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A N D I N T E G R A T E D M A N U F A C T U R I N G S Y S T E M S

Damian KRENCZYK[1], Małgorzata OLENDER[1*], Krzysztof KALINOWSKI[1], Cezary GRABOWIK[1], Grzegorz ĆWIKŁA[1]

[1] Institute of Engineering Processes Automation and Integrated Manufacturing Systems, Faculty of Mechanical Engineering, Silesian University of Technology, Gliwice, Poland
[*] malgorzata.olender@polsl.pl

PRODUCTION ORDER VERIFICATION IN VIRTUAL MANUFACTURING NETWORK USING SIMULATION SYSTEMS

Abstract: Today's dynamic market places new demands on manufacturers, with regard to the continuous and rapid response to market changes and more frequent replacing older products with new ones. Producers looking for new solutions that meet the requirements related to the possibility of further production, without incurring even more manufacturing costs. The change in strategy business method gives the possibility to use the so-called Virtual Manufacturing Network (VMN), which may be the answer to these problems, production in the shortest possible time and at limited cost. This paper proposes a method to help the process of planning the production flow in Virtual Manufacturing Networks to assist solving problems related to the process of alternative routes selection in the network.

1. Introduction

A different approach to production planning than conventional can bring many benefits to manufacturers and allow for maintenance on the market. Ability to use their spare capacity on resources, skills and experience enables the use of opportunities arising from the market, which is used by the producer group provides an opportunity to perform certain orders, which would not be possible for a single company. An occasional, temporary cooperation provides opportunities, but it has to do with also a lot of risk, because it is often requires cooperation with several companies at the same time. The combination of all the elements at every stage, and even more in the planning stages of production requires a tremendous effort. With specific demands, requiring increase the level of flexibility, frequent changes in resources productivity and cost reduction, correspond to solutions associated with production in the Virtual Manufacturing Networks (VMN) form [1, 2, 3].

Cooperation in the network requires making many decisions, not only related to the single enterprise, but also to the cooperation of several companies as a whole. Production planning is thus even more complex task, where through the geographical dispersion of enterprises, transmission and processing of information becomes more difficult, but it is the basis for the good functioning of the network. The progress which also took place in the IT technologies in the communication areas, overcomes barriers and allows working with anyone, regardless of the geographical distribution of suppliers [1, 3, 4, 5, 6].

In the following sections an example of verification of orders in the VMS, in which the choice of the organizational structure variant is supported through the use of simulation systems will be presented.

2. Production order verification in Virtual Manufacturing Network

Deciding to participate in virtual organizations, companies expect to increase the level of flexibility, minimizing production time, by sharing their free resources, skills and experience to cooperate on a specific order with cooperators.

Virtual organization according to [10] is characterized as the organizational structure, based on different ways of cooperation in order to use their available resources, skills, knowledge, etc., to carry out a specific project, or to seize opportunities arising from the market. An integral element associated with the virtual organization is the information technology. Cooperation of organizations associated with the project, means that all business partners are connected in a so-called. Manufacture in a virtual network, characterized by the fact that it is a network formed temporarily. Co-operators are not bound permanently, which in turn causes an increase the dynamics in their functioning. In the event of a conflict, or failure to comply with assigned tasks, it is possible to change co-operator. Sharing their resources, skills and experience required also an adequate level of mutual trust suppliers, allowing for the execution of orders without the obstacles that would prevent success.

The proposed model of decision problem is associated with the problem of scheduling the flow of the production process in which the production system is defined as [11]:

$$S=(M, C, PP, B), \tag{1}$$

where:

S – the production system,

$M = \{M_i^{\varepsilon}, i = 1,2,...,m_{\varepsilon}; \varepsilon = 1,2,...,R\}$ – production resources,

m_{ε} – the number of resources owned by $\varepsilon^{\text{-th}}$ manufacturer,

R – the number of manufacturer in the network,

$C = C^P + C^T$ – the unit production cost (C^P) and the unit costs of transport (C^T),

PP=$\{P_j, j = 1,2,...,n\}$ - production processes,

B - storage capacities for individual producers.

