniu Arena. W wyniku przeprowadzonej symulacji procesu wytwarzania z wykorzystaniem informacji z raportu obciążeń stanowiskowych zlokalizowano obszar do doskonalenia. Powtórna analiza przepływu materiałowego pozwoliła zaproponować zmianę parametrów wejściowych dla modelu symulacyjnego we wskazanym obszarze. Wyniki drugiej symulacji wskazują istotne zmiany w zakresie efektywnego wykorzystania stanowisk pracy oraz zwiększenia wydajności linii produkcyjnej. W praktyce może to stanowić podstawę do wprowadzenia symulowanych zmian w omawianym systemie produkcyjnym.

Słowa kluczowe: system produkcyjny, modelowanie, symulacja, produkcja, montaż, usprawnianie procesu

1. Introduction

When searching for products, customers tend to focus on finding both cheap and high-quality items. However, the criteria that determine the value of low price and high-quality are changing over time and becoming increasingly stringent [15]. Therefore, in order to remain competitive, manufacturers need to ensure flexibility, the ability to dynamically respond to changes and operate effectively [14]. From the current point of view, technological progress can be divided into forth main eras in history, which are characterized by revolutionary solutions in a given period of time – from Industry 1.0 to Industry 4.0 [15]. However, more and more publications also describe the fifth revolution – Industry 5.0 [8, 20]. As part of the current

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fourth industrial revolution, an overall increase in efficiency is expected, thanks to the effective analysis of data generated in intelligent environments and the integration of digital production systems. Digital transformation supported the development of modern information technologies, such as: cyber-physical systems, Internet of Things, Internet of Services, Big Data, smart factory [4, 7]. The concept of Industry 5.0 is to complement the fourth revolution and puts more emphasis on sustainable development and people [8]. Industry 5.0 uses, among others, the synergy effect by combining innovation and human creativity with the efficiency and reliability of machines [20].

Implementation and integration of modern digital technologies constitute the way to transform traditional production systems into future production systems, which are often characterized by high complexity [15].

Complex production systems are characterized by a large number of different variants of settings or layouts, which makes it difficult to choose the right solution using classical analytical methods. Computer modeling and simulation can be a tool that effectively supports the understanding of the process and proper decision-making at various levels of management of the manufacturing and assembly processes [17, 18]. Simulation methods allow for a relatively quick, efficient and easy way of searching for acceptable solutions, without having many limitations and not only solving specific problems [19]. Due to the development of modeling and simulation, the trend of digital twins is also gaining momentum. Traditional simulation and modeling methods have limited capabilities to assess the performance of a given production system, while the technology of digital twins through the integration of Internet of Things systems is a breakthrough in this regard. The Internet of Things is based on real data from the system obtained in real time [16].

The aim of the article is the analysis and improvement of the furniture production and assembly process carried out in the Make-to-Order z system using computer simulation methods.

2. Modeling and simulation in industrial practice

The variety of phenomena that occur in industry and the unpredictability of some incidents contribute to the growing interest in the topic of modeling and simulation. According to Gościński, modeling is "the act of selecting an acceptable substitute called a model for the original, i.e. it is an approximate reproduction of the most important properties of the original" [5]. Simulation consists in creating a model that reflects a given phenomenon and observing its behavior by manipulating independent factors. Running a computer simulation is intended to present possible phenomena occurring in the modeled process, but it can be carried out in order to obtain various effects. In the case of computer simulation, three main categories should be distinguished - simulations for forecasting, identification and rationalization purposes. In case of prognostic simulation, quantitative and/or qualitative characteristics of the tested system's functioning under given conditions are determined; in case of identification purposes, quantitative and/or qualitative rules for the functioning of a given system are prepared, while for rationalization purposes, quantitative and/or qualitative characteristics of a system are determined that meet certain rationality criteria [9].

Due to the significant increase in the computing power of devices in recent years, many different computer applications have been developed to create simulations. A large group of simulation programs are the programs that enable for creating simulations of discrete processes [19].

When it comes to production processes simulation, the most popular tools include: Flexsim, Dosimis, Enterprise Dynamis, Visual Simulation, Arena, eM-Plant, Lean MAST, Plant Simulation, ShowFlow 2, SIMUL8 [3, 13]. The choice of the proper software is important for the simulation effect – depending on the needs and the purpose of the simulation. A significant aspect is also to be guided by functionality in terms of how the model is built. Another important criterion when choosing the software is the selection of tools for reporting and analyzing simulation results [21]. This criterion is related to the fact that broad knowledge is required of a user modeling the simulation, despite a usually intuitive interface, transparent functional blocks and graphical facilities in the form of 3D animations used in simulation programs [19].

The literature on the subject [1, 6, 11, 12] indicates that computer simulation is increasingly often used in practice in the field of improving production systems and processes. A properly built simulation model enables many experimental and analytical activities to be carried out for a real production system, e.g. in terms of material flow or production system efficiency. These analyzes may concern, among others: examining the impact of the introduced changes and the possible effects they may have on the system. As a result of these tests, a set of data is obtained on the basis of which the company's management can make further decisions regarding to the management of the production system.

