Manage and control information flow in virtual manufacturing enterprises

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Abstract. Requirements set by clients regarding, on the one hand, the highest quality of services provided, on the other hand, shorter and shorter order completion dates, cause that enterprises are often unable to cope with them. A production load or limited production resources also means that enterprises are no longer able to accept a new order for their production plan. The following problem is outlined here - send the customer away empty-handed, or try to execute the order, but with a much later execution date and expose to the cost of contractual penalties. Therefore, solutions are sought, which can be particularly advantageous for producers in the small and medium-sized enterprises (SME) sector, for whom this is an increasingly frequent problem - sometimes means “to be or not to be” on the market. One of the possibilities for enterprises is to use the concept of a virtual manufacturing enterprises, which mainly consists in sharing the free production capacity of each producer within the virtual network. A network that has been established even between individual enterprises that are geographically dispersed. By establishing a group of several companies cooperating at the same time, one should find such a thread of agreement that it would be possible to cooperate, and also to achieve a common goal, which is to make a final product for the recipient. If it is necessary to make a final product that meets the assumed criteria, it is necessary not only to define the level of cooperation, but also there exists much need for a mechanism to manage and control information flow among manufacturers. Therefore, it is necessary to have information on production issues, such as the quantity and quality of spare production capacities, their access time, additional resources, semi-finished products, and since these are geographically dispersed enterprises, the location of each enterprise is also important. In addition, the network itself is established on the basis of information contained in the production order, so you can adjust the number of participants to your needs, and assign tasks accordingly. All executive actions are taken on the basis of the proposed algorithm, which describes the entire decision-making process, how to collect information, where to keep them, and above all, who should be responsible for providing information.

1. Introduction
New technologies, rapid aging of products, etc., force rapid response and decision-making. Not only competition, but also the situation in the environment, cause it harder for companies to stay on the market. Especially, that the sector of Small and Medium-sized Enterprises has no access to some solutions and possibilities compared with large enterprises. On the other hand, smaller enterprises can use the possibility of easier adaptation to changes and flexible response to what is happened on the market [1, 2, 3]. Thanks to this possibilities, SMES Enterprises (Small and Medium-sized Enterprises)
can establish cooperation with other enterprises using a Virtual Manufacturing Network model. With the proviso that, a company being in a temporarily network, shares its free production capacity. Such cooperation allows the company, to use what is currently unused (machines) and to carry out the production process with cooperators from the network at the same time, without stopping and blocking its own production orders. The problem with such a solution is the way, how information are collected, how information are flown, where information are keep and who will make decisions and form the Virtual Manufacturing Network [4, 5, 6].

This article will be focuses on aspects of information flow, between cooperators in the Virtual Manufacturing Network. The algorithm for selecting network participants, who have free production capacities is also presented.

2. Virtual Manufacturing Network

Virtual Manufacturing Network is form by individual enterprises. They are geographically dispersed. They temporarily cooperate, for the production order needs. This cooperation, consists on sharing their production resources, skills and knowledge. Each of producer, makes available its free production resources in various time intervals. Through cooperation, producers have a chance to realize the production order, without stopping their own previously implemented production plans. Because producers are geographically dispersed, the time transport between producers should be also included in the model. Also it is split production and concurrent with existing production, the order of tasks is important to. Having a set of free production resources, it is necessary to determined the order of done operations. Next operations have to be in accordance with the specification of the technology card. Then need to be specify, which producer is responsible for which production piece. The technological routes of the production processes are created on the basis of the production resources each of the producers. According to set of data and set and routes, partly finished products are sent between producers to get final product. In this type of production, firstly there is a problem associated with a huge amount of data to be processed. Second, there must be someone, who will analyze all this data. Such person can be an integrator. For creating a Virtual Manufacturing Network, integrator have to collect and analyze all data, which are important to the develop of production plans. Due to the fact that the network consists of several manufacturers, it is a complicated process. Integrator must keeps this data in the event of problems in cooperation between producers, and also, when new orders appear and when new producers signaling their willingness to cooperate. Temporary cooperation and change of the producer in a new order, causes that, the virtual network is dynamic. Network can constantly change, because of the number of its participants and also of free production resources. For the purposes of data analysis, integrator needs a proper database, that will help with cooperation and integration, in a both way, the integrator-producer and producer-producer level. Exactly on the basis of properly collected and analyzed data, and as well, as creating a Virtual Manufacturing Network algorithm and supporting production planning algorithm, can respectively production processes planning [7, 8, 9, 10, 11].

