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COMPUTER SIMULATION OF LOGISTICS PROCESSES MANAGEMENT – POSSIBILITIES AND SOLUTIONS

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Abstract: The article presents the concept of modern simulation systems applicable in the analysis of the logistics chain configuration. The main goal of the article is to present advanced possibilities of using various methods of simulation of a logistic system, or to determine the appropriateness of introducing changes in the configuration of a logistics chain or the assessment of already prepared solutions for given logistics processes. The article contains a description of information technologies that can be used in simulation, including specialized simulation programs, spreadsheets, languages and simulation interfaces etc. The article presents the basic issues related to the creation of a logistics project simulation, as well as the possibilities of the FlexSim 3D Simulation software, which easily allows to map complex logistic processes. The simulation, including the data generated during its implementation on individual logistic processes, allows the selection of the most advantageous and optimization of the solutions used so far in a given process. The article presents an example of simulation of logistics issues in the production process and examples are presented to explain the cognitive appeal of this method based on the use of computer technology and FlexSim 3D Simulation software.

Keywords: logistics management, simulation, logistics processes, FlexSim

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Introduction

Contemporary trends in the industry strive to improve efficiency and shorten the production time of products, which also applies to production activities, i.e. logistics processes associated with it. As part of pursuing this goal, most enterprises implement in their structures computer aided work systems and simulation software for planning and verifying the correctness of the execution of individual processes. The fundamental change in business practice resulted from shortening the time of resource flow, reducing transport costs as well as the use of intelligent means of internal transport and electronic communications. Enterprises entered the era of a global economy in which logistic activities play a very important role (Nowakowska-Grunt 2011). Production is identified with the integration of all resources and services flows, while the concept of logistics often refers to functioning in many areas of the production process (Nowosielski 2008). As part of logistics called industrial logistics,

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we can highlight the logistics responsible for establishing cooperative ties, the location of the departments' headquarters, as well as all activities of the process of the production process in the company (Matuszek 2016, p. 298). Therefore, due to the wide range of logistics processes operating in industry, their effectiveness is more and more often verified and streamlined using simulation methods. The approach to the issue of simulation was closely related to specific technological possibilities in a given period of time, as analyzing the definition of simulation over the years, one can notice a large evolution of this field, largely conditioned by the increase in technological progress. In 1969, Gordon G. described the simulation as follows: "We can define the simulation of systems as a technique for solving problems by observing the behavior of the dynamic model of the system during specific time" (Gordon 1974). Another important definition will be Naylor's T.H. from 1975, stating the following: "we define simulation as a numerical technique for experimenting on certain types of mathematical models using a digital machine to describe the behavior of a complex system over a long period of time" (Naylor 1975). An equally important definition of the simulation will be the definition of T. Wach from 1983, who indicated that "Simulation is a study of a complex objective system (real / hypothetical) by observing changes occurring over time and in the dynamic model of this system under the influence of changing internal and external conditions relative to the system" (Metera, Pańkow, Wach 1983). The latest definition quoted by Beaverstock M. et al. from 2011 indicates that "Simulate means to imitate or copy the actual system by means of experiments carried out on a model representing (depicting) this system" (Karkula 2013). Simulation therefore means imitating some real process or system. This is related to the construction of the model, which will represent the analyzed issue that allows testing ideas or performing an experiment. On the other hand, the model should honestly reflect the relationships that occur in the analyzed system, both the logical aspects guiding the activities and the physical environment. Simulation in logistics is a complex process consisting of several stages. The first step is to define the process and purpose of the analysis. The next step is the process of collecting and analyzing the available data. The third stage of logistic simulation is the design and construction of the model of a given logistics process. Next, the model should be verified and so should its compatibility be validated with the actual system or its assumptions. The final stage is to analyze the results of the experiments carried out and to optimize the process by selecting the most suitable conditions for its implementation. It is also worth emphasizing that omitting any stage of the process may result in erroneous conclusions from the simulation (Zieliński 2009). It can therefore be concluded that the current popularity of logistics processes in production has significantly increased the demand for new simulation tools that would enable efficient modeling of processes, their optimization, analysis and automatic creation of applications and solutions to implement these processes (Kott, Grondys, Chłąd 2018).

