

Production flow planning method applied to virtual manufacturing enterprises

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Abstract. The development of production technologies, customer-centric philosophies and, above all, increased uncertainty around today's market, make companies look for solutions that would support their functioning on the market. Keeping up with changes requires, among other things, proper planning of production processes and high investments in innovative technological solutions. For this reason, it is increasingly difficult to make a modern product alone. That is why enterprises from the small and medium enterprises sector are looking for solutions that would enable to continue production without the need to have all the specialized production resources dedicated to individual products. Therefore, companies outsource the choice, configuration and or manufacture components that they are not able to do themselves. Another option is to join the virtual manufacturing network, where manufacturers temporarily share their spare capacity. Such cooperation is possible even for individual enterprises that are geographically dispersed. The proposed solution of generation of possible production routes (based on game theory) also takes into account the time and costs required to transport intermediates between manufacturers (alternative routes). The obtained results are the lead time and costs of manufacturing processes.

1. Introduction

The increase in customer expectations, caused that companies are looking for solutions that would allow them to stay on the market [1, 2, 3, 4]. Changes on the market have forced changes in organizations. In order to use spare production capacities, companies from the sector of small and medium-sized enterprises cooperate to create the so-called virtual production network. The idea of a virtual manufacturing network is based on the use of spare production capacity of producers in the network, to produce the final product. This is temporary cooperation. In addition, enterprises are geographically dispersed [5, 6, 7, 8]. The specified cooperation is temporary, determined by the production period of the product. Due to the number of temporary participants in the network, changing with each new type of order, the nature of the network changes dynamically. Having the appropriate input data concerning, among others, the number of network participants and their spare capacity, possible variants of routes for production processes are determined.

The network participants are selected on the basis of the producer's selection algorithm. In addition to the problem of selecting producers in the network, planning the production flow is a significant problem for this issue. Therefore, it is proposed that generation of possible production routes in a dynamic production network should be determined on the basis of the presented algorithm, taking into account individual spare capacities of all producers [9, 10, 11]. The planning of production processes



and the selection of a technological route involves a series of decisions to be taken. The planner who makes the decision must know, which potential partners he has at his disposal, but also - what are the alternative technological routes available, what transport costs are involved with and whether they make it possible to produce the final product. The decision made (regarding the choice of technological route) is based on formalisms drawn from game theory [12, 13, 14, 15]. Each player strategy is assigned specific sets of variants of production routes for all processes included in the production order, the players must look for solutions for the same sets of strategies. Finally, the solution of the game should result in one set of routing variants. The general algorithm for solving a solution, consists of individual steps the result of which is the route set proposed for the planner. It is assumed that these data are related to a specific production order, i.e. regarding the specification of a set of technological processes, technological requirements for individual operations, size of production series and due dates for the implementation of the order. Based on this information, the integrator (decision maker) is looking for producers, who meet the requirements of the task.

Efficient implementation of this process, requires obtaining calculation results related to routes and costs (production and transport) for data obtained from individual network members. The paper presents an example of such a computer-aided assistance with the use of software supporting scheduling and re-scheduling of discrete production KbRS. The main task of the KbRS system is to plan the use of production resources over time. This is to ensure the execution of the order with the appropriate allocation of machines. To determine a set of possible schedules, data related to the determination of times and costs on resources are required, in accordance with the planned routes in the production system. In order to generate schedules compatible with data from the model, i.e. the number of machines, times, costs, it is necessary to specify the number of processes, number of positions, etc. The obtained results are the lead times and costs of production processes for selected configurations of manufacturers that make up the network. Thus, such results are the basis for choosing a final solution, that must be met by the remaining selection criteria.

2. Practical implementation supported by the KbRS system

By creating a virtual manufacturing network, the integrator must have input data. On the basis of data from producers regarding free capacities, their type and time of access, the integrator establishes a virtual production network. Based on these data, it determines possible technological routes. Then it becomes possible to determine the production schedule.

To determine a set of possible schedules, data related to the determination of times and costs on resources are also required, in accordance with the planned routes in the production system [16, 17, 18]. For this purpose, the KbRS package was used. In order to generate schedules in accordance with the order, first enter the basic data: number of machines, processing times and costs. An assortment of production performed in the machining department was selected for the experiment. Such choice was dictated by the fact that, routes of technological processes carried out in this department are performed, in the case of many operations, on shared resources. The production order adopted for the experiment is presented in table 1.