3. Technological identification of furniture assembly

During the elaboration of the production system under study, it is necessary to collect basic information and input data. In the initial phase a model is developed at the appropriate level of detail while simplifying the entire projection at the same time [2]. Further part of the article presents the process of building a model for a manufacturing and assembling system of finished products, which is custom-made furniture, e.g. lockers. For this purpose, the Arena simulation program will be used. The tests were carried out in real production conditions as part of the author's research.

3.1. Identification of the manufacturing and assembly process

The technological identification of the production process of lockers made of chipboard was carried out in production conditions of a selected furniture manufacturer. As a result of this identification, the characteristics of the phenomena occurring in the selected production process were obtained. In the technological identification of the finished product, technological cards, available machine documentation, as well as historical data of production processes were used. Process time standards for individual activities were adopted on the basis of registers of operations from machines and devices.

3.2. A model of furniture assembly production system

The production process described further in the article concerns the production of a standard locker in accordance with customer order, which consists of warehouse and transport processes, robotic material handling, semi-automatic cutting with a panel saw, edge banding, milling, drilling, assembly and packaging. The process flow is presented in the block diagram (Fig. 1).

Table 1 characterizes individual processes involved in the production of a furniture cabinet. The elaboration of this type of production process characteristics is the basis for starting work on constructing a simulation model.

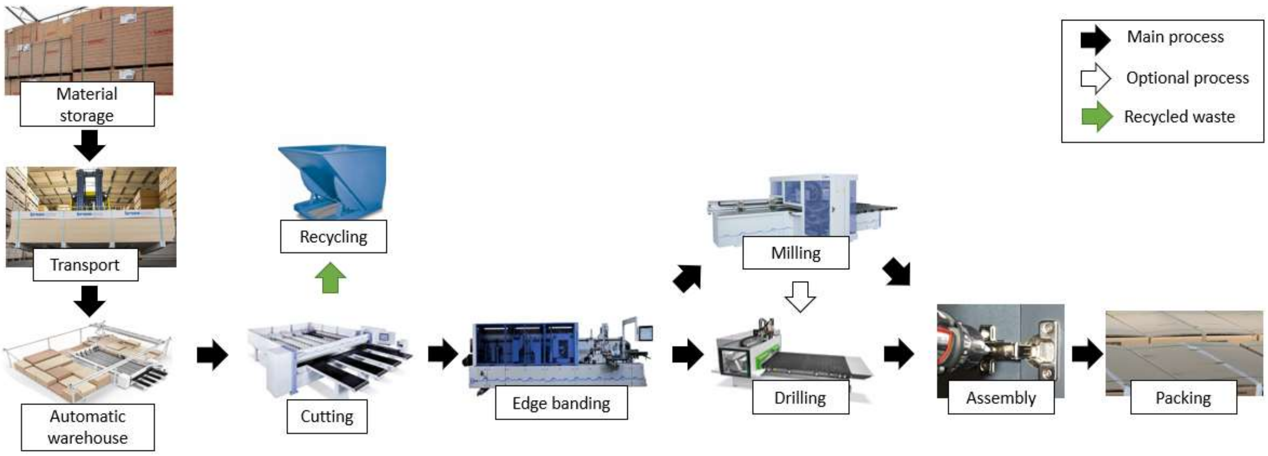

Figure 1. Process flow of furniture manufacturing and assembly

Table 1. Furniture manipulation, production and assembly processes

No.	Process name	Resource	Description
1	Storing material	Block warehouse	A separate area of the production hall is intended for block storage of chipboard sheets
2	Transport	Forklift	Transport of chipboard sets for loading the TLF buffer
3	Material handling	TLF – automatic warehouse	Frameportal center for handling and lifting chipboards
4	Cutting	Panel saw	Numerically controlled panel saw with automatic loading from an automatic warehouse
5	Storage	Storage area	Picking the cut chipboard sheet elements on pallets according to the order
6	Recycling	Container	Picking the unused cut chipboard sheet elements into special containers
7	Edge banding	Edge bander	One-sided banding of straight edges, with automatic feeding and turning of elements
8	Milling	CNC machining center	Milling holes and shapes in chipboards
9	Drilling	CNC machining center	Drilling technological holes in chipboards
10	Assembly	Assembly line	Assembly of finished furniture elements
11	Packing	Packing line	Packing of finished furniture (lockers)

3.3. Assumptions for the simulation model

The assumptions for a simulation model concern a furniture industry enterprise. The simulation model was created in Arena program and elaborated using the available functional blocks, including a fully automated warehouse for storing and leading out chipboards, as well as a simulation model of chipboards cutting process (according to the production order, the **so-called cutting**), edge banding, milling shapes and holes for hinges, drilling holes for mounting pins, complete assembly, as well as packing and securing the finished product. The assumptions of the model include the process of comprehensive storage before cutting the chipboards to a given size. The *Mag_plyty* block (Fig. 2) is responsible for generating items (units) together with the *Pole_mag_plyty* module that defines the preparation time for the processes of further manipulation. This model is part of the transport processes within the input warehouse. Blocks (*Pole_mag_plyty*, *Transport_Mat_1*, *Woz_wid_1*, *Pole_TLF*, *TLF_Start*) are responsible for transport activities supplying the automatic warehouse with chipboards. The simulation model is shown in Figure 2. All numerical data needed to define the simulation model was obtained from the appropriate enterprise management systems [13].