Simulations in logistics processes

Simulation in logistics is applicable in a situation where it is difficult to investigate a given logistic problem through an analytical approach, e.g. high storage warehouses are characterized by high dynamics of logistic processes, which is why using simulation tools is a very common necessity. These tools mainly facilitate solving broadly understood logistic problems, as a result of which there is a high level of competitiveness in this field. The advantage of simulating logistic processes is financial savings, because you do not have to create physical models and there is the possibility of experimenting and constantly changing and improving the model in real conditions (Aschauer, Gronalt, Mandl 2015, p. 505-539). During the simulation, you can create many scenarios of the process and check their impact on individual elements of the system and process in the company's environment. The experiments carried out help to make the best decision in the process selection. In logistic processes verification of simulation models is also of great importance. Logistic models belong to the group of dynamic models and require a detailed analysis of their behavior (Balcerak 2003, p. 29). Logistics processes rely to a large extent on planning activities aimed at cost-effective flow of raw materials, finished products or stocks and related information. The main task of logistics is to provide the right product, in the right quantity, to the right customer and at the right time, while keeping the lowest costs mentioned above. process (Beaverstock et al. 2012). We distinguish three basic areas of logistics activities related to the stages of the production process. The first area is distribution logistics, which includes the flow of products from the manufacturer to the final purchaser. The second area is supply logistics dealing in the delivery of goods in accordance with the requirements of time, quantity and quality (Szczepanik, Strzelczyk 2018). The third area is production logistics covering all activities related to the supply of materials, raw materials and semi-finished products to the place of production as well as their effective flow. Each of these logistic processes can be the subject of research using simulation methods. Simulation methods referring to supply logistics can be included in the company's standard activities, e.g. during the analysis of the consequences of irregularities regarding the quantity and quality of deliveries (Burg Burg van den, Ham van der, Kleijnen 1979). It is also influenced by the high development of innovations in the company, which results in the increase of applications of modern simulation methods while making decisions. Simulation of logistics processes enables verification of the designed solution without a real implementation. Simulations of logistic processes often concern effective management of transport, distribution and people, i.e. the following issues: determining the impact of changes in parameters and process properties; determining the flexibility and capacity of the system; indication of process bottlenecks, indication of the number of process elements and type of infrastructure; determination of the number of employees needed; delays in delivery; equipment failures, determination of losses and downtime reduction with maximum synchronization and coordination of all logistics related processes in connection with production processes. In connection with the above, the issues of simulation and the effects of irregularities in the area of supply are of particular importance, as the creation of inventories and the reduction of production parameters is not recommended (Rostkowska 2014, p. 53-60). Before starting the simulation one should consider the choice of the appropriate simulation and research tool, because to a large extent the choice of the tool determines the course of the simulation project (Gierulski, Luściński, Serafin 2012, p. 844). The most popular logistic simulation programs on the market today include FlexSim, Dosimis-3, Arena, Robot Studio, Tecnomatix Plant Simulation ProModel, Witness. Some properties and characteristics of the software are presented in *Table 1*.

Table 1. Selected parameters of the simulation software used to analyze and optimize logistic processes

Program property	Program name			
	Production line simulation / Virtual factory			Robotics-specific simulation software
	Arena	FIexSim	Tecnomatix Plant Simulation	Robot Studio
Trial version	+	+	+	+
Student version	+	+	+	-
Materials for students	+	+	+	+
Restriction applied in the trial version	Model with only 20 elements	No limits on the model. Limited functionality: no data tree view, command console, optimalizer	Model with only 80 element*	30 days trial, full functionality
Logical diagram	+	-	-	-
Simulation of manufacturing processes	+	+	+	+
Programming robots offline	-	-	-	+
Simulation of robot motion	+	+	+	+
Simulates people at work	+	+	+	-
2D Simulation/Animation	+	-	+	-
3D Simulation/Animation	Post procesor	+	+	+
Access to the parameters of object	+	+	+	+
Import of CAD 3D models	+	+	+	+
Using custom 3D models	-	-	-	+
Script programming languages	C/C++	C++, FlexScript.	SimTalk	RAPID
Creation of custom libraries	+	+	+	+
Production statistics	+	+	+	-
Diagnostic tools (breakpoints, watch. etc.)	+	+	+	+
File format of the report	spreadsheet (*csv), txt, pdf, html, xml	spreadsheet (*csv), htm, html, png	html, htm, txt	-

Source: Autor's own elaboration on the basis of (Rostkowska 2014, pp. 53-65)