Table 1. Production plan.

No	Prod. name	No of tech. operations	Bath size
1	Bevel gear	3	400
2	Taper roller	5	250
3	Bevel gear	5	250

The entered data is shown in figure 1.

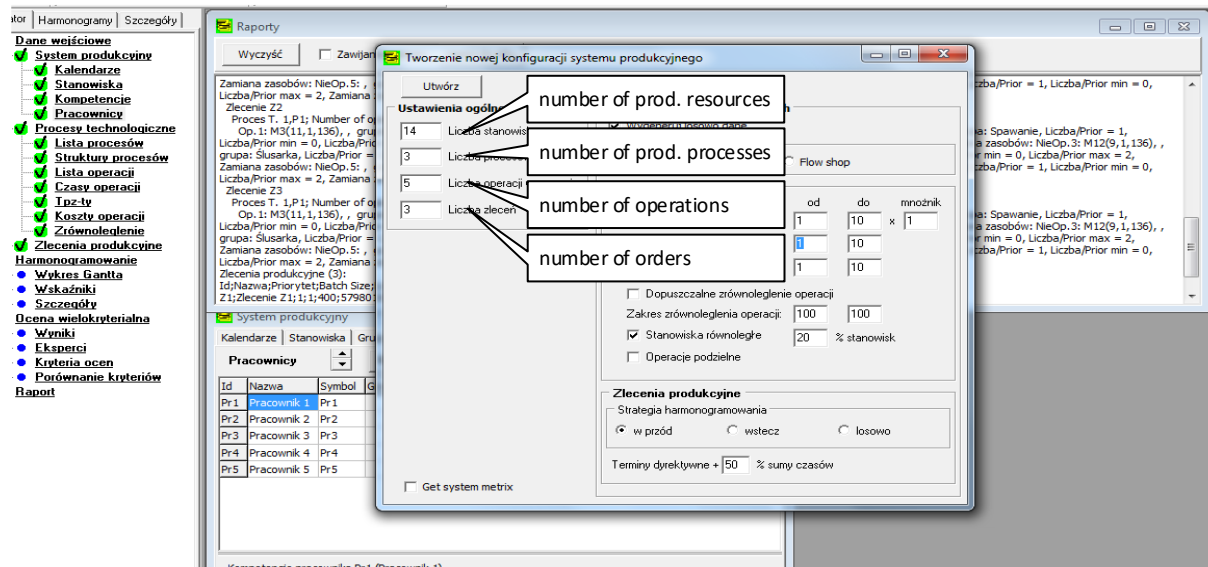


Figure 1. Input data to the KbRS system.

Then, after the initial data can be entered particulars of the orders, including the data on production batches, sequence of operations with allocated resources, times of technological operations, etc. Figure 2 shows an example production order to be made in the virtual production network. The order consists of several production processes. Each process requires the assignment of a production resources, according to the specification of the production process.