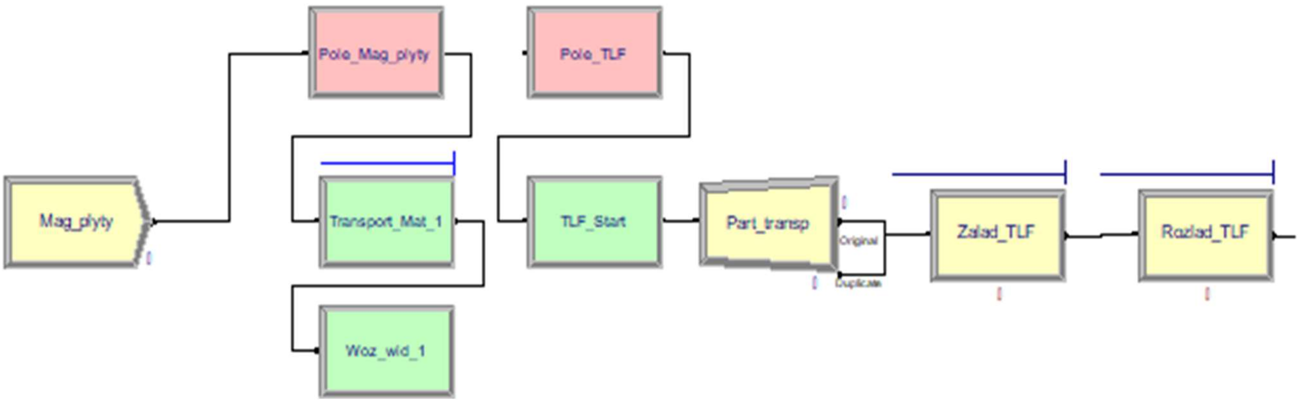

Figure 2. A general simulation model of the warehouse space of the analyzed manufacturing system

In the simulation model, the *Mag_plyty* block is responsible for supplying the manufacturing process with material – chipboard (*plyta_wior*). The duration of running the simulation was set at 8 hours (1 shift) (Fig. 3). Figures 4 and 5 show in detail the parameters of the selected functional blocks in the Arena environment at the analyzed stage.

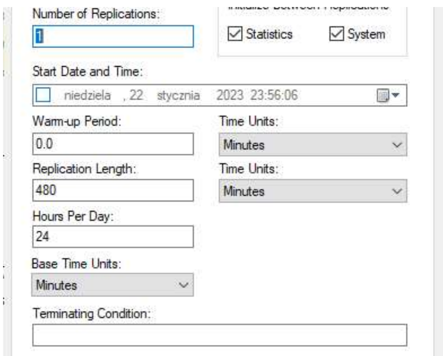

Figure 3. Main parameters of the simulation run

In order to better illustrate the operation of cutting chipboards in accordance with the production order, there will be input buffers within the machining station, including a block storage warehouse for chipboards (*Mag_plyty*), an automatic warehouse storage field (*Pole_TLF*), and a frameportal center (*Zalad_TLF* i *Rozlad_TLF*) (Fig. 2).

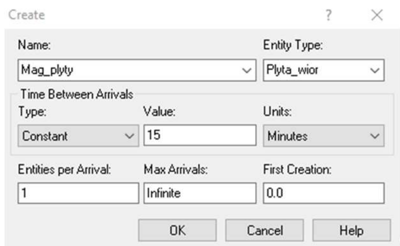

Figure 4. Parameters of the block supplying the model with the input material – chipboard

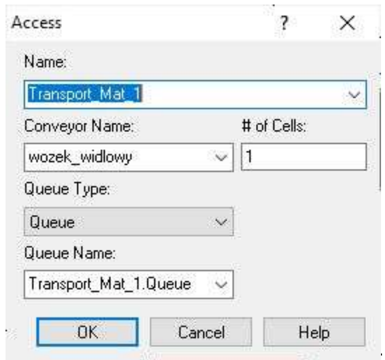

Figure 5. Parameters of the block transporting the input material to the automatic warehouse (TLF)

The use of buffers allows for a better use of manipulation and machining stations consisting of 2 automatic panel saws (defined in model as *Ciecie_300* and *Ciecie_400*), 2 edge banding machines (*Okleinowanie*_1 and *Okleinowanie_2*), CNC machining centers for milling and drilling (in the model *Frezowanie* and *Wiercenie* blokcs), and final preparation lines of the finished product by its assembling and packing (*Montaż* and *Pakowanie* blocks).

