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Evaluation of the operation expedience of technological resources in a manufacturing network

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Abstract. Cost-effective manufacturing and technology-based manufacturing are basic keywords in contemporary manufacturing. Efficiency and productivity require extremely good job management, correlation of resources and competencies to production requirements, as well as continuous monitoring of possible wastes and additional expenditures, i.e. real efficiency of the continuous improvement process. In the current article the methodology of technological resources and competence management evaluation in terms of manufacturing system ontology are analysed in pre-order and post-order fulfilment stages. The expedience of resources operation and order outsourcing, but also corresponding risk management principles are analysed. The elaborated methodology enables enterprises to implement a more rational utilization of manufacturing resources by estimating the influence of existing competencies and technological possibilities into productivity and efficiency.

Key words: e-manufacturing, system ontology, technological resources, requirement analysis, system behaviour.

1. INTRODUCTION

The value of a product in an enterprise forms during realization of different business processes. Basically, business processes are structures and targeted sets of elementary events, functioning by fixed rules. Certain resources and knowledge are required for the occurrence of elementary events. Process efficiency can be expressed through the cost or time of the exploited resource.

The main part of the added value to the customer is created by the production system. Therefore the production system plays a central role in every manufacturing company. At the same time, production is one of the systems, which have the most complicated configuration and functionality in the company where various technological processes run simultaneously. Technological resources constitute an important part of the production system, characterized by technological possibilities. They determine the nomenclature of workpieces that can be produced in a certain production system.

Make-to-order (MTO) production needs availability of different technological resources and high flexibility. If machine tools of a manufacturing system have more technological capabilities [1,2], they enable wider production nomenclature, higher accuracy and complexity. Technological possibilities and the competence of employees have direct influence on the workstation productivity and therefore on the whole manufacturing process productivity and efficiency [3]. Every new manufacturing order challenges both technological resources and specific competencies while exaggerating becomes costly. Optimal use of technological resources facilitates efficiency and productivity. Analysis of necessary technological possibilities and competencies (requirements loop) before every order, and analysis of efficiency of performance (behaviour loop) after fulfilment of an order are necessary. Performance appraisal analysis sustains essential part in the continuous improvement process. Irrational prolongation of the production time is directly related to insufficient technological possibilities, and idle time rate increase refers to the absence of necessary competence.

Ensuring efficiency in a single enterprise becomes an increasingly sophisticated task as the nomenclature of products expands, clients' expectations to quality grow higher, and technological improvement is needed to ensure competitiveness. As a solution, attention is directed towards the development of production networks and clusters, enabling rational resource sharing and limitation of expenses. Networking presumes the possession of adequate information about partners' technological capabilities. Therefore development of a web-based information system with corresponding database is inevitable. Rational decision-making for such information system is not possible without estimation of the outsourced work amount, distances between subcontracted workplaces, but also possible risks of involving partner enterprises.

2. ONTOLOGY OF A PRODUCTION SYSTEM

A system is a set of interacting or interdependent entities forming an integrated whole. Most systems share common characteristics, including structure, behaviour, interconnectivity and functions [4]. A system may consist of subsystems. A company is a system that operates in a certain location and in a certain customer-oriented field of activity. A company may belong to a group (network), whereby its belonging to the network may be abstract (undetermined) or the company may have certain connections or functions in the network. One example of determined belonging to the network is the cluster structure [5].

The increasing product complexity and emerging manufacturing globalization require the cooperation and coordination of manufacturing enterprises [6]. The resource sharing and reuse among these enterprises are essential for achieving efficiency and competitiveness. Manufacturing companies may operate in networks, complementing each other via technological resources. With an aim to make collaboration more efficient, information systems are developed that enable to describe technological resources of a company, determine expediency of their use, analyse the rate of use of the resources and, if necessary, make exchange transactions, offering unemployed resources and buying necessary resources with the aim of mutual benefit. This information system requires unified ontology and semantics from the viewpoint of system development as well as system use.