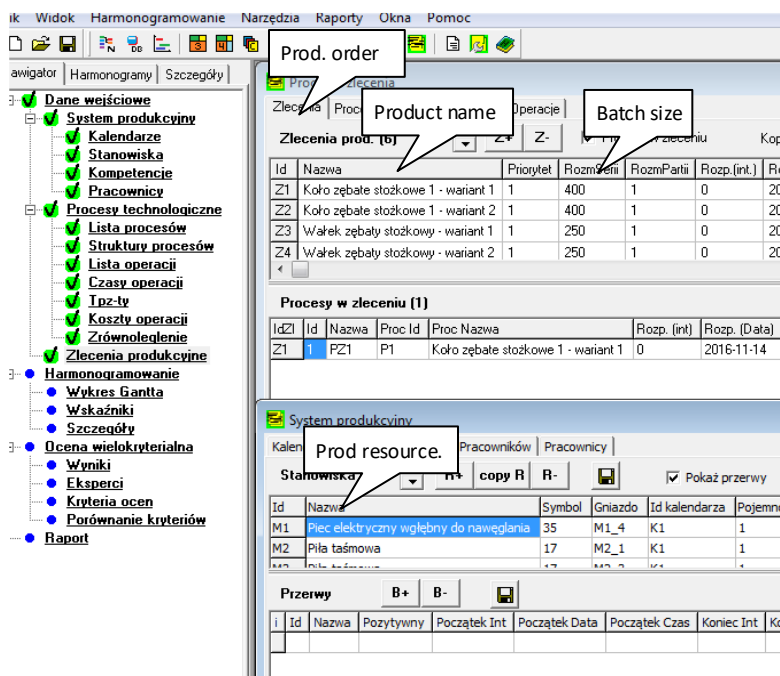


Figure 2. Production order data in the KbRS system.

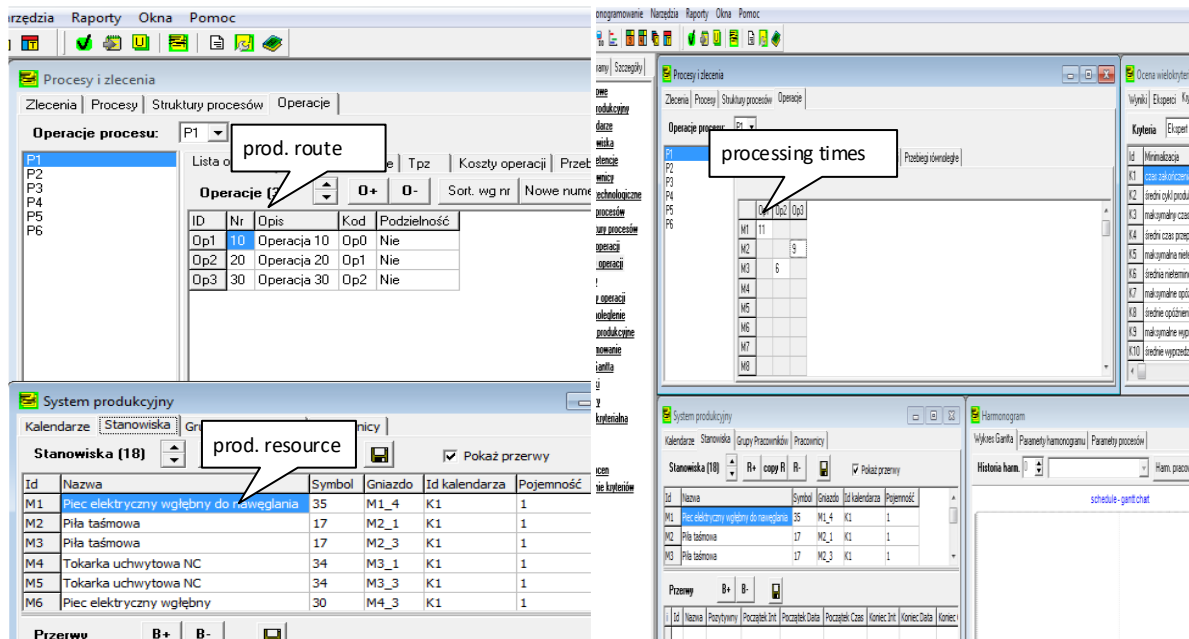


Figure 3. Data on operations for production order.

In addition, this form specifies the size of the production series for each production processes.

In the next step information on the flow of processes was introduced, and, for all production resources, for each product, the processing times of technological operations was introduced, according to the routes (figure 3).

Then, after input of production time data on resources, unit production costs for each machine were introduced (figure 4).