In the proposed simulation model, all resources of the manufacturing system form the resource set **Z**. For the considered system of the chipboard cutting process in accordance with the production order, there are the following elements of the set **Z**={*Mag_plyty*, *Woz_wid_1*, *Zalad_TLF*, *Rozlad_TLF*, *Ciecie_300*, *Ciecie_400*, *Mag_Braki*, *Okleinowanie_1*, *Okleinowanie_2, Frezowanie, Wiercenie, Montaż, Pakowanie*, *Mag_WG*}.

The workpieces in the presented system form a set of items **P={P1}.** For each such element from set **P**, an item flow table **T** was created (Table 1). The dimensions of this table (14x14) result from the number of elements of the **Z** set.

The values in the table at the intersection of the relevant resources inform about the maximum number of items in the target resource.

In the described example, in the first row *Mag_płyty* of table **T**, the value "15" was entered at the intersection with the column *woz_wid_1*. It means that the transport batch of item **P1** from the *Mag_płyty* warehouse with a forklift truck *woz_wid_1* consists of 15 pieces of chipboards. Similar relations [19] were established for the remaining resources of the production system (Table 2). Depending on the available and prepared space, the maximum buffer capacity was determined expressed in the number of boards, including boards after cutting.

Table 2. Chipboards and their elements flow table (capacity) for item **P1**

P1 From \ To	*Mag_plyty, [pcs.]*	*Woz_wid_1, [pcs.]*	*Zalad_TLF, [pcs.]*	*Rozlad_TLF, [pcs.]*	*Ciecie_300, [pcs.]*	*Ciecie_400, [pcs.]*	*Mag_Braki, [pcs.]*	*Okleinowanie_1, [pcs.]*	*Okleinowanie_2, [pcs.]*	*Frezowanie, [pcs.]*	*Wiercenie, [pcs.]*	*Montaż, [pcs.]*	*Pakowanie, [pcs.]*	*Mag_WG, [pcs.]*
Mag_plyty, [pcs.]		15	-	-	-	-	-	-	-	-	-	-	-	-
Woz_wid_1, [pcs.]	-		15	-	-	-	-	-	-	-	-	-	-	-
Zalad_TLF, [pcs.]	-	-		**1500**	-	-	-	-	-	-	-	-	-	-
Rozlad_TLF, [pcs.]	-	-	-		4	5	-	-	-	-	-	-	-	-
Ciecie_300, [pcs.]	-	-	-	-		-	4	36	-	-	-	-	-	-
Ciecie_400, [pcs.]	-	-	-	-	-		5	-	45	-	-	-	-	-
Mag_Braki, [pcs.]	-	-	-	-	-	-		-	-	-	-	-	-	-
Okleinowanie_1, [pcs.]	-	-	-	-	-	-	-		-	8	28	-	-	-
Okleinowanie_2, [pcs.]	-	-	-	-	-	-	-	-		12	33	-	-	-
Frezowanie, [pcs.]	-	-	-	-	-	-	-	-	-		4	16	-	-
Wiercenie, [pcs.]	-	-	-	-	-	-	-	-	-	-		65	-	-
Montaż, [pcs.]	-	-	-	-	-	-	-	-	-	-	-		1	-
Pakowanie, [pcs.]	-	-	-	-	-	-	-	-	-	-	-	-		1
Mag_WG, [pcs.]	-	-	-	-	-	-	-	-	-	-	-	-	-	

Creating this type of table **T** (Tab. 2) of the flow of objects in set **P** for the defined and appropriately grouped elements of the **Z** set is necessary before building a model of the production system. Due to the complexity, specificity and variety of objects constituting the manufacturing systems, the number of functional blocks used in the model may vary.

Based on the material flow table (Tab. 2), Figure 6 shows a full model of the manufacturing process of locker type furniture (**P1**) produced to an individual customer order, on the basis of which the simulation was run according to the settings.

Time parameters [8] for selected production processes of the simulation model discussed in the article are presented in Table 3. The experiment assumed using triangular and normal distributions as the most useful ones for describing the occurring phenomena. The calculations were carried out in the Statistica 9.0 environment [13].

