PRODUCTION PLANNING AND CONTROL USING ADVANCED SIMULATION SYSTEMS

Damian Krenczyk [1], Malgorzata Olender [1]

[1] Silesian University of Technology, Faculty of Mechanical Engineering, Institute of Engineering Processes Automation and Integrated Manufacturing System
Konarskiego 18A, 44-100 Gliwice

Corresponding author: Malgorzata Olender, malgorzata.olender@polsl.pl

Abstract: Nowadays the enterprises must quickly respond to changes on the market. One of the aspects related to the possibility of achieving a competitive advantage is to increase the flexibility of production system in adapting to changing customer requirements. One of the solutions on this respond is the use of advanced computer simulation system supplemented by automatic simulation experiments module for varying input parameters. Simulation helps user make decisions at various levels of the company, such as calculation of planned investment costs, changing the workstations settings, execution of orders etc. The user should have input information, such as a schedule, itinerary, or time of machines, to properly execute the model. In the paper the possibility implementation of experiments in advanced computer simulation system has been presented. For the preparation of the experiments and generate the results two modules: Experiment Wizard and Analyze Experiment Results were used. Experiment preparation allows checking the process parameters without carrying them out in the real world.
The article shows the possibility of supporting the preparation of simulation experiments modules to automate the process of model parameterization and examples together with an analysis the results has been presented
Key words: discrete production, simulation, manufacturing process, production planning, control production.

1. INTRODUCTION

Changing customer demands and expectations, as well as technological developments, are the indicators of activities for enterprises that need to dynamically respond to changes in the market. Bringing new products into the market, or improving existing ones, requires changes not only in the the human resources or financial areas, but also at the level of the manufacturing and distribution processes. Using the simulation systems (eg. *Enterprise Dynamics*, *FlexSim*, *Arena*, *Taylor II*), manufacturers can verify that the planned production orders can be executed on time.
Measurable benefit of using this type of computer support is the ability to verify the production schedules quickly and economically, without tedious and time-consuming tests in the real production system.
In recent scientific publications [1, 3, 4, 5, 7-11] there are many references to the modeling, simulation, ways of using simulation systems, and application in the areas of production planning and control. In [10] has been described, among others, the problems which users of computer simulation systems must deal with, such as modeling of the production process methods and the aspects that can be solved by means of simulation in the enterprises. They have focused, with the exception of the description of the theoretical aspects of simulation, for discussion about chosen discrete simulation systems, as well as shown the practical side and examples. Other subject is the simulation modeling with complex simulations, here the focus was on optimization of production systems as well. In both cases, the common part is the use of the *Enterprise Dynamics* simulation system [6].
In this paper as a basic modeling tool has also been used *Enterprise Dynamics* simulation system. In the following sections subjects related to the modelling and simulation was discussed, and in the main part of paper the implementation of the model together with the use of the automatic module of the experiment execution has been demonstrated. Within the performed simulation experiments critical resources has been identified and the required storage capacity of inter-resource buffer has been verified. Simulation verification of the results of production planning and control phases is associated with the information acquisition about the modeled processes. This is required at the stage of creating a mathematical form model that they reflect the real system properties witch model will be subject to the simulation.

2. SIMULATION

Currently, simulation is a very important tool for managers and executives who need to make decisions at various levels of the company. It has a wide range of applications and can support the decision based on analysis of data relating to the execution of orders, production management systems, procurement planning, changing settings of the workstations, or the cost of their investment.

There is no other tool, which would allow to quickly answer the question of feasibility of the production, and, if necessary, to quickly change parameter settings entered into the system model. To perform a simulation model we must have the appropriate knowledge of the production system being designed - for example: number of machines, the production flow control method, buffers capacity, etc. That is all what is necessary for an adequate representation the real production system. Preparing the simulation experiments should be carried out in accordance with the diagram shown in Fig. 1.

