A CONCEPT OF ADVISORY SYSTEM SUPPORTING PARTNER SELECTION IN VIRTUAL ORGANIZATIONS

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Summary: This article presents a concept of an advisory system supporting partner selection in virtual organizations (VO). The solution integrates advantages of four modules. Two of them well known and already used in another applications and the other two dedicated and specially developed for the needs of dispersed manufacturing environment. The beginning of the paper serves as an introduction in the problematic of dispersed manufacturing environment. Further part of the text contains information necessary to understand functionalities of the designed system. It shows criteria set used to enterprises selection, steps of the selection procedure and inference rules. Last section presents conclusions and concept of the future work.

Keywords: advisory system, manufacturing, virtual organization, algorithm.

1. Dispersed Manufacturing Environment

Dispersed manufacturing environment is understood as a space that integrates independent manufacturing units. Producers consolidate their efforts in order to better exploit opportunities occurring in a dynamic environment. Cooperation between several independent companies located in different places may proceed smoothly when participants have knowledge about potential and capacity of others. It is also more convenient to make preliminary agreement considering general rules of common work. For this purpose potential business partners set up cluster. In most general sense cluster means geographical concentration of industries that gain performance advantages through co-location, [1]. United Nations Industrial Development Organization defines them as sectoral and geographical concentrations of enterprises that produce and sell a range of related or complementary products and, thus, face common challenges and opportunities. These concentrations can give rise to external economies such as emergence of specialized suppliers of raw materials and components or growth of a pool of sector-specific skills and foster development of specialized services in technical, managerial and financial matters, [2]. Members of such groups usually use the same system based on the Internet technology which enable them easy and secure communication and data exchange. Thanks to these solutions enterprises gain knowledge about partners and formulate preliminary cooperation procedures. In result the group achieves high level of flexibility and can quickly react to client needs without needless waste of time on the organizational issues.

When several companies belonging to a cluster start realizing particular project or order in cooperation they are often described as a virtual organization (VO).This indicates that with respect to law they operate independently but for the need of a given market opportunity they temporary become one business unit realizing common goal. Figure 1 presents concept of the VO arising within a cluster.

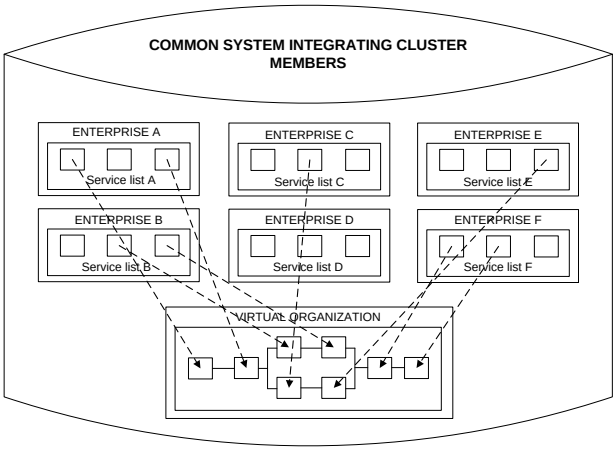

Fig. 1. Concept of the Virtual Organization arising within a cluster [3]

Cluster usually concentrates significant number of manufacturing units. For this reason many VO exist at the same time and one manufacturer may be involved in several contract realized in cooperation concurrently. This situation is visualized in the fig. 2.

It is also very probable that a cluster concentrates several business units with the same competencies, their factories may be facilitated in the similar machines and tools. Due to the fact, very often there is more than one potential contractor for a given task. Obviously each choice is related with particular consequences for a customer. Different configurations of Virtual Organization for the same order are characterized with different price, realization time, quality, risk level and many other minor factors. Significant number of alternatives and variables make process of VO structure establishment very complex. Searching for satisfying solution in such cases should be supported by an advisory system equipped in algorithms which deliver necessary logic and enables quick calculations of pros and cons.