Table 3. Contents of the block of basic time parameters of simulation processes

Process - Basic Process													
	Name	Type	Action	Priority	Resources	Delay Type	Units	Allocation	Minimum	Value	Maximum	Std Dev	Report Statistics
1	Zalad_TLF	Standard	Seize Delay Release	Medium(2)	1 rows	Triangular	Minutes	Value Added	0.5	0.8	1.5	.2	☑
2	Rozlad_TLF	Standard	Seize Delay Release	Medium(2)	1 rows	Triangular	Minutes	Value Added	0.5	0.8	1.5	.2	☑
3	Ciecie_300	Standard	Seize Delay Release	Medium(2)	1 rows	Triangular	Minutes	Value Added	2	5	8	.2	☑
4	Ciecie_400	Standard	Seize Delay Release	Medium(2)	1 rows	Triangular	Minutes	Value Added	2	5	8	.2	☑
5	Okleinowanie_1	Standard	Seize Delay Release	Medium(2)	1 rows	Triangular	Minutes	Value Added	2.5	3	3.5	.2	☑
6	Okleinowanie_2	Standard	Seize Delay Release	Medium(2)	1 rows	Triangular	Minutes	Value Added	2.5	3	3.5	.2	☑
7	Frezowanie	Standard	Seize Delay Release	Medium(2)	1 rows	Normal	Minutes	Value Added	.5	2	5	.2	☑
8	Wiercenie	Standard	Seize Delay Release	Medium(2)	1 rows	Normal	Minutes	Value Added	.5	2	5	.2	☑
9	Montaz	Standard	Seize Delay Release	Medium(2)	1 rows	Normal	Minutes	Value Added	6	8	10	1	☑
10	Pakowanie	Standard	Seize Delay Release	Medium(2)	1 rows	Normal	Minutes	Value Added	.5	4	1.5	1	☑

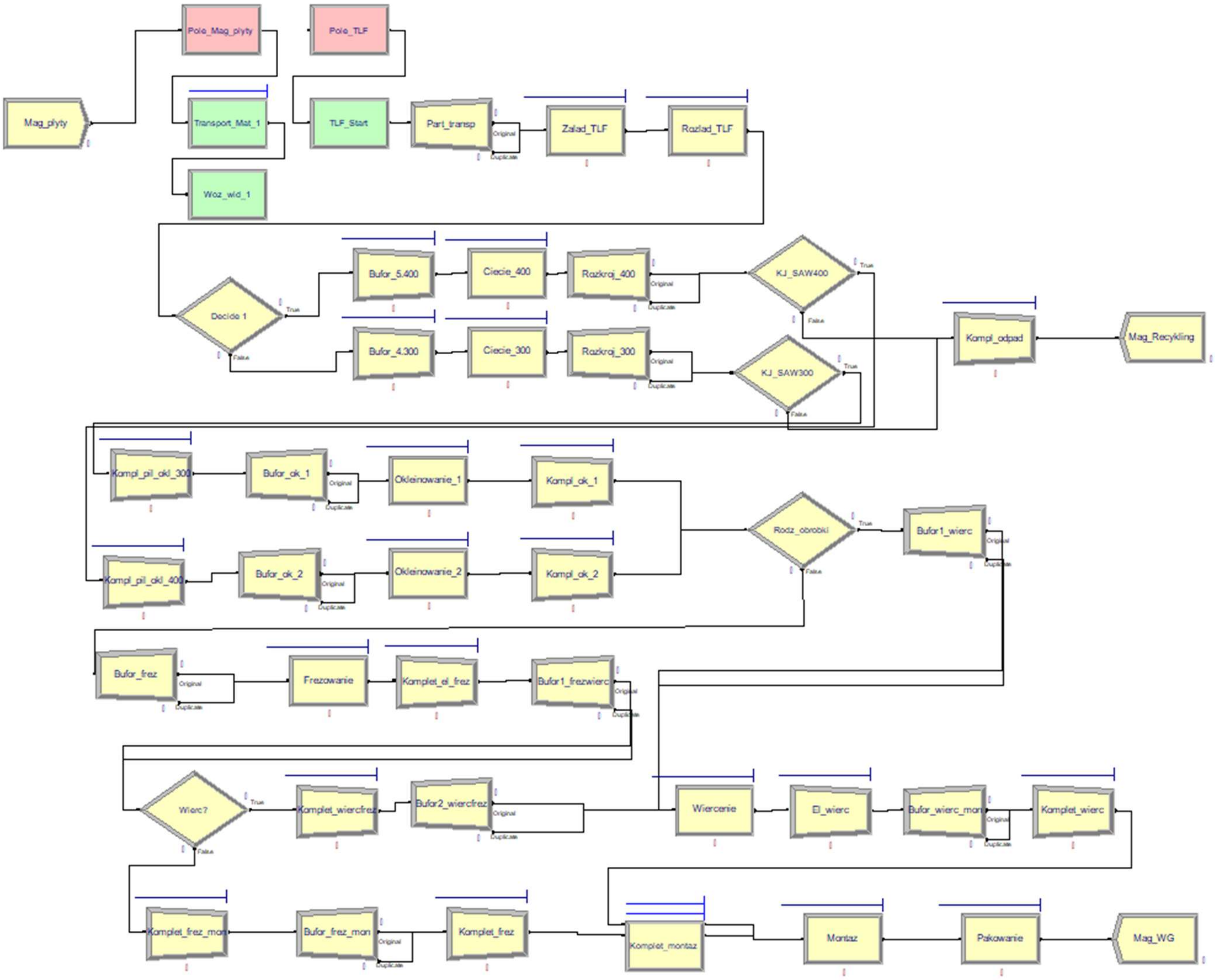

Figure 6. A Simulation model of the locker manufacturing and assembly system in an analyzed company in the Arena software

The classical methods of describing the duration of technological operations involved mainly using statistical methods. Due to the very extensive mathematical apparatus, probabilistic models are rarely used. However, in the subject literature dedicated to industrial practice and the description of phenomena occurring in production, probabilistic models based on the following types of distributions can be found [10]: exponential, Weibull, normal, Gumbel, Ferecht, Reyleight, Gamma, log-normal, triangular, uniform.