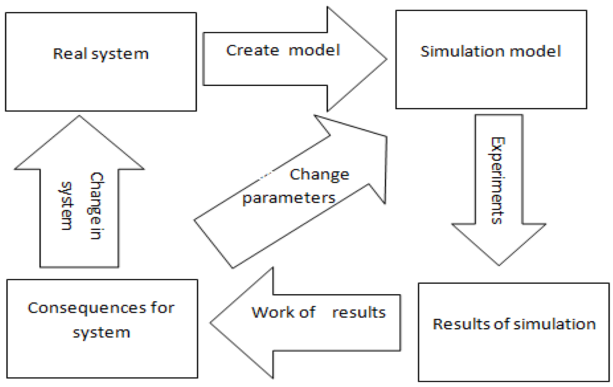


Fig. 1. Progress in the implementation of modeling and simulation

Based on the behavior of the real system, the simulation model is preparing on which the changes in the system will be tested. Planner, according to the results, implements the execution parameters which are the best solution at the moment.

Application of the simulation incurs many costs for the company, but in comparison with the benefits that result from the use of the simulation system, it is worth taking the risk. Examples of the benefits of the use of the simulation are [2, 12]:

- checking the operation of the production at changed parameters, machines, etc.,
- making changes without destabilization of the company operations,
- quickly obtaining the results,
- more accurate working knowledge of the current production system,
- detection of disruptions in production,
- narrowing down the parameters causing a deviation from the norm.

The above advantages of the simulation systems and the fast technological development makes that on the market appear better and better versions of the simulation systems allowing for better visualization performed experiments. Financial outlay incurred for the purchase of the systems, the amount of work to create the model, analyzing the results and implementation of chosen solutions are preferable to testing of the changes in the production system, which may be to destabilize of the entire enterprise.

During the production flow planning it is important that developed model will be a good representation of the real system, that all generated modifications can be applied without obstacles.

4. SIMULATION PREFERENCES

Performing simulation experiments related to the search for the best solution from the set of feasible solutions, requires a change in the model parameters according to the accepted optimization criterion for each simulation.

In the proposed simulation model there are two production processes. The processes flow is independent from each other in the system. For the flow of both processes, queuing in inter-resource buffer is carried out according to three predefined rules: Fifo, Lifo, and Random. For each single simulation pass during the experiment, the buffers queuing rule is changed. These changes are automatically performed after each pass (see Fig. 4). Used queuing rules may occur in parallel on different buffers and there are various variations of their available of n-element set. The total number of variations L was calculated as n-tuples of an n-set:

$$L = n^n \tag{1}$$

For the case presented in this paper, the number of all possibilities of variation queuing is $3^3 = 27$. During the conducted simulation experiments have been verified all of them, which will choose the most advantageous solution. In order to automate the process of carrying out simulation experiments all possible variants of the queuing have been saved in the queuing matrix Mq, which general form is as follows:

$$Mq = \begin{bmatrix} qr_{1,1} & qr_{1,2} & \dots & qr_{1,m} \\ qr_{2,1} & qr_{2,2} & \dots & qr_{2,m} \\ \dots & \dots & \dots & \dots \\ qr_{L,1} & qr_{L,2} & \dots & qr_{L,m} \end{bmatrix} \tag{2}$$

where:

$qr_{i,j}$ – *i-th* queuing rule allocation on *j-th* buffer,

$i = 1,2,\dots L$; L - total number of queuing rule variations,

$j = 1,2,...m$; m - total number of inter-ressource buffers in the production system.

Each of the horizontal vectors of the *Mq* matrix constituted a set of queuing rules for a single course during the implementation of simulation experiments.

3. SIMULATION MODEL

The simulation model is being built always for a specific purpose. Depending on the features it has, can be distinguished following simulation models [5, 6]:

- static – represents a production system at a particular point in time.
- dynamic – represents a production systems as they change over time,
- stochastic in which one or more inputs is a random variable and random inputs lead to random outputs – the model should choose an appropriate random number generator,
- deterministic – which has a known set of inputs, which will result in a unique set of outputs.