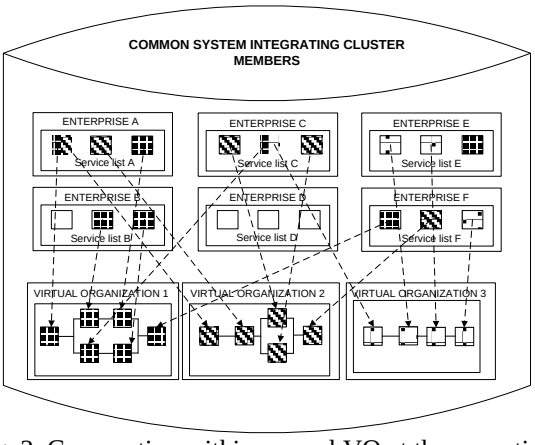

Fig. 2. Cooperation within several VO at the same time

2. System Supporting Partner Selection in Virtual Organization

The decision process in case of VO requires many data from several sources. For this reason the developed system supporting partner selection in dispersed manufacturing environment consist of four different layers. The system is pictured in the figure 3.They are bound to enable communication and data acquisition. The arrows in the fig. 3 indicate direction of the data flow.

It is assumed that the enterprises operating within cluster have to be connected with each other. This function is fulfilled with application based on Internet technology which enables easy communication, data and document exchange. This is very popular tool used not only in clusters but also in organizations which have divisions in different localizations. In the fig. 3 it is visualized as a Manufacturing Platform.

PDM/PLM application is also an integral part of the developed system. The fact that there is great variety of PDM/PLM applications available on the market increases probability that members of the cluster use different tools in this field. In such case there is necessity of data conversion to uniform data format and make it readable for every organization belonging to the association. This layer functionality enables stock, orders/projects and documentation control. Module aiding partner selection will acquire from PDM/PLM data related to the order e.g. list of operations necessary for its realization, process time per unit for each task, ordered quantity as well as information about company such as quality level gained by the manufacturing unit. This layer will not be further described because it is also standard and generally known element.

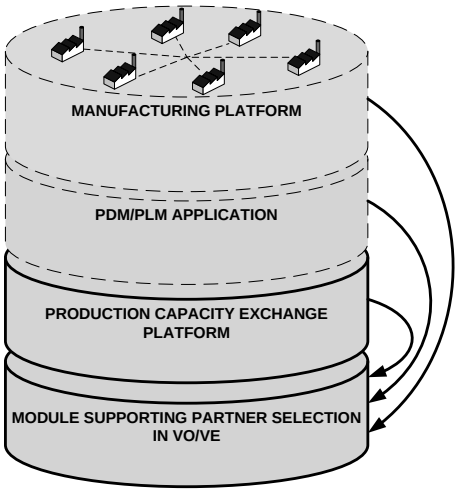

Fig. 3. Concept of the system supporting partner section in dispersed manufacturing environment

Production Capacity Exchange Platform constitutes layer dedicated for the proposed advisory system. It enables cluster members utilize their spare production capacity and acquire missing if there is a need. It also serves as a tool of communication in this field. It provides the advisory system supporting creation of VO/VE with information regarding

type of technology made available by members in a given month and number of man – hours offered within each category of tasks.

Module supporting partner selection in the VO/VE is a key element of the entire advisory system therefore the developed algorithm, set of inference rules and selection criteria. The system user may check how many possible solutions are available at the given moment and what is predictable result of implementing them. The selection criteria, set of rules and algorithm will be described in the next sections of this article.

Detailed information concerning functions of each module and data delivered to the Module Supporting Partner Selection in VO/VE are presented in table 1.

Tab. 1. Functions realized by the system modules and data delivered necessary for further analysis

Module	Functions	Data
MANUFACTURING PLATFORM	• Safe data exchange • Safe information exchange • Fast communication	• Contract details • Technical documentation • Negotiation progress and results
PDM/PLM APPLICATION	• Stock control • Orders control • Projects management • Documentation management	• Quality level • Ordered quantity • Process time (Tj) in man-hours • List of tasks included in order (workflow)
PRODUCTION CAPACITY EXCHANGE PLATFORM	• Utilizing production capacity surpluses • Complementing capacity shortages • Fast communication and access to the data concerning capacity	• Type of technology available • Number of man-hours available within the technology
MODULE SUPPORTING PARTNER SELECTION IN VO/VE	• Calculating weights of tasks listed in the considered order • Assigning tasks to cooperating units in accordance to the implemented rules set. • Determining risk factor for the chosen VO/VE configurations. • Visualization of each VO/VE configuration in form of graph. • Conducting sensitivity analysis for weights given to the selection criteria by the system user • Balancing workload within a cluster.	• Possible configurations of VO/VE which enable order/project realization • Cost of the order/project realization within each proposed configuration • Risk level of each configuration • Quality level of each configuration • Influence of wages assigned to the criterion by system user on the received result (sensitivity analysis)