Figure 1 presents the creating of a Virtual Manufacturing Network algorithm. Integrator collects relevant data about the each of the producers. Based on this data, he ties a network and then allocate tasks between producers. Such an algorithm, consists of several steps, that integrator is follow on.
In the first step, integrator must have information about the production order. He must know the size of the production order, the batch size and etc. Then, on this basis, he creates questions, which producer has the necessary production resources and at specified time. Then he receives feedback about the free production resources, each of the producers. At this moment, a preliminary set of data about the network participants is created. Then, on this basis, integrator creates variants of routes of the production process. If it is possible to define a route, in the next step is selected an optimal route. The route is selected by the such term - minimum costs (production and transportation costs). If it was not possible to create a route, integrator returns to the point related with the search for additional, not used production resources and tries again to determine the route for the given process. If it is impossible, to create a route, by the set of free production resources, the integrator stops the whole algorithm. In this case he for example waits for the appearance of a new producer and then transforms the established network into a new one. It may also happened, that from a set of free production resources, it is impossible to create several route variants. In this situation, the integrator decides whether to follow this one route, or whether to look for additional production resources. Independently, of whether it will be one route or several route variants, integrator gets a set of important information on the output, which includes not only the route of the production process, but

**Figure 1.** Algorithm of creating Virtual Manufacturing Network.
also partial production and transport costs. The obtained partial cost data is determined by the producers. The information on the output is the next step for the new algorithm [12, 13, 14, 15].

Regardless, how big will be the network (how many will be producers connected), the integrator must collect and process all data, related with the producers and also with the production order. In this aim, a database is very useful and will support the storage of all information.

3. Information flow in VMN
Creating a virtual network by an integrator is a complex process. Based on the information coming from the market and from the each of the producers, integrator must indicates, who cooperate with whom and on what terms they will be cooperate. To, the virtual network creation method will be satisfactory for everyone, every effort should be make, to ensure that, the information flow is at the appropriate level. All participants cooperate in the network must have access to information, related with the cooperation. However, the integrator should be level up, because he decides about the character of the network and he chooses the producers to the network.

On figure 2 shown the algorithm, concerning on the type of information flow, starting from the input data to the algorithm, and ending with information about the route selection according to which,

![Figure 2. Information flow in VMN.](image-url)

On figure 2 shown the algorithm, concerning on the type of information flow, starting from the input data to the algorithm, and ending with information about the route selection according to which,
the production process will be realized. The whole algorithm has been divided into two stages. The first one, concerns on the information flow market - integrator. On this stage, information related with the production order is collected, for e.g. number of production processes, the size of the production series, etc. On the second stage, the information is more related with the production process itself. They concern about the integrator – producers level. Due to fact, that there are a huge amounts of data (from few, to several producers, depending on the complexity of the order) and that, these information are sensitive, a suitable database is needed [9, 10, 16, 17]. To meet the needs of producers, will be built a platform, where all important information will be placed. Next to the integrator, the producers will also have access to the platform. These solution will allow to easier and more dynamic control over on data (such a huge number of producers and their production data), but also allow the integrator to focus on "connect" and choose the best producers to the Virtual Manufacturing Network. Each of producers are responsible for the part related with entered data. Each of them are also informed and knowledge, when and which of their free production resources can be used in the Virtual Manufacturing Network. Another advantage of data input by producers, is that they can do it regular by itself, basis on changes in the production plan. Thanks to this, integrator has access to the latest information and can use it in the best way. The platform will be properly configured for the planned tasks. In addition, people who are not connected with the virtual network will not have access to the data. The platform will be properly secured, and producers will be able to log in to accounts, created individually for them. They easily will make any changes on their accounts.

4. Conclusions
Producers, facing the challenge of changes on the market, try to use their potential and stayed on the market. With unused production resources and the possibility to use them, they can collaborate with others through a Virtual Manufacturing Network. By temporarily participation in the network, they not only share their free resources. They have to also divide information about production data with integrator. Without proper information, integrator will not select the producers, who fulfill the criteria for the network and he will not know, what production resources are available in the individual producers.

The article shows the algorithm related with creating a Virtual Manufacturing Network. In addition, these algorithm has been extended with additional information, which was included in and shown by the second algorithm. Without this information, integrator cannot build the right level of cooperation between himself and the producers. Due to production flow planning in Virtual Manufacturing Networks, integrator must have and view huge amount of data, including, for example free production resources of several producers. That is why, building an appropriate data platform, supporting the collection of the main data is so important. Such a platform will be a big help for integrator, because there will be a set of data in one place and he can easily "work" on them. For producers, it will be easier way to entering their basic data, regular and correcting them up to date.

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