On the other hand, taking into account the nature of the modeled system, it is distinguished by the following models of the system [5, 6]:

- discrete – in which the state of the variables of the model changing only at a discrete points in time.
- continuous – in which the state of the variables of the simulation model change continuously over time.

Regardless of the selected type of model, it is created to meet a specific purpose. The model reflects the real system and the experiments that are performed, which reports on the final results can be used in further work. One application of simulation models can be, for example: order planning, or comparing different flows of production processes. Modeling allows determining what relationships exist between elements and defines the parameters of individual objects. During the preparation of a simulation model designer should have complete and accurate input data. The input data to the system model can be: schedule, jobs due-date routes with setup and cycle-times, data on the equipment, storage, transportation, etc. Then on the basis of the data the model is being built, through which it is possible to observe the production flow.

Those are very important information, because it will be on the basis of the changes in the real system. The results could to respond to the problems about: the productivity of the manufacturing system, the degree of the resources utilization or identifications of the critical resources (bottlenecks), and so on. The advantage of simulation modeling is the ability to quickly narrowing down the search area in which there was a deviation from the standards. There is no need to focus on the whole model, but on the selected objects, which significantly shortens the time of searches and allows the planner to more thoroughly analyze it interesting location.

On the market there are many computer simulations systems. Due to the versatility of use, ability to create sophisticated models, specialized modules, where one of them is experiment wizard module, it was decided that in the paper the Enterprise Dynamics (ED) simulation system was used.

Constructed in the ED model is an approximate representation of the part of the production process. It is a production of the torsion bars for the two automobile brands, as two types of products. The processes differ the route. As a method of queuing selection (lifo, fifo) of the inter-resource buffers was used automatically read data from the prepared tables. In this way the changes are not needed each simulation time in the model.

Cycle-times for each production resource have been defined as an determined value, whose value for resource M1, M2, and M3 was successively 25, 17, and 30 units time. It was assumed single shift production (eight hours) for five days a week. Semi-

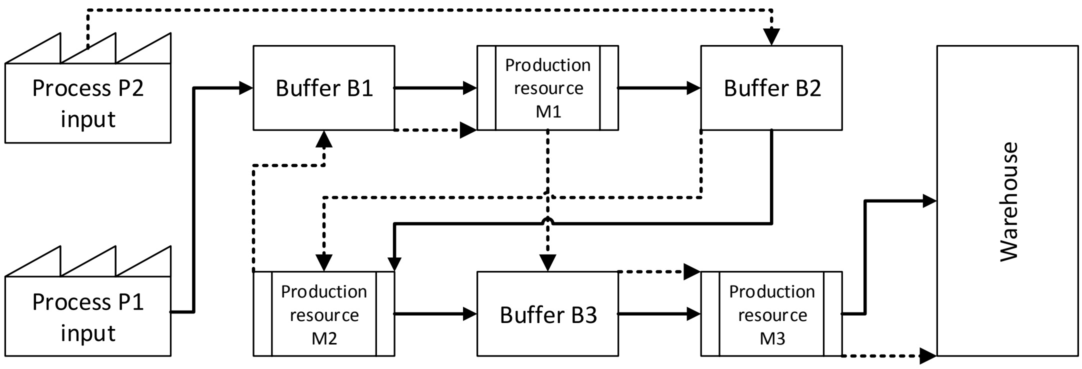


Fig. 2. Production processes flow

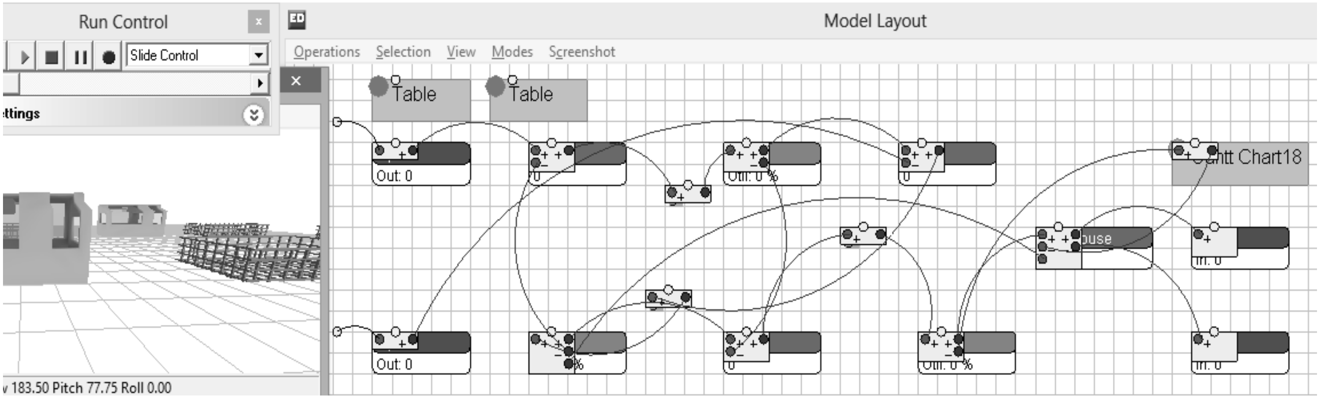


Fig. 3. Simulation model

finished product is coming into the system in a continuous manner. Production system model diagram was shown in Fig. 2. The production is performed on two lathes (M1, M2) and a milling machine (M3). Between production resources inter-resource buffers are placed, where products are waiting for processing.

The simulation model was built using the basic objects available in the ED. In order to transfer products between objects the input and output channels were used. Products entering the object utilize the input channels, and leaving the object - output channels. The Model view, together with the connected channels, is shown in Fig. 3. For the processes P1 and P2 the connection of objects is as follows:

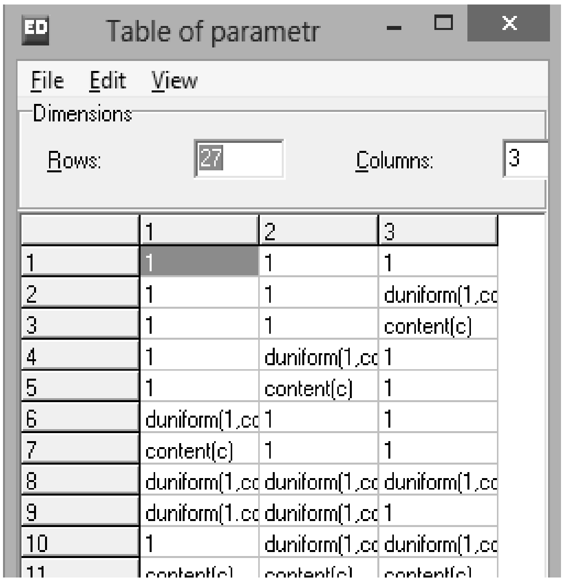
Process P1: *Input1 – Buffer1 – Gantt Initialize – Server1 – Buffer2 – Gantt Initialize – Server2 – Buffer3 – Gantt Initialize - Server3 – Buffer4 – Sink1.*

Process P2: Input2 – Buffer3 – Gantt Initialize – Server2 – Buffer1 – Gantt Initialize – Server1 – Buffer3 – Gantt Initialize - Server3 – Buffer4 – Sink2.

For the inputs (Input1, Input2) number of products coming into the system is determined as unlimited for one shift.

The parameters of the individual objects during the phase of creating the model should be specified. It was assumed that in the inter-resource buffers, the product queuing for each simulation was determined by using the parameters stored in the table

(parameter) shown in Fig. 4. According to the record, for each buffer the way of queue leaving (queue discipline) is different. Parameterization have been selected in three ways: Fifo (first in, first out), Lifo (last in, first out), and Random. Then, after the model with relevant parameters has been saved the next step was the launch of the *Experimental Wizard Module*.



	1	2	3
1	1	1	1
2	1	1	duniform(1,cc
3	1	1	content(c)
4	1	duniform(1,cc	1
5	1	content(c)	1
6	duniform(1,cc	1	1
7	content(c)	1	1
8	duniform(1,cc	duniform(1,cc	duniform(1,cc
9	duniform(1,cc	duniform(1,cc	1
10	1	duniform(1,cc	duniform(1,cc
11	content(c)	content(c)	content(c)

Fig. 4. Experimental parameters.

5. EXPERIMENTAL WIZARD MODULE

5.1 Module parameterization

The experimental module allows performing various experiments in an automatic way for many simulations without the need to run each individually. It consists of two successive sub-modules: *Experiment Wizard* and *Analyze Experiment Results*. In *Experiment Wizard Module* (see Fig. 5) all the parameters needed to carry out the experiment have been determined. In the form simulation method, the number of observation, the duration of a single observation and the model various parameters is determined.

It was decided that the simulation method has been *Simulation Separate runs*, which means that in the course of the experiment will be carried out single and independent simulations. Observation time period of a single simulation was 8h. Number of observations was 27 (number of all variation possibilities of queuing).

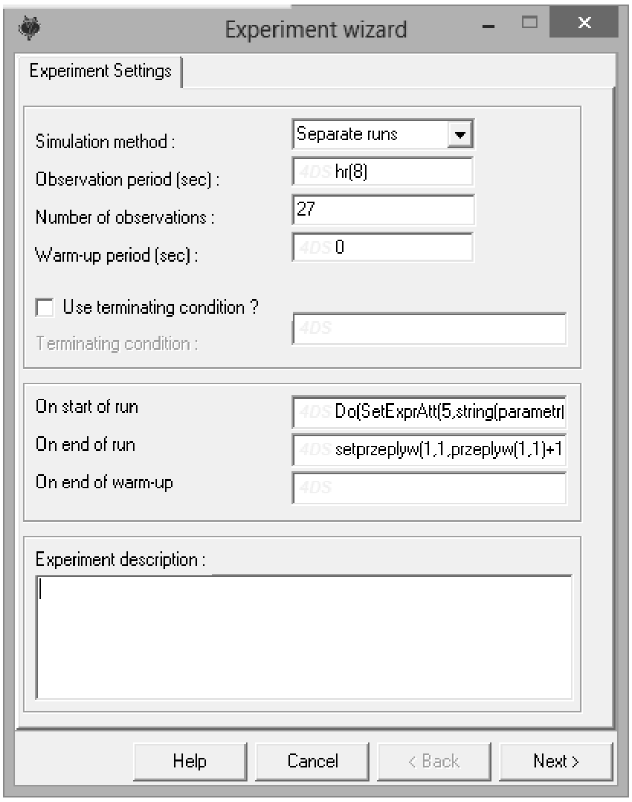


Fig. 5. Experinemts wizard

5.2The analyzed object selecting.
To analyze the results of the experiments a single object *Buffer1* has been selected. Then, the measured quantity was defined as *Performance Measures* option. The selected number of products leaving the inter-resource buffer 1 for each duration of observation as chosen as an output value.

5.3 Experiment results
In the course of the simulation experiments (each performed 27 independent simulation runs) the impact of changes in input parameters (queuing rule at the buffers) for indicators of work of individual components of the model has been recorded. There were recorded such indicators as: average staying time in the resources, average content, availability of the resources, status (idle, busy, block, etc.), input/output (number of product that have entered/left a specified resource), etc.
Of particular importance was the analysis of the impact of the queuing rules on the size of the average stock in buffers - in this context, the average staying time of products in an buffers and average storage levels in each simulation run have been analyzed. The results of average values for the buffer 3 shown in Figures 6 and 7. As can be observed the best results were obtained for the simulation run 1st, 2nd, 5th and 11th. These runs correspond to the following types of rules allocated to the buffers in the production system:

1st: *buffer 1- fifo; buffer 2 - fifo ; buffer 3 - fifo*
2nd: *buffer 1- fifo; buffer 2 - fifo ; buffer 3 - rand.*
5th: *buffer 1- fifo; buffer 2 - lifo ; buffer 3 - fifo.*
11th: *buffer 1- lifi; buffer 2 - lifo ; buffer 3 – lifo.*

In these cases, except that the minimum values of the storage levels, the average residence time of the products in the buffers was the smallest, which is also reflected in the execution time of production orders.

10. CONCLUSIONS

Nowadays, enterprises must quickly respond to changes on the market. One of the aspects related to the possibility of achieving a competitive advantage is to increase the flexibility of production system in adapting to changing customer requirements. Useful in this problem turns out to be the use of advanced simulation computer systems supplemented by automatic simulation experiments module for varying input parameters. One of the example of such simulation packages is *Enterprise Dynamics* presented in this paper.
For the preparation of the experiments and generate the results two modules: *Experiment Wizard* and *Analyze Experiment Results* were used. There are modules for automating execution of simulation experiments. Automatically perform a set number of without the need to pass each time parameter setting again each passage experiment. Generated results and indicators show the status of the system for any number of pass simulation. The obtained results can be narrow down and reanalyzed for this area where there are problems with meeting the norms of production. Automatically carry out set number of runs without the need to setting again each time parameters of current experiment. Generated results and indicators show the status of the production system for any number of simulation runs. The obtained results can be narrowed down and reanalyzed for this area where there are problems with meeting the norms of production.
Shown in this paper the possibility of simulation systems and presented examples together with an analysis of the obtained results indicate the high potential of such tools especially at the operational level of planning, where they are not widely used currently.

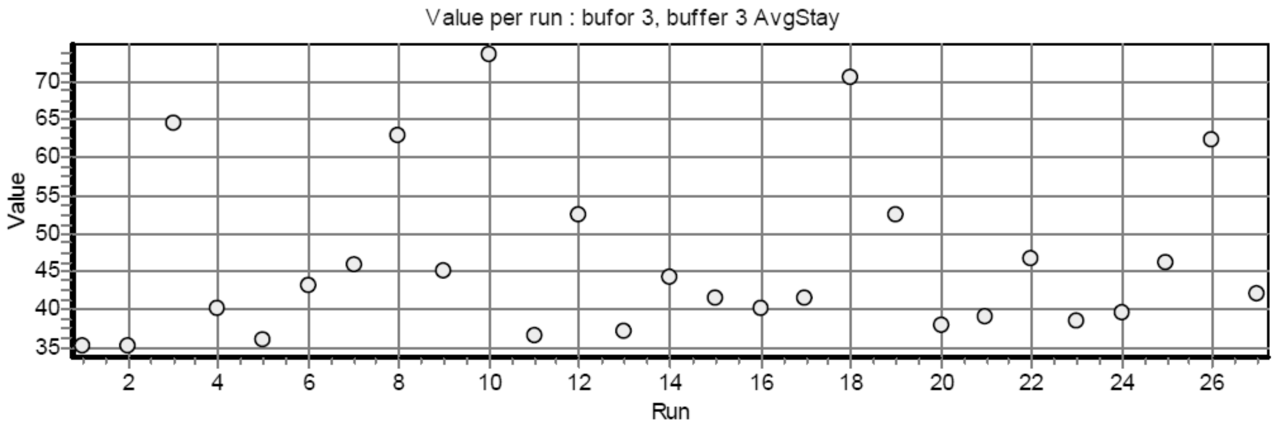


Fig. 6. The average staying time of products in an atom (buffer 3) over the total runtime

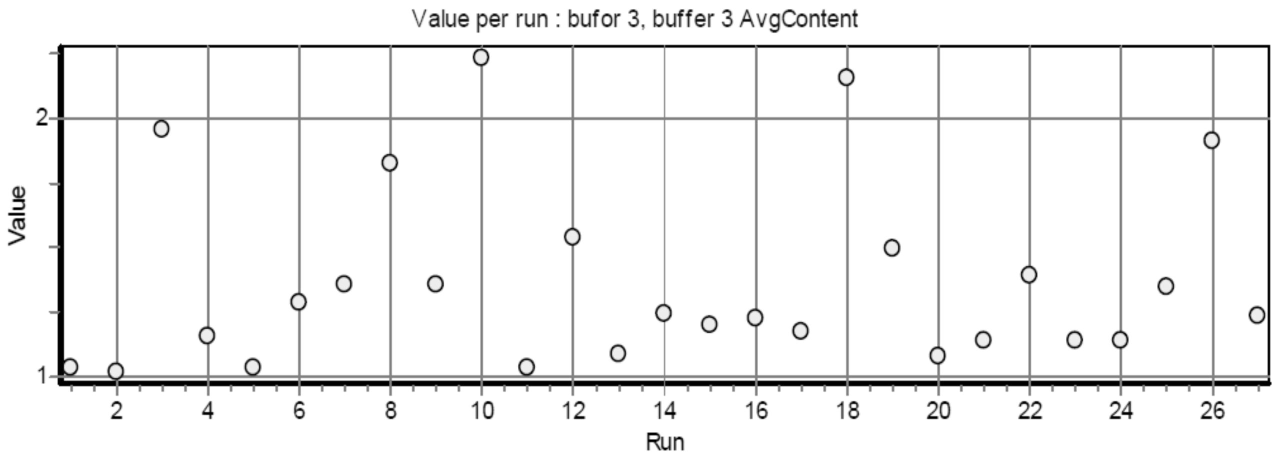


Fig. 7. The average number of products that have stayed buffer 3 atom

REFERENCES

1. Allen T. T., (2011). *Advanced Modeling with ARENA*, Introduction to Discrete Event Simulation and Agent-based Modeling, pp. 161–174 Springer, London.

2, Banks, J., Carson, J. S., Nelson, B. L., Nicol, D. M., (2010). *Discrete-Event System Simulation*. 5th ed., Prentice Hall, Upper Saddle River, NJ.

3. Baudet, P., Azzaro-Pantel, C., Domenech, S., Pibouleau, L. (2011). *A discrete-event simulation approach for scheduling batch processes*. Computers & Chemical Engineering, vol. 19, pp. 633–638, Supplement 1.

4. Chandra, C., Grabis, J., (2007). *Simulation Modeling Approaches*, Supply Chain Configuration, pp. 207–223, Springer, New York, USA.

5. Cohen, M., (2008). *SimWiz – a Self-Learning Tool for Learning Discrete Event System Simulation*, Iskander M. (ed.): Innovative Techniques in Instruction Technology, E-learning, E-assessment, and Education. pp. 370–374, Springer, Netherlands.

6. Enterprise Dynamics Simulation Software, (2014) http://www.incontrolsim.com/.

7. Krenczyk D., (2006) *Automatic generation of simulation model for computer simulation* (in Polish), R. Knosala (red.): IX Conference Computer Integrated Managenemt. t. 2. , pp. 26–35 Oficyna Wydawnicza Polskiego Towarzystwa Zarządzania Produkcją, Opole, Poland.

8. Krenczyk, D. (2012). *Data-driven modelling and simulation for integration of production planning and simulation systems*. Selected Engineering Problems, no. 3, pp. 119–122, Gliwice, Poland.

9. Kuljis, J., (1998). *The Usability of User Interfaces to Simulation Systems*, Macredie R. et al. (eds.): Modelling for Added Value, pp. 215–238, Springer, London.

10. Lewandowski, J., Skołud, B., Plinta, D., (2014). *Production systems organisation*. (in Polish), PWE, Warsaw, Poland.

11. Pawlewski, P., Dossou, P. E., Golinska, P., (2012): *Using Simulation Based on Agents (ABS) and DES in Enterprise Integration Modelling Concepts*,. Rodríguez J. M. C. et al. (eds.): Trends in Practical Applications of Agents and Multiagent Systems. vol. 157, pp. 75–83, Springer, Berlin–Heidelberg.

12. Robinson, S., (2004). *Simulation: The Practice of Model Development and Use*. John Wiley & Sons, USA.

Received: September 01, 2014 / Accepted: December 10, 2014 / Paper available online: December 15, 2014 © International Journal of Modern Manufacturing Technologies.