3. Selection Criteria Implemented in the Developed System

The developed system uses several criteria during the decision process. The criteria are visualized in the fig. 4. Some of them are obligatory and cannot be omitted like time of an order realization. The system does not take into consideration configurations which exceed the deadline set for an order completion. Additionally it is always checked if a given company being potential contractor has enough capacity to realize a task to be assigned on time. The rest of criteria (Cost, Risk, Quality) may be optional. If the system user gives

weight equal 0 to one of them then it is not considered in the decision process. The importance of each of these three criteria is set by the system user.

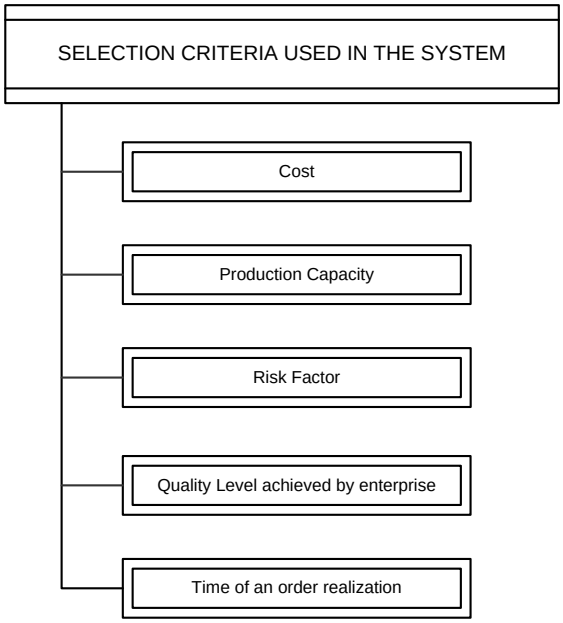

Fig. 4. Selection criteria used in the developer system

Each of the criteria has quite complex character that results from mathematical model built in the phase of the system design. Some of them are connected with particular set of rules used during reasoning process. Characteristic of each criterion is presented below all together with respective diagram. The diagrams presented in the fig. 5, 6 and 7 form extended version of the diagram presented in figure 4.

- **Cost** consists of four elements shown in fig. 5:
  - fixed cost resulting from entering given enterprise *j* to a VO/VE, joining the advanced dynamic structure requires from the company additional effort especially in the field of communication. Workers involved in the assigned tasks realization has to gain data about previous step(s) of the process and also inform unit chosen to the next tasks about details;
  - fixed cost resulting from work on assigned task *i* done by the enterprise *j*;
  - variable cost connected with the task *i* realization in the enterprise *j*;
  - transport cost for particular batch of product per unit distance from enterprise *j* to enterprise *h*.

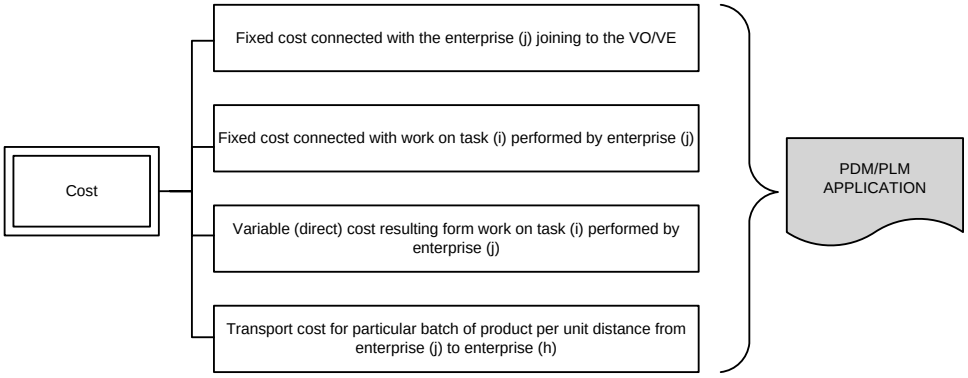

Fig. 5. Elements of costs included in the system.