The presented distributions are largely applicable to production processes simulation. However, this requires extensive knowledge of the production process itself, as well as the methodology of developing simulation models. Most of these distributions require applying advanced numerical techniques and experimentation on large samples, which significantly increases the cost of using these methods in industrial practice. Therefore, during the technological identification of a given process, it should be assumed at the outset that the applied probabilistic model is able to provide information on the characteristics of occurring changes during the production process [10].

Normal distribution is used to reflect time processes with a certain symmetry. Triangular distribution is most often used to describe phenomena that are only positive values, such as process execution time. It is characterized by a simple estimation of the input parameters of the model and is limited to three time estimates: two extreme ones (the shortest and the longest) and the most probable one [10]. Uniform distribution is adopted wherever the randomness of events in a certain interval of time values is assumed. It can be used to describe processes that are not stabilized in terms of production [22]. As a result of conducting research in real production conditions, probabilistic models were generated in the Statistica 9.0 software, which made it possible to adjust the distribution describing the assumed phenomenon. The maximum likelihood method was used, for this purpose the Anderson-Darling test [23] was used. As a result of the analysis, it was assumed that in most cases the fluctuation of individual operations' duration can be described by a triangular or close to normal distribution, less often by a uniform distribution. If a given process is described using a probabilistic model based on a triangular distribution, the technological process itself tends to have technological breaks, during which chipboards are loaded (internal buffer) and unloaded (powering the saw) at the same time, and the process itself is not interrupted by an emergency stop.

After executing simulations based on the above model, Arena generated a number of reports.

4. Evaluation of the results obtained in the simulation

On the basis of the built model of the production system and the input parameters included in it, it is possible to analyze the flow by referring it to the actual results achieved by the company.

4.1. Analysis of the simulation report

The production volume based on the simulation (480 min, 1 work shift) is 9 finished pieces of furniture (lockers). Due to the specificity of cutting boards from ready-made pieces of chipboard, the waste generated in the process is approximately the equivalent of 4 chipboards, which will then be recycled. One of the possibilities of analyzing the production process flow based on the functionality of the software is the assessment of the use of workstations and the accumulation of materials at the workstations. For single-shift production, the simulation will have some limitations related to a wider production picture. In order to more fully illustrate the simulation models, it was decided to complete the reports with the second and third shifts. From the simulation model for 3 shifts, data was obtained in which the furniture production volume is 113 pieces, with 17 waste chipboards. The results of reports from 3 work shifts are presented in Figure 7.

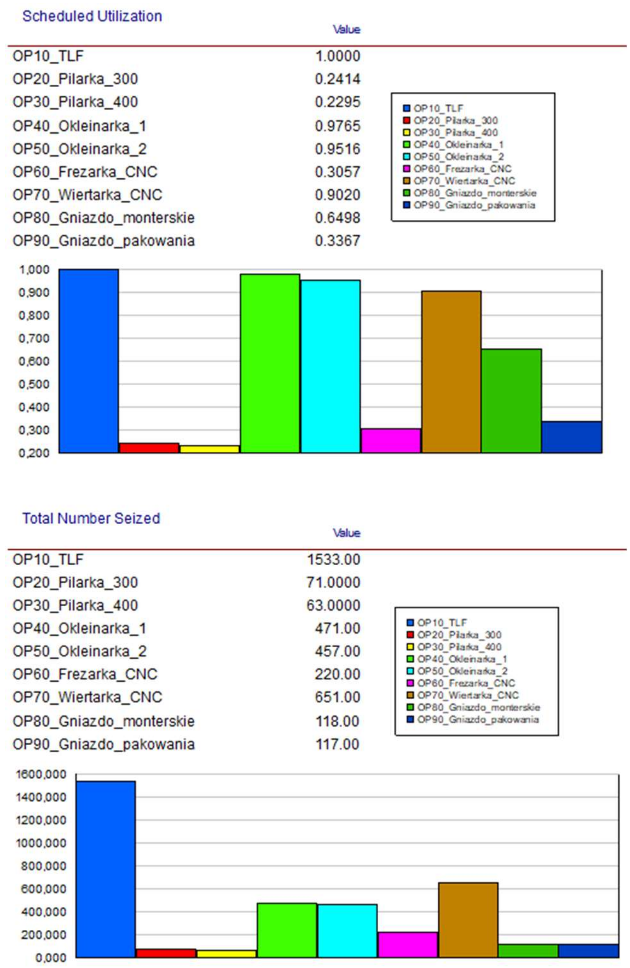

Figure 7. Usage on workstations for the 3-shift model – percentage (top) and accumulation of material on selected workstations (bottom)