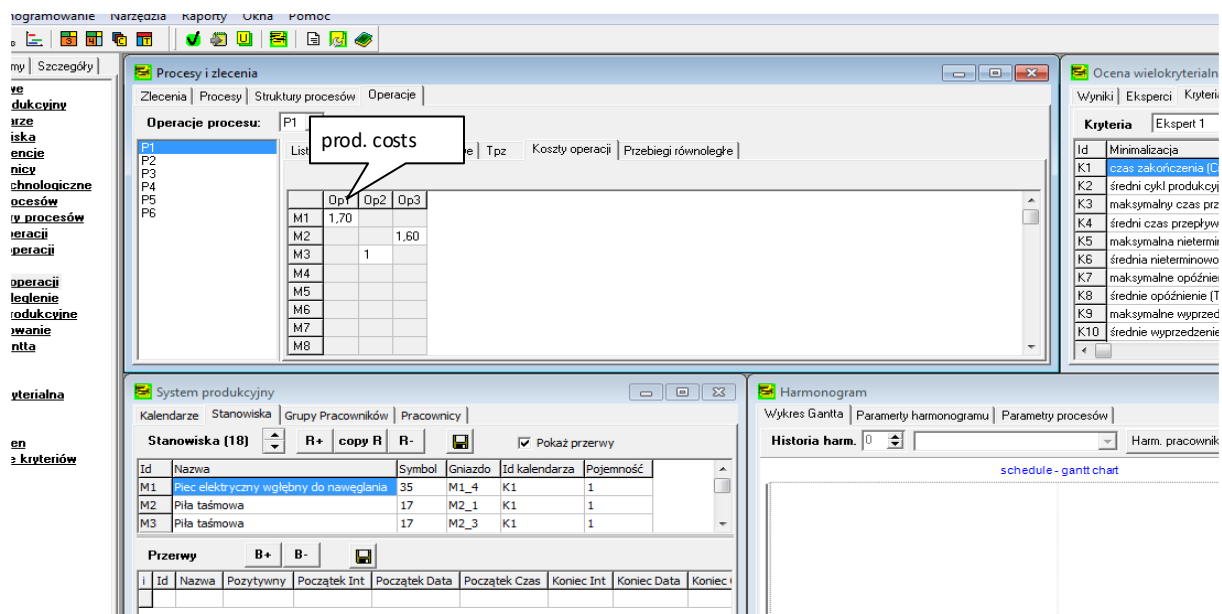


Figure 4. Data on production costs.

In the next stage, for the input data related to the use of production resources, reports for the production order and individual production processes were generated (figure 5). It is a cumulative

report showing the used production resources for individual operations making up the production order.

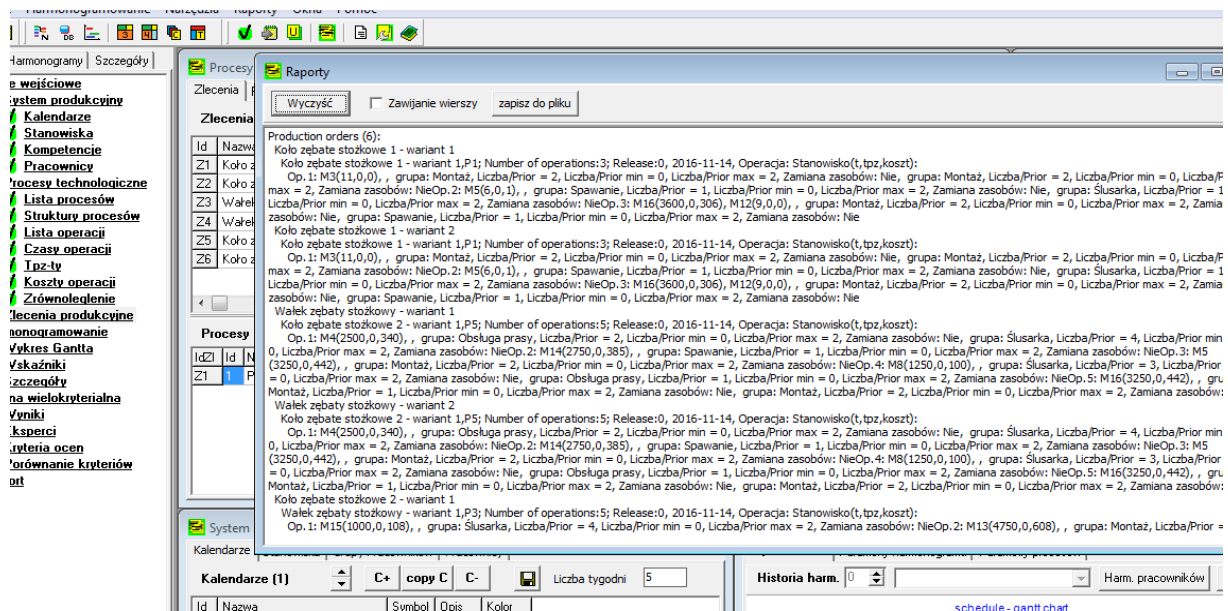


Figure 5. The report in the KbRS system.