– **Production Capacity** is basic criterion that enables considerably reduce solution space. Its structure is visualized in the figure 5. Theoretically it can be assumed that all members consolidated in the cluster are able to realize each task from any order but in practice it is not possible. First thing that has to be checked is technical conditions. Each task requires particular equipment if certain machine or tool is not offered by the company on the Production Capacity Exchange Platform (PCE Platform) then it is not considered as a candidate to the task realization. The rule for this part of reasoning process is following: 'If enterprise *j* has technical capacity necessary to the task *i* realization then enters the enterprise *j* to the list of potential contractors of the task *i*'. This aspect of capacity is named as a qualitative approach in the system model. The capacity has to be measured more precisely in man-hours available in the certain period. The system compares the number of hours offered with the number of hours needed. It does not let assign more hours to the enterprise then it was declared on the PCE Platform. This aspect is shown in the diagram as a quantitative approach.

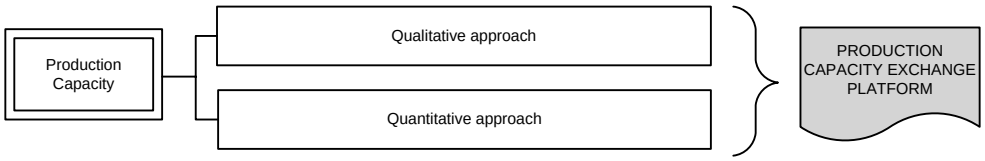

Fig. 1. Elements of Production Capacity included in the system.

– **Risk Factor** is connected with two elements:
  – first of them is ratio between number of man-hours declared on a PCE Platform (aij) to accumulated number of man-hours assigned in a given category of work ($\sum$xij). The smallest result of the quotient the bigger risk factor because of the small safety buffer to be used in case of unexpected events;
  – second indicator that influences level of a risk is a task weight. The bigger task weight the bigger risk. The weight is calculated on the base of kind of

competence needed for the task realization. If the competence necessary for the task realization are unique in scale of entire cluster than the risk is higher because there is not many possibilities of replacement when the chosen contractors fail to meet the expectations. Another indicator of the weight is ratio of the man-hours of the task to man-hours of entire order. If this proportion has high value then it gives higher weight to the task. Structure of the Risk Factor is presented in the fig. 7.

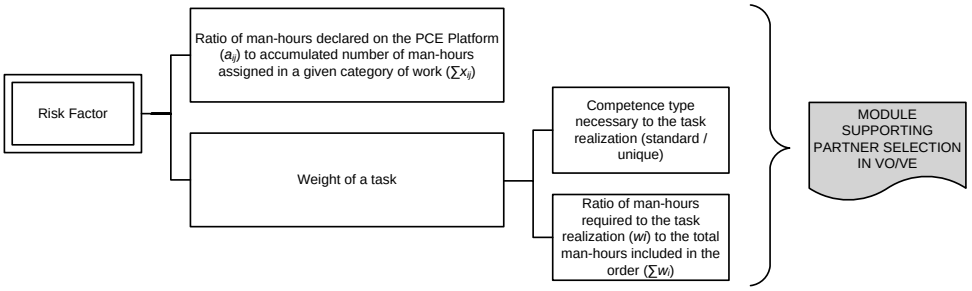

Fig. 2. Risk factor components included in the system.

- **Quality level** achieved by a company. This criterion is expressed by number. It is assumed that all cluster members use the same system to their quality measurement. If this is not true there should be specified common system of determining quality level in each production unit belonging to the consolidation. The data referring to the quality issued should be saved in PDM/PLM system.
- **Time of an order realization** has binary character. It is not important how many days the process takes but whether it finishes before or after deadline. Obviously VO/VE configurations which does not meet fixed deadline will not be taken in consideration in the further analysis.