Spreadsheets are the most popular tools of general application, as a result of which the possibilities related to the change of results and data to the simulation model are small, MS Excel. In turn, specialized simulation languages are used to design very advanced simulation problems, and here SLX, SIMSCRIPT should be distinguished. However, it should be emphasized that modern specialized simulation packages, eg FlexSim 3D, enable building a model in a limit form using "drag and drop" tools and procedures, and data can be entered into the model using the available parameter masks based on eg real data for processes. These tools allow you to easily create complex models without the need for advanced IT knowledge and in a short time (Skowron-Grabowska 2014). The final tool consists of general-purpose programming languages, which are characterized by the possibility of implementing any model and high flexibility. The construction time is long, and the implementation itself requires a lot of IT knowledge, these are languages based on the procedural paradigm (Pascal) or on object-oriented methodology (Object Pascal, Java etc.) (Kreuter Wagner 2003, p. 28).

Modern simulation software – FlexSim

FlexSim 3D Simulation is a modern simulation set that allows simulation, optimization and modeling of complex processes taking place in the company's structures. Areas that are most often supported by this tool are primarily logistics, services and production. The OpenGL technology used in the tool makes it possible to build a three-dimensional model as well as process visualization. This technology is used by leading graphic designers. Selected parameters to determine the usability of the FlexSim software are presented in *Table 2*.

Table 2. Selected parameters of the FlexSim software

No.	Parameter	FlexSim
1.	Technology	Modern technology in real 3D
2.	Objects	Creating objects, access to the library, open system
3.	Drawing	Importing DWG formats
4.	Animation operators	Possibility to analyze the movement of body parts
5.	Analyses	Designing statistics by users
6.	Combining technologies	Combining technology with operators, forklift trucks
7.	Interfaces	Excel, SQL
8.	Format	Shapes 3D CAD programs, extended textures
9.	Experimenter	Built-in experimenter, tools for many experimental scenarios (OptQuest)
10.	Agent technology	Agent-based technology for modeling processes in a warehouse

Source: (Mendlikowski, Pawlewski 2015, pp. 5740-5744)

The process of building a simulation in FlexSim relies on the above-mentioned objects being dragged and dropped onto the plane and successively combining these objects into one system in accordance with the flow and further parameterization. The objects were designed in such a way as to allow for a complete mapping of the properties of the real system components, but with complete control over the structure of the emerging model. Through the use of an intuitive interface, it is possible to build models based on already existing CAD plans as well as to create your own 3D objects, tailored to the individual needs of users (*Figure 1*).