A standardized terminology needs to be semantically consistent across the organization boundaries, since the communication aspects of information require that communicating parties have the same understanding of the meaning of the exchanged information [7–9]. Representation of knowledge is also a medium for human expression [10]. An important contribution to the success of Internet is its openness, so anyone can contribute to the body of information [11] in terms of common taxonomy. An approach to defining manufacturing taxonomy and axioms, based on a manufacturing system engineering (MSE) ontology is presented in Fig. 1.

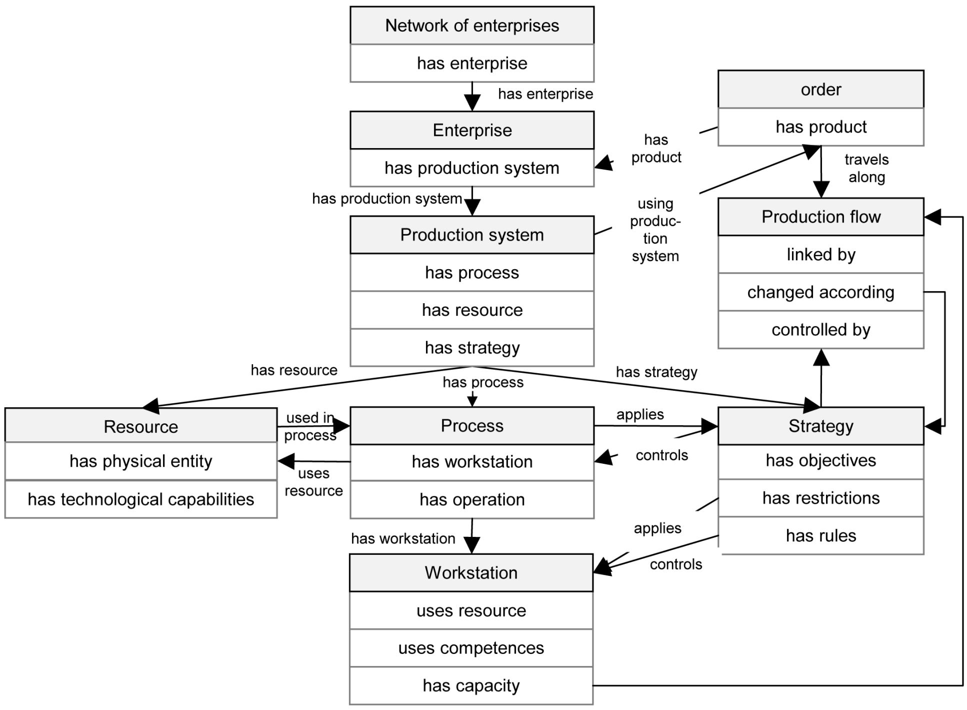


Fig. 1. Model of the ontology of a production system.

The production system has certain resources, processes and strategies (Fig. 1). Production system is characterized by physical environment (number, type, model of machine tools, their layout and location) and functional environment that is expressed by technological possibilities of machine tools. Machine tools have mutual logistical relations inside the system as well as with the external environment.

Technological possibilities of a company's production system depend mainly on the technological possibilities of the machinery (machine tools, presses, welding equipment etc). Technological possibilities can be defined as a set of characteristics of a device (machine tool, industrial robot, manufacturing cell) for producing a specific workpiece or performing a certain technological task. Manufacturing a product requires implementing a certain amount of technological possibilities. When the necessary parameters for manufacturing a product exceed technological possibilities of a machine tool, the use of different machine tools is required. While manufacturing simple and similar products, it is usually not economically reasonable to use too complicated equipment.

Technological possibilities of the equipment, belonging to the production system, determine greatly the essence of the processes taking place in this system and are also a basis for forming possible strategies.