Analyzing the data from Figure 7, it can be concluded that the workstations are not evenly loaded. The TLF station (automatic warehouse) and edge banding machines are loaded almost at 100%, and e.g. both saws at respectively 24% and 23% of the available working time. In some real conditions, such a situation actually takes place in this enterprise. This situation results from the specificity of realizing orders, the nature of the handling robot's operation and the high efficiency with which the saws can work. As shown in Table 1, the saws in one cycle can simultaneously cut 4 and 5 chipboards respectively (this is evidenced by the flow analysis), which was also included in the simulation. The picking of chipboards before the cutting process results in undesirable waiting times at the cutting stations.

4.2. Corrected simulation model based on previous assumptions

In the analyzed case of the production of the P1 item, there are a number of possibilities for introducing changes to the production (simulation) process in order to stabilize workstation loads (reducing the impact of bottlenecks), thereby increasing production efficiency. Having a simulation model in a comprehensive and quick way (based on experts knowledge, process improvements, statistical calculations or the trial and error method) it can be checked whether and how the change of selected parameters will affect final results.

As part of the discussed simulation model, the possibility of changing the amount of the picked material (chipboard) before the cutting stations was proposed. The modification concerns the reduction of the number of boards (respectively from 4 to 3 pieces for the *Ciecie_300* station and from 5 to 4 pieces for the *Ciecie_400* station) to one batch subject to the cutting process at both analyzed cutting stations. The area of changes made to the model is marked in Figure 8.

After implementing the changes, another simulation of the analyzed process was carried out for the time of 1440 minutes (3 work shifts).

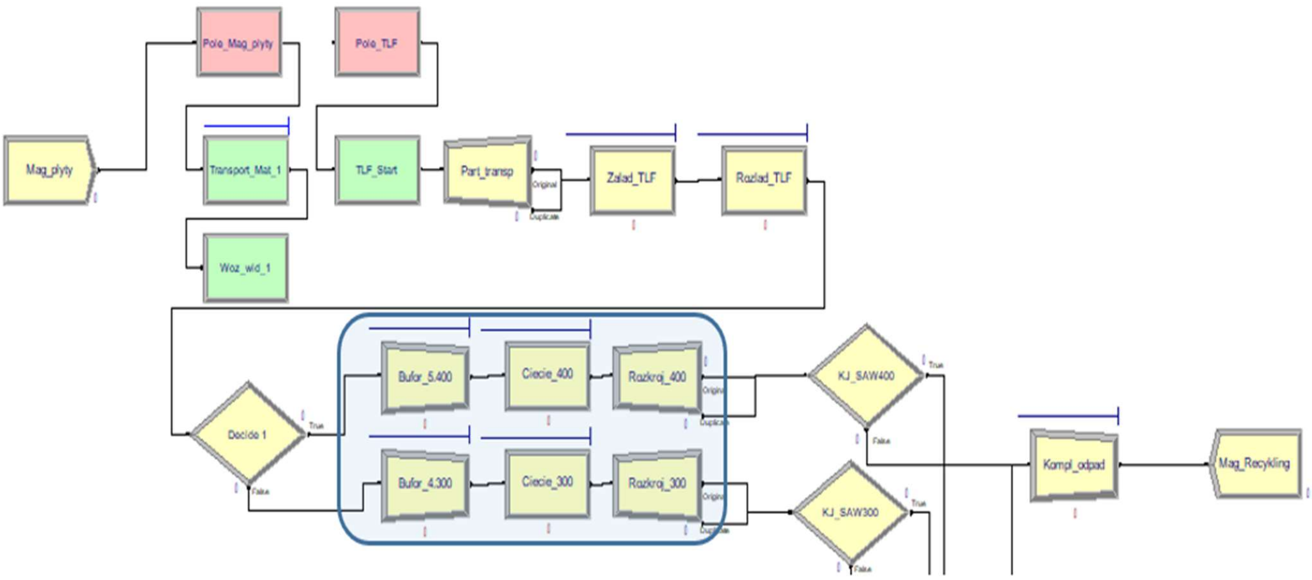

Figure 8. The area of proposed changes in the simulation model (fragment)

4.3. Analysis of the corrected model report

Based on the corrected model, the analysis of selected Arena software reports was repeated (Fig. 8). The production volume based on the simulation (1440 min) is 133 finished furniture pieces and the amount of waste is approximately equivalent to 15 chipboards for recycling.

Similarly, the occupancy of and material accumulation at certain stations were analyzed. The simulation reports show that the reduction in the number of assembled chipboards before the cutting process increases the use of both saws, which was the desired effect of the corrected model. In addition, the simulation model shows that the proposed change has a positive effect on increasing productivity by 16 additional finished products, mainly due to the reduction of waiting time for material. The illustrative results have been collected and presented in Table 4.