4. Algorithm Supporting Partner Selection in VO/VE

The data needed to use the criteria set determined in the previous section are acquired from different layers of the system designed but they are finally processed in the Module Supporting Partner Selection in VO/VE. This part of the system, thanks to implementation of advanced algorithm, is able to advice user about most suitable VO/VE configuration in accordance to the defined constraints. Each step of the algorithm is such complex that it could be presented in form of sub steps but it requires presentation of extensive mathematical model. For this reason the algorithm steps are presented briefly to grasp general idea and aim of the planned calculations. The algorithm is described in diagram block, fig. 8.

Step 1 covers acquiring data about the preferences for the given order. If any of the three criteria is not important for the customer then the weight of this criterion is equal 0. The system only lets to choose numbers for the weights which sum is equal 1. This information is crucial for the functions in step 8.

Step 2 consists of preparation space for the further operations. During this phase the system collects list of tasks needed to the order realization and list of potential candidates

for each task. It checks which member of the cluster has necessary machine/tools and enough man-hours to realize the task.

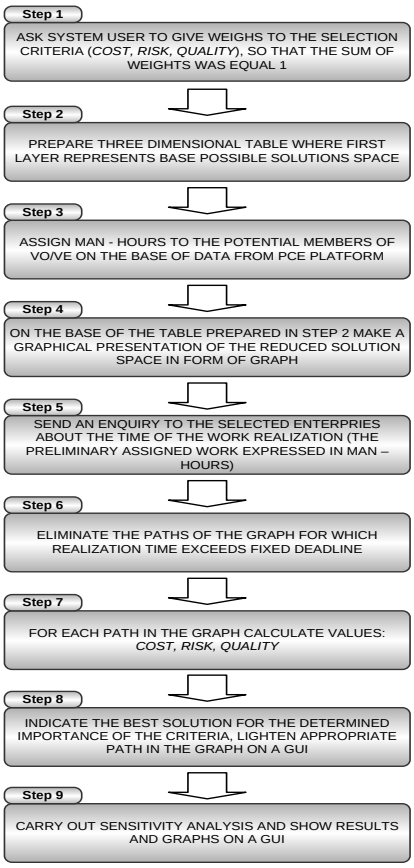

Fig. 8. Main steps of the algorithm developed for module supporting partner selection in VO/VE.

In step 3 man-hours are assigned to the potential contractors in accordance to the determined inference rules. The system checks whether there is possibility of realizing one task in one production unit. If it is not, then the task is divided between several contractors. The weight of task is also important variable in this place.

Step 4 enables to convert numerical data into graph. This form is assumed to be clear and readable for the system user.

In step 5 the system verifies which of the found alternative configuration does not fulfill necessary condition. This condition is deadline for order realization.

Step 6 enables to see on GUI reduced solution space with the paths of the graph which meets the fixed deadline.

Step 7, the three values: cost, risk and quality will be calculated in accordance with information given in section 3. In this place the system gather arguments that enable to asses and rank the configurations, left after the preliminary elimination made in step 5 in a logical way.

In step 8 the system indicates preferred solution. It is obviously chosen with consideration of the criteria weights determined by the system user in step 1.

Step 9 enables to check what would happen if other values of weights were chosen. This last part of the procedure enable to take a more rational decision and find out the best alternatives in case of unexpected events like machine failure in one of the chosen units. The algorithm presented in this section enables to effectively use a significant number of data. If the decision process is not supported by any artificial intelligence then the decisions are usually taken intuitively and there is not possibility to explain them logically. Here the solution search is transparent. Additionally the system characterizes big flexibility because user decides which criteria are taken in the analysis and what is their importance. It is big advantage because in practice for some orders the highest priority is quality while for the others cost.

5. Conclusions and Future Work

The developed system is expected to be a very useful tool for enterprises associated within a cluster. In last decades one can observe a clear trend towards integration related with strive to flexibility and innovations. Operating in the modern business structures like virtual organizations requires new aiding applications with special functionalities adjusted to the specific conditions. The proposed system has very universal character and can be easily extended with a new criterion or another algorithm for example genetic or branch and bound algorithms. The procedures stipulated in the system are tested with data from really existing cluster CINNOMATECH. A special model reflecting character of this cluster was built in AnyLogic. It has hybrid character because comprises elements of agent modeling approach in field of each enterprise characteristic modeling and process approach in field of an order realization. The results of the developed algorithm testing will show whether any corrections and modifications are required.

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