In addition to the technological environment (machine tool with its technological possibilities) the machine tool operator with his/her competences belongs to the workstation. The human's skills, knowledge, experience and motivation to apply them in a team influence how many pieces he/she can produce during a certain time period using a certain machine with certain technological possibilities. Therefore using the same machine and applying the same organizational methods, one employee can produce much more details than another during the same time. Influence of the human factor to the productivity is larger when the process is less automated [12]. This combination (machine tool with its technological possibilities and machine tool operator with its competence) determines technological capability of a workstation and forms the basis when determining the company strategy and order portfolio and planning production flows. Raising efficiency of the production flow begins with raising the workstations' productivity through the development of technological capabilities and competence.

3. A MODEL FOR ANALYSING THE CAPABILITIES OF THE MANUFACTURING SYSTEM

Business strategies of small and medium-sized enterprises (SME) are mostly based on order-centred manufacturing. Make-to-order is a production environment in which a product is produced according to customer's order. The final production is usually a combination of standard and custom-designed items to meet the specific needs of a customer. In such type of organization the sequence of the main business processes is usually the following:

Sell – Design – Produce.

MTO organizations have typically discontinuous flow of operations, which are highly customized and often use unique production methods. The manufacturing processes must be highly flexible, but quite often are not very cost effective. As identified by Toyota's Chief Engineer, Taiichi Ohno, in the Toyota Production System seven forms of waste are distinguished [13]: inventory, delay, motion, transportation, overproduction, overprocessing and defects.

Production planning task becomes even more difficult when products are quite different by complexity and technology. Additional costs are typically caused by poor organization of production (delays or unsuitable use of resources), unpractical production structures (excessive transportation times) and incompetence (lacking of needed competence analysis).

According to the system development and behaviour ontology, we can distinguish two decision-making circles (Fig. 2). The basic loops are:

– requirement loop, defining technological possibilities/competencies required for order fulfilling; it relates these to existing possibilities/competencies and technological capabilities of the production system;
– behaviour loop, observing the correspondence of performance level activities to order fulfilment measures of efficiency and compares outputs with expert estimation of the system capability.

The correspondence of the manufacturing needs (resources, competencies) to the manufacturing system capability (technological possibilities of technological devices, existing competencies) determine the success of the manufacturing process (productivity, efficiency). Overestimation of technological possibilities and existing competencies causes additional cost to manufacturing. Underestimation of the capabilities brings along uneven resource allocation or possible profit loss.

Requirement loop is carried out by comparing the required needs and manufacturing feasibility expert estimation. As indicated in Eqs (1) and (2), required

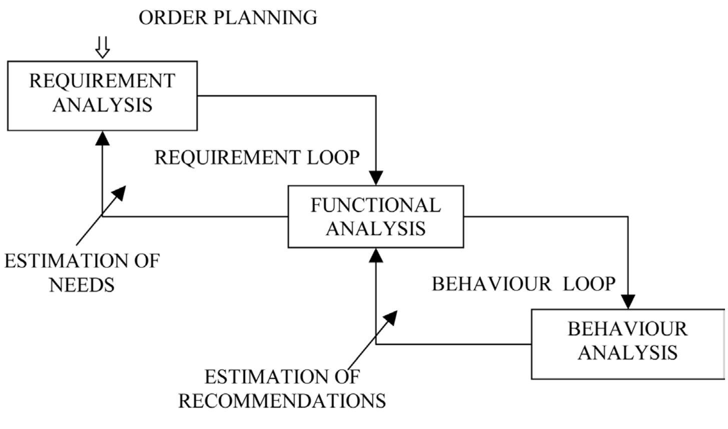


Fig. 2. Event and process engineering design model, proceeding from the needed complexity.

needs are based upon the number of necessary parameters $\bigcup P_w$ (product dimensions, manufacturing accuracy, surface finishing, surface roughness, etc) compared with the number of production system parameters $\bigcup P_s$ and needed competencies $\bigcup S_w$ to existing competencies $\bigcup S_s$ [14]

$$\bigcup_{i=1}^{p} P_{Wi} \leq \bigcup_{i=1}^{p} P_{Si}, \tag{1}$$

where p is the number of technological parameters,

$$\bigcup_{i=1}^{q} S_{Wi} \leq \bigcup_{i=1}^{q} S_{Si}, \tag{2}$$

where q is the number of competencies.

Expert estimation of the utilization expedience can be given regarding the following aspects:

s_1 – estimation of technological resources (manufacturing methods, technological possibilities), $s_1 = \{0,1\}$;

s_2 – estimation of the manufacturing competence (necessary and existing skills and knowledge), $s_2 = \{0,1\}$;

s_3 – estimation of the manufacturing organization structure (workshop layout, level of automation, complexity of the manufacturing path), $s_3 = \{0,1\}$.

Complex estimation of the utilization expedience is $S = s_1 \times s_2 \times s_3$. It is the decision of the management, based upon experience and behaviour loop results.

While analysing the behaviour of the production system we can perform order-based comparison of system parameters with overall economic parameters and make strategic decisions in terms of product mix, order fulfilment, enterprise technological excellence or management strategies. Corresponding parameters are shown in Table 1.

Utilization rate U_{ind} is expressed as

$$U_{\text{ind}} = \frac{T_{\text{m}}}{F}, \tag{3}$$

where T_{m} is the machine tool using time and F is the overall working time.

Table 1. Performance indicators for order fulfilment analysis

No	Performance indicator	Primary factor influenced by the performance indicator
1	Utilization rate	Overall equipment effectiveness (OEE)
2	Setup rate	Cost
3	Flexibility index	Cycle time
4	Idle-time rate	Productivity
5	Non-productive time rate	Productivity
6	Variance index	Cost
7	Fulfilment rate	Productivity

Utilization rate of machine tools indicates the rate of useful, productive time of machine tools compared with overall working time (workload). Workload of machine tools depends on the number of shifts. In case of one-shift work, usually utilization rate of machine tools between 75%–85% is considered effective.

Also overall equipment effectiveness (*OEE*) could be used to quantify how well a manufacturing unit performs relative to its designed capacity, during the periods when it is scheduled to run. *OEE* breaks the performance of a manufacturing unit into three separate but measurable components: availability, performance, and quality (Eq. (1)). Each component shows an aspect of the process that can be targeted for improvement. Availability represents the percentage of scheduled time that the operation is available to operate, often referred to as uptime, performance represents the speed at which the work centre runs as a percentage of its designed speed, and quality represents the good units produced as a percentage of the total units started. *OEE* may be applied to any individual work centre, or rolled up to department or plant levels. This tool also allows for drilling down for very specific analysis, such as a particular part number, shift, or any of several other parameters. It is unlikely that any manufacturing process can run at 100% *OEE*. Many manufacturers benchmark their industry to set a challenging target, 85% is not uncommon:

$$OEE = A \times P \times Q, \tag{4}$$

where A is availability, P is performance and Q is quality.

The setup rate is defined as

$$S_{\mathrm{ind}} = \frac{T_{\mathrm{sp}}}{T_{\mathrm{m}}}, \tag{5}$$

where S_{ind} is the setup rate and T_{sp} is the setup time (time needed for converting a manufacturing process from running the current product to running the next product).

Setup rate indicates the percentage of time needed for converting a manufacturing process from running the current product to running the next product, compared with overall working time of machine tools. The less time is needed for setup compared with overall working time of machine tools, the higher is efficiency.

Flexibility index is defined as

$$F_{\mathrm{ind}} = \frac{nT_{\mathrm{sp}}}{NT_{\mathrm{ct}}}, \tag{6}$$

where n is the number of different types of workpieces in a time period (nomenclature), N is the production amount of workpieces in a time period and T_{ct} is the average cycle time in a time period.

Cycle time is measured by the amount of time per unit (e.g., hours/part). Cycle time is a measure of throughput (units per a period of time), which is the reciprocal of the cycle time. Lead time and cycle time are related to work in progress (W) in the entire process, in a relationship described as:

$$L = T_{\mathrm{ct}} \times W, \tag{7}$$

where L is the lead time and W is work in progress, and

$$L = \frac{W}{T}, \tag{8}$$

where T is throughput.

Lead time is measured by elapsed time and can be expressed as a sum of transportation time, setup time, control and measurement time, operation time and idle time.

Idle time, also called waiting time, indicates stoppage of work of employees or machines or both due to any cause:

$$I_{\mathrm{ind}} = \frac{T_{\mathrm{i}}}{L}, \tag{9}$$

where I_{ind} is idle time rate and T_{i} is idle time.

Non-productive time T_{nt} consists of all times when no value is created to the customer:

$$T_{\mathrm{nt}} = T_{\mathrm{tr}} + T_{\mathrm{sp}} + T_{\mathrm{mc}} + T_{\mathrm{i}}, \tag{10}$$

where T_{tr} is transportation time and T_{mc} is measurement and control time.

Also non-productive time rate T_{ind} can be calculated:

$$T_{\mathrm{ind}} = \frac{T_{\mathrm{nt}}}{L}. \tag{11}$$

Variance index V_{ind} and fulfilment rate R_{ind} can be calculated as

$$V_{\mathrm{ind}} = \frac{n}{N}, \tag{12}$$

$$R_{\mathrm{ind}} = \frac{q}{Q}, \tag{13}$$

where q is orders fulfilled in time period and Q is total number of orders per time period.

After a positive decision of order fulfilment in an enterprise, the optimal use of production system resources is essential, targeted to optimized resources allocation.

4. OPTIMAL USE OF TECHNOLOGICAL RESOURCES IN PRODUCTION FLOW ORGANIZATION

Performance of a manufacturing system is realized through completing technological tasks. The result depends on the fact how production system is organized, tasks formed and forwarded to workstations. Inputs to this activity are production volume and product mix. The main parameters, describing expediency of the use of technological resources, are:

- extent of using technological resources;
- extent of using machine tools;
- extent of flexibility – exchangeability of technological resources.

Factors that determine how well production system is realized are the following:

- suitability of the company's technological resources to the company's profile;
- efficiency of use of these technological resources in production.

The optimal manufacturing planning is traditionally based on the use of mathematical programming by optimizing the objectives that represent the results we want to achieve and considering possible constraints existing in production. This approach can be used in determining optimal number of machine tools.

The choice and type of machine tools have a strong direct influence on the efficiency of the company. Capacity decisions have a major impact on all other production planning issues (e.g., aggregate planning, demand management, sequencing and scheduling, shop floor control). Once we have decided that we need to add capacity, the question arises: how much and when should capacity be added? To estimate the need for using additional resources and the optimal level of inventory, both product-mix planning and aggregate planning models can be used. In both models decisions are related to corresponding constraints. For the need to increase (decrease) the accessible capacity, different tools of sensitivity analysis or post-optimality analysis can be used.

Optimizing technological routes and dividing production operations among workstations are the most essential tasks in addition to determining the number of required resources. The model for determining numerically technological resources is the following:

$$\min \sum_{j=1}^{J} (X_j P_j + C_j \sum_{i=1}^{I} \sum_{k=1}^{k_i} Y_i k_j t_{ikj}), \tag{14}$$

subject to constraints:

$$\sum_{i=1}^{I} \sum_{k=1}^{k_i} Y_{ikj} t_{ikj} \le X_j F_j \eta_j, \quad j = 1, 2, \ldots, J,$$

$$\sum_{j=1}^{J} Y_{ikj} = N_i, \quad k = 1, 2, \ldots, K, i = 1, 2, \ldots, I,$$

$$X \geq 0, \quad X_i = int,$$

$$Y_{ikj} \geq 0, \quad Y_{ikj} = int,$$

where i is the type of processed workpiece (from the product mix), N_i is production amount of workpieces in a time period, j is the type of the machine tool, I is the number of types of possible workpieces for processing using machine tool j, k is the number of processing types, J is the number of types of machine tools, which enable to perform the processing type k, t_{ikj} is time of realization of the process ik using machine tool j, F_j is effective work time front of the machine tool j, η_j is planned loading coefficient of machine tool j, P_j is the price of the machine tool j used for processing workpieces of type i (from the product mix), C_j is the cost of a working hour of machine tool j, X_j is the number of machine tools of type j used for processing workpieces of the type i (from the product mix) and Y_{ikj} is the number of workpieces of type i used for processing operation k using machine tool of the type j.

Exploitation of machine tools has to be as unvaried as possible. Bottleneck cannot be evoked at a machine tool, which has several technological possibilities. Hence the need for choosing processing methods in the phase of composing manufacturing routes and alternative routes, if necessary. Therefore, the expert system should belong to the information system of technological resources management.

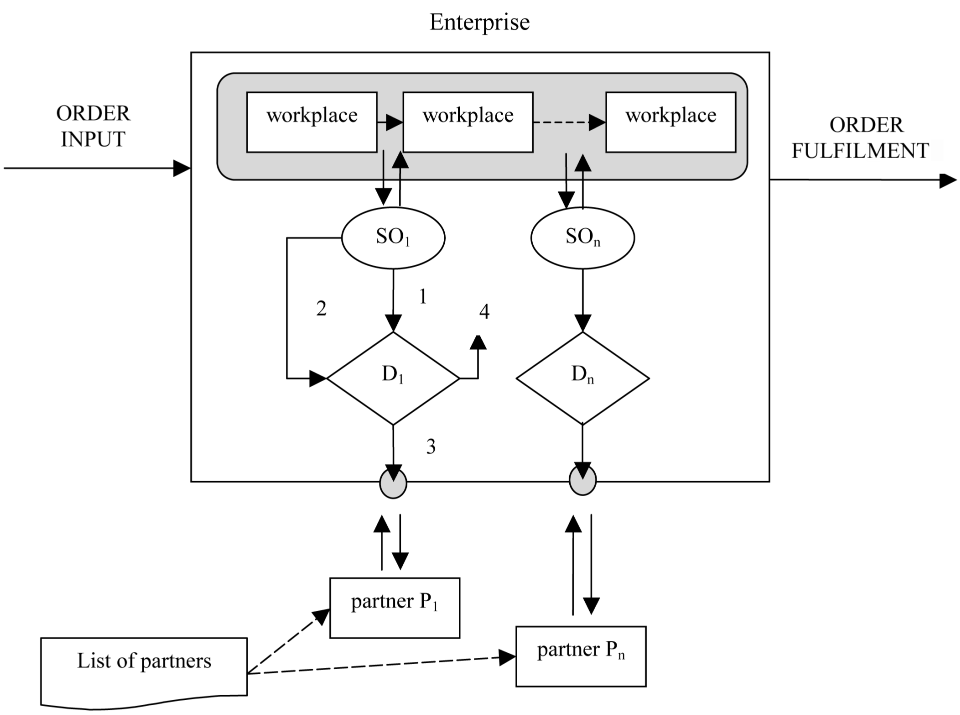
5. NETWORK MANUFACTURING AND RISK ASSESSMENT

Every order has to be fulfilled in time and according to quality requirements. The main problem lies in cost optimization. If the company lacks previous experience, competencies and technological possibilities (Fig. 2), possible risks arise with fulfilling the order in time and with high quality, and staying on the planned level of expenses at the same time. In this case, network of partners can be used.

Network manufacturing and formation of clusters have increased considerably in recent years. The main cause lies in customers' pressure on quality and order fulfilment time, but also in need to minimize production costs. It is quite difficult and is not always beneficial to strive for technological consummation. When a company has defined its technological capabilities on both levels, production system and work places, it expects it from other partners as well. Thus, a network with certain resources and capabilities is created that can increase or decrease, depending on circumstances.

E-manufacturing (e-mfg) can play a key role in improving the efficiency, throughput and responsiveness of a company. E-mfg is the use of (web-based) information technology to exchange efficiency of manufacturing and related processes. E-mfg is the application of open, flexible, reconfigurable computing techniques and communication for the enhancement of efficiency of the whole supply chain. As e-mfg is supported by information technology (such as Internet) and has the capability in multi-site management