Table 4. Comparison of selected results of 2 simulations carried out

Simulation	Resource	Picking buffer [pcs.]	Finished product [pcs.]	Recycled waste [pcs.]	Resource usage [%]	Seized material [pcs.]
1 (first)	*Ciecie_300*	4	117	13	24	71
	Ciecie_400	5			23	63
2 (corrected)	*Ciecie_300*	3	133	15	33	98
	Ciecie_400	4			26	76

It is worth noting that as part of the production operation before the modification of the simulation model, the assembly usage was at the level of 65%. The changes introduced to the simulation model resulted in an increase in production volume due to more efficient delivery of components to the assembly station. This increase amounted to 9 pp. Figure 10 presents a summary of the results of furniture production, respectively for the simulation of 1, 2 and 3 shifts.

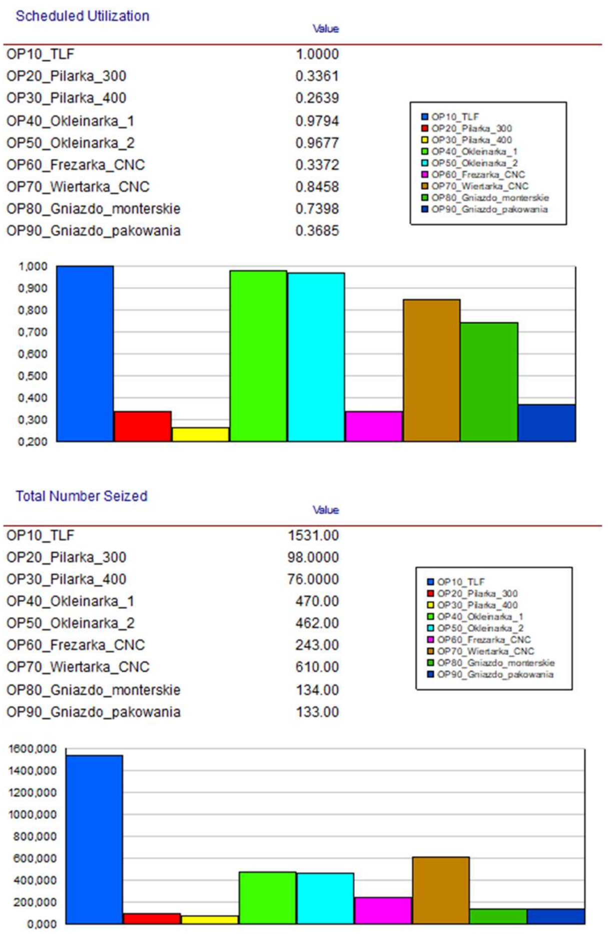

Figure 9. Usage on workstations for corrected model – percentage (top) and accumulation of material on selected workstations (bottom)

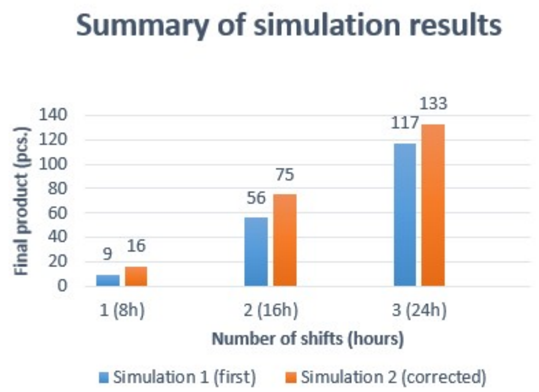

Figure 10. Comparison of furniture manufacturing and assembly simulation results

It should also be noted that the proposed change does not significantly affect the size of the accumulation, although it is a bottleneck in the scope of the TLF stand in both simulations. Consideration of this phenomenon is the subject of further research by the author conducted as part of his doctoral dissertation and the analyzed production system.

5. Summary

Analyzing the manufacturing system with the use of computer simulation methods provides a lot of valuable information on its functioning and enables us to achieve measurable material benefits. However, this requires the user to properly identify the processes taking place in the given production environment and to have proper knowledge of the correct approach to building simulation models and conducting experiments on them.

On the example of a furniture company, basic parameters shaping the process of chipboard cutting, edge banding, drilling and milling holes, as well as final assembly and packaging of the finished furniture were defined, which enabled for the construction of a proper simulation model. As a result of simulating the manufacturing process with the use of information from the bench load report, an area for improvement was located. The re-analysis of the material flow made it possible to propose a change in the input parameters for the simulation model in the indicated area. Based on the prepared simulation model, the process of furniture production and assembly were re-simulated, additionally taking into account the proposal to change the size of the buffers.

The results of the second simulation show significant changes in the effective use of workstations and increase in the efficiency of the production line. This gives the possibility to conclude that based on this type of simulation models, many different variants of the material flow can be created and compared in order to improve the manufacturing process.

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