In addition, the KbRS system also generated Gantt charts showing the graphic flow of processes in production systems related to the participants of the virtual manufacturing network (figure 6). It also allows the analysis of indicators of the use of production machines depending on the production process and the production order.

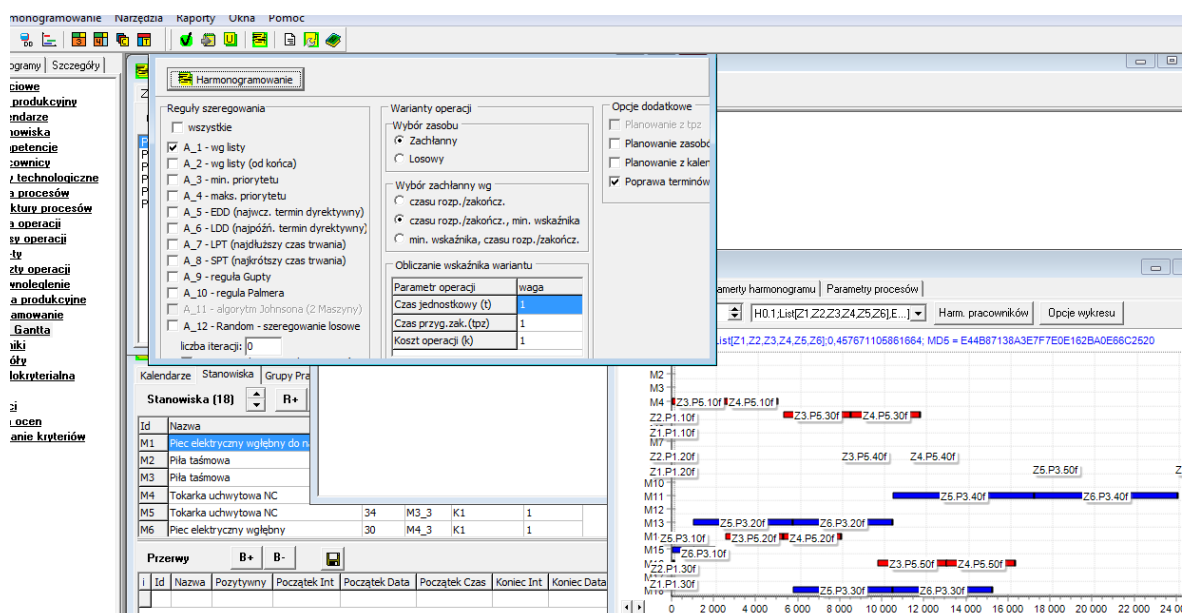


Figure 6. Gantt chart in KbRS for a production order.

Depending on the needs of the planner, the schedule can be displayed in its entirety, according to all data, i.e. used production resources in production processes or according to the scheduling rules.

The results contained in the reports generated by the KbRS system were compared with the results obtained as the values of the sheet payment matrix regarding the production game solution [8]. The estimated production costs amount to 61017.5 contract units, and the costs related to transport resources are 2934 units.

3. Conclusions

Enterprises, in particular from the small-medium enterprises sector, are looking for solutions that would allow the use of spare production capacity. One of the possibilities is to use the concept of a virtual manufacturing network. Enterprises share their free production capacities. This is a temporary cooperation to complete the final product. In addition, these enterprises are dispersed geographically. In order to establish a virtual production network, a decision maker / integrator is needed, who will not only be responsible for the shape of the network, but also for the creation of technological routes. The integrator/planner must have information on the spare capacity of each producer on the network. In addition, he must provide information as to whether the resources can be used to perform the planned production order and in what dates they are available. On this basis, technological routes of the production process can be developed. In order to generate schedules compatible with the production order, the KbRS package was used. It is a package that supports creating schedules and generating results in the form of Gantt charts and reports. At the output, information about all production operations included in the production order is obtained. The obtained results can be compared with the results obtained by another method.

4. References

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