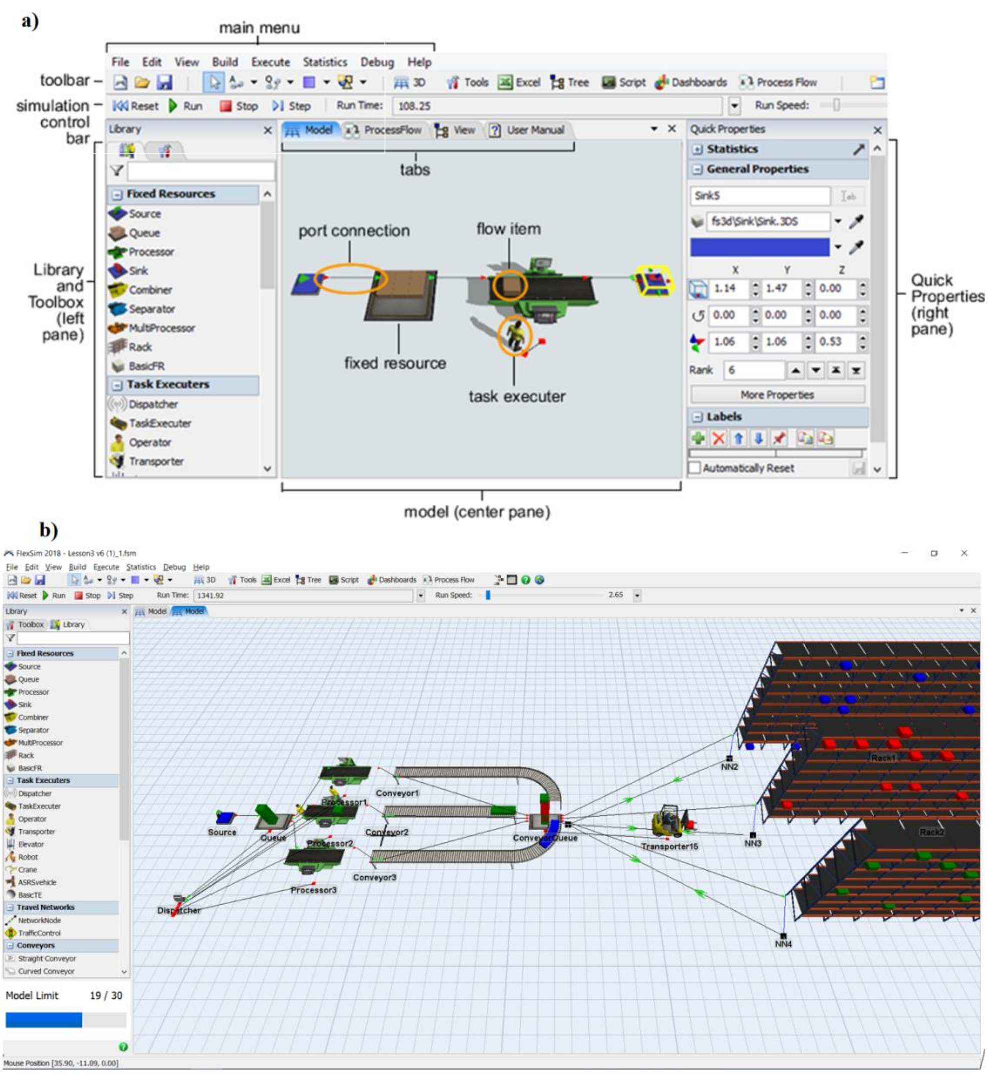

Figure 1. FlexSim user interface (a) and example of the model (b)

Source: a) Overview of the FlexSim user interface (Tmnsimulation.com.au/…); b) FlexSim Community Forum Version 6.0 Tutorials (https://archive.flexsim.com)

FlexSim is also distinguished by computational capabilities that affect the level of advancement of this tool. The built-in OptQuest® module makes it possible to achieve an optimal solution in a short time. The extensive numerical layer allows to obtain significant results by analyzing selected scenarios and reviewing the space of possible solutions. On the other hand, the Experimenter module allows you to repeat the simulation the right number of times, which is determined individually depending on the problem as well as its degree of dynamism of the describing parameters (Klaś 2017, p. 165). Simulation models using the FlexSim program are useful primarily for the analysis of new problems and changes in process organization. It also gives the opportunity to examine company bottlenecks that limit system performance. An advantage is also the verification of complex logistic processes, optimization of material flow as well as design of operator service schemes and operators' work (Beaverstock, Greenwood, Nordgren 2017). One of the purposeful examples of the FlexSim application is the case study of the simulation of the FMCG (Fast Moving Consumer Goods) enterprise, which was carried out using units of measure such as time and distance. Seconds were assumed as time units while the unit of distance was taken millimeters. It was assumed that the simulation period would include a two-shift work mode, i.e. 16 hours. The next step was the mapping of the actual state of the enterprise and its resources. In this case, access to the object's data library was used. The next stage was the establishment and design of the technological line and the shape of the product. When the line was mapped, connections of individual flows were made and technical flow data was introduced. The values relating to machine failure rates, i.e. MTBF, MTTR, are supplemented, as is the ExpertFit tool. The generated data was entered into the simulation using global tables that generate stops along with the connection to the given machine. As a result of in-depth analysis, three experimental technological lines were created, i.e. a real line, a line with a buffer before the sealing device, and a line with buffer before the palletizer. As a result of the simulation, the FlexSim program made it possible to observe many possible problems appearing on the production line related to the processes of product security and packaging. The results of the simulation showed that the palletizer was waiting for the goods, not the other way around. The results of the observations also showed that the buffer did not bring benefits because it is not a direct cause of clogging of the line (Pawlewski et al. 2016). After the next observation, it was noticed the actual problem which was the product piling up before the welding device. The simulation allowed for early identification of the problem and implementation of the necessary corrective actions by creating an additional solution. In the next step, the optimal buffer capacity on the last line was checked. The maximum buffer capacity has changed. The experiment was repeated twice taking into account parameters such as the number of pieces that came out of the cartoner in front of the buffer and the cartoner blocking rate during simulation as well as the number of pieces of goods that entered the line and the number of cartons that left the line. The results, therefore, allowed to determine the best solution in the product packaging process. From the above, it follows that performing simulations in the FlexSim program brings many benefits. First of all, you can get an exact solution to the problem. It is also possible to carry out experiments and introduce real conditions and assumptions. Using FlexSim is also easy to apply. Another advantage is the possibility of extending the tested period, which reduces the time of waiting for effects and, therefore, improve and control the process in long-term conditions. Conducting experiments using simulation is also very cost-effective because it does not generate high costs (Kawa, Fuks, Januszewski 2016). It also ensures repeatability of conditions and verification of critical states by introducing disturbances, e.g. disturbances on the production line. It can therefore be concluded that simulations of logistics processes using the