For a particular production order functions of the objective are defined:

F1: minimizing the production cost [11]:

$$F1(\sigma) = \sum_{j=1}^{h} \sum_{h=1}^{H_j^{\sigma_j}} \left(C^P_{(mp_{1h}),(mp_{2h})} * mp_{3h} \right) \rightarrow \min \tag{2}$$

F2: minimizing transportation costs between producers:

$$F2(\sigma) = \sum_{j=1}^{h} \sum_{h=1}^{(H_j^{\sigma_j}-1)} \left(C^T_{(mp_{1h}),(mp_{1(h+1)})} * N_j \right) \rightarrow \min \tag{3}$$

In [11,12] the authors propose to use the definition of a decision problem taken from game theory to search for solutions associated with the choice of production routes from alternative routes. The decision-making situation in discussed area is considered as a non-cooperative, 2-person, non-zero-sum game with complete information. Players are represented as objects of the objective function (in this case *F1* and *F2*). However, to be able to apply the proposed decision-making model is necessary to set the cost of production and transport which are part of the objective function and the associated value of payments to players.

To solve this task are suitable [7,8,9] methods based for numerical simulation models. This model for a given class of production systems (in this case VMN), thanks to the possibility of its parameterization can be used together with the simulation system to determine the above-mentioned costs.

3. Practical example

The Virtual Manufacturing Network which consists of three manufacturers is being considered. Manufacturers share their production resources in order to perform production order. Each manufacturer offers three resources that can be used for the execution of the order.

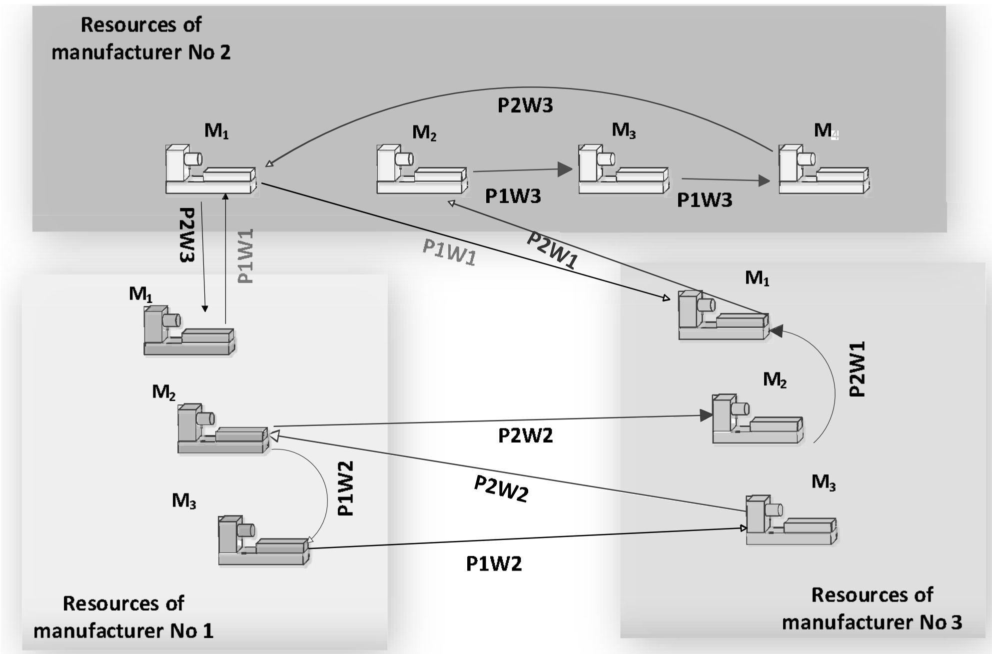

Fig.1. Production flow in VMN

Each of the manufacturers is designed to perform part of the production order. The problem is related to the production planning, especially with a choice of the route from the available alternative routes.

It was assumed that there are three variants of the process flow in the production system. Each of the variant is comprised of two separate processes - a process P_1 and P_2. The flow of production processes of individual producers is shown in Fig. 1. Each manufacturer has its resources, the first - three, the second - four, and the third – three.

3.1. Simulation model

Parametric simulation model takes into account the variability of production processes flow has been prepared for presented class of production systems.

The model was created in the system Enterprise Dynamics (ED) simulation system. ED is a computer simulation and visualization system developed by In Control Simulation Solutions company, and is an object-oriented simulation platform with configurable and scalable simulation environment.

In the model (Figure 2) may be entered the following parameters for each simulated variant:

- production routes,
- technological operations time,
- unit costs of production,
- transportation costs.

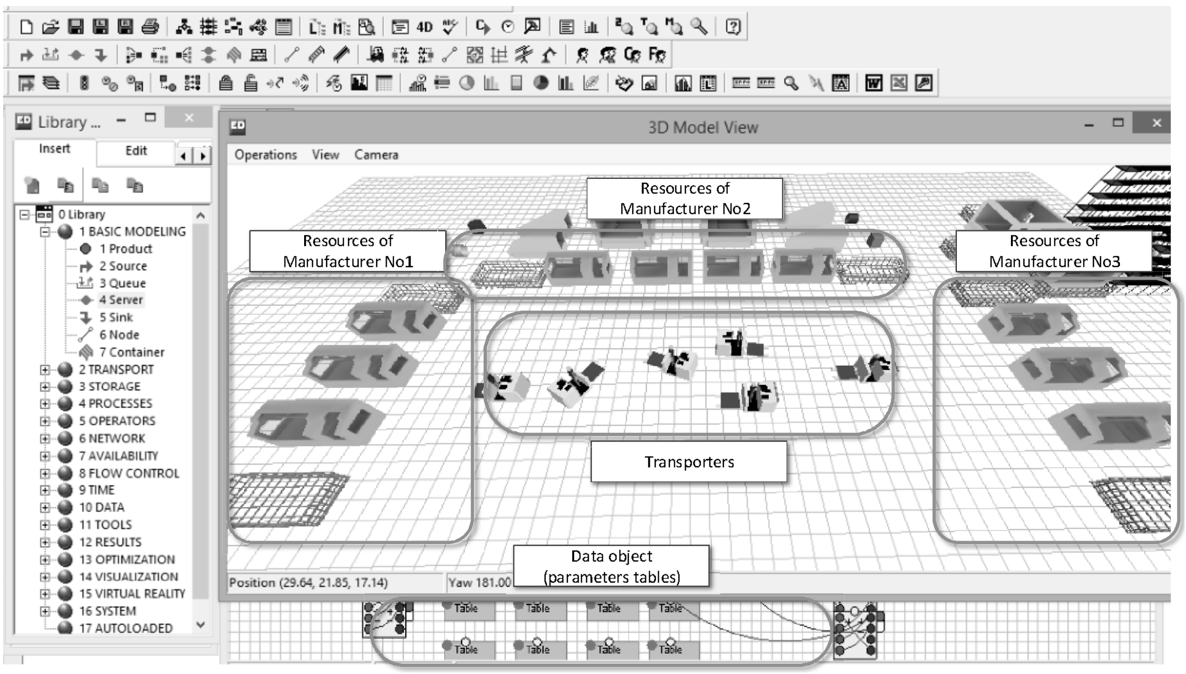

Fig.2. ED simulation model

To the model routes (Fig. 1) operation processing time, unit costs of production (Table. 1) and the cost of transport (Table 2) have been entered.

Tab. 1. Processing time (and cost)

		Manufacturer No1			Manufacturer No2				Manufacturer No3		
	Variant	M_1	M_2	M_3	M_1	M_2	M_3	M_4	M_1	M_2	M_3
Process P_1	W1	5(5)			4(7)				9(3)		
	W2		7(4)	4(4)							8(6)
	W3					8(5)	6(3)	10(2)			

Process P_2	W1					8(5)			9(7)	7(3)	
	W2		7(2)							7(5)	8(3)
	W3	5(6)			4(5)			10(4)			

Tab. 2.Transportation costs

		Manufacturer No		
		1	2	3
Manufacturer No	1	0	400	550
	2	400	0	300
	3	550	300	0

The results of experiments were reports containing information about the production and transportation cost (Fig. 3) for each simulation run (for each production route). It is only a part of results that it is possible to generate during simulation experiments. Complete report contains information on all of the resources that make up the production system (simulation model). It is therefore possible to conduct a comprehensive analysis to the individual case with regard to the capabilities and efficiency of the production plans.

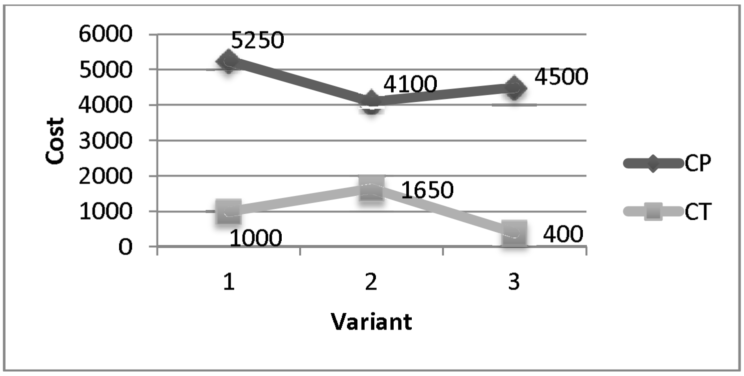

Fig. 3. CP – the sum of production cost, CT – transportation cost.

Additionally, by using simulation and visualization system it was possible to obtain the information on coefficient of production resources utilization, time of production cycle and lead times for each product. The use of a discrete-event simulation systems to determine the operating parameters of the production system has proved to be an effective tool supporting the planning process at the operational level.

4. Conclusions

One of the possibilities of using resources available in enterprises is to participate in Virtual Manufacturing Networks. Planning the production flow within such organizations, forcing manufacturers to seek more effective methods to make decisions related to the choice routefrom alternatives. It allows to answer the question if the manufacturing network is capable to effectively respond on market demands. Presented method can be successfully used with most computer simulation systems, which are characterized by object-oriented method of simulation model creating and offers configurable and scalable simulation environment.

References

1. Wadhwaa S., Mishraa M., Chan F.: Organizing a virtual manufacturing enterprise: an analytic network process based approach for enterprise flexibility. International Journal of Production Research, 2009, vol. 47/1, pp. 163-186
2. Lei R., Zong S.: Collaborative Production in Networked Manufacturing. 5th International Asia Conference on Industrial Engineering and Management Innovation (IEMI 2014), Atlantis Press, 2014, pp. 357-362
3. Fujii S., Kaihara T., Morita H.: A distributed virtual factory in agile manufacturing environment. International Journal of Production Research, 2000, Vol. 38/17, pp. 4113-4128
4. Peng Q., Chung C., Yu C., Luan T.: A networked virtual manufacturing system for SMEs. International Journal of Computer Integrated Manufacturing, 2007, Vol. 20/1, pp. 71-79
5. Liang F., Fung R. Y. K., Jiang Z., Wong T.N.: A hybrid control architecture and coordination mechanism in virtual manufacturing enterprise. International Journal of Production Research, 2008, Vol. 46/13, pp. 3641-3663
6. Xinyu L., Liang G., Weidong L.: Application of game theory based hybrid algorithm for multi-objective integrated process planning and scheduling, Expert Systems with Applications, 2012, 39, pp. 288-297
7. Son Y.J. and Wysk R.A.: Automatic simulation model generation for simulation-based, realtime shop floor control Computers in Industry, 2001, 45(3) pp. 291–308
8. Bergmann S. and Strassburger S.: Challenges for the automatic generation of simulation models for production systems Proc. of the Summer Computer Simulation Conf. SCS, 2010, pp. 545–9
9. Huang Y., Seck M.D. and Verbraeck A.: From data to simulation models: component-based model generation with a data-driven approach. Proc. of the Winter Simul. Conf. 2011, pp. 3724–34
10. Burn J., Marshall P., Barnett M.: E-business Strategies for Virtual Organizations. Butterworth-Heinemann, Oxford, 2002
11. Olender M., Krenczyk D.: Production orders planning in virtual production networks (in Polish), Innowacje w zarządzaniu i inżynieriiprodukcji. T. 1. red. Ryszard Knosala. Opole: Oficyna Wydaw. Polskiego Towarzystwa Zarządzania Produkcją, 2016, pp. 644-656
12. Krenczyk D., Olender M., Simulation aided production planning and scheduling using game theory approach, Applied Mechanics and Materials, 2015, vol. 809/810 pp.1662-7482