FlexSim program are very useful in making process decisions, and each process variant can be thoroughly analyzed in order to determine the best process solution if necessary (Wójcik, Zabost 2016, p. 145-163).

Conclusions

The current technological progress and dynamic development of information systems significantly affect the use of more and more advanced, and as a result, more accurate simulation and logistics design systems. The number of engineering ventures in logistics is constantly growing, using simulation and 3D modeling (Gregor). Computer simulation is an ideal tool supporting all decision-making processes and comprehensive system analysis. The models used in the simulation have a positive effect on reducing the risk and investment costs as well as possible changes (Kadłubek, Krzywda, Krzywda 2017). Simulation allows you to replace real operations with computer experiments so that you can quickly and without high costs be able to match the simulation to the needs of a given client (Gierulski, Luściński, Serafin 2012, p. 853). Verification of the problem with the use of computer simulations contributes to lowering the degree of uncertainty during the implementation of logistic processes. An important issue, however, is the choice of a tool for analysis and its use. The article presents the basic issues related to the creation of a simulation project as well as the FlexSim 3D Simulation software, which easily allows you to map complex logistic processes. The user-friendly program interface and the ease of creating models, as well as a large number of logistic objects that can be used, lead to the use of this tool in the simulation process (Klaś, Jurczyk 2017, p. 41-53). Requirement of meeting the high demands of customers today is associated with high flexibility as well as the ability to control and manage processes in logistics. Therefore, in order to significantly increase the efficiency of all processes in logistic facilities (warehouses, distribution centers, handling terminals), there is a high need for modern and efficient simulation tools, to which FlexSim may undoubtedly be included (Karkula 2013).

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SYMULACJA KOMPUTEROWA W ZARZĄDZANIU PROCESAMI LOGISTYCZNYMI – MOŻLIWOŚCI I ROZWIĄZANIA

Streszczenie: W artykule zaprezentowano koncepcję nowoczesnych systemów symulacyjnych znajdujących zastosowanie w analizie konfiguracji łańcucha logistycznego. Nadrzędnym celem artykułu jest przedstawienie zaawansowanych możliwości zastosowania różnych metod symulacji systemu logistycznego, bądź też stwierdzenie zasadności wprowadzenia zmian w konfiguracji łańcucha logistycznego lub oceny przygotowanych już rozwiązań danego procesu logistycznego. Artykuł zawiera opis technologii informatycznych, które mogą znaleźć zastosowanie w symulacji, w tym specjalistyczne programy symulacyjne, arkusze kalkulacyjne, języki i interfejsy symulacyjne itd. W artykule zaprezentowano podstawowe zagadnienia związanie z tworzeniem symulacji projektu logistycznego, jak również zaprezentowano możliwości oprogramowania FlexSim 3D Simulation, które w łatwy sposób pozwala odwzorować złożone procesy logistyczne. Symulacja wraz z uwzględnieniem wygenerowanych w trakcie jej realizacji danych o poszczególnych procesach logistycznych umożliwia wybór najkorzystniejszych oraz optymalizację dotychczas stosowanych rozwiązań w danym procesie. W artykule przedstawiono przykład symulacji zagadnień logistycznych procesu produkcyjnego oraz zaprezentowano przykłady służące wyjaśnieniu atrakcyjności poznawczej tej metody w oparciu o wykorzystanie techniki komputerowej i oprogramowania FlexSim 3D Simulation.

Słowa kluczowe: logistyka, symulacja, procesy logistyczne, FlexSim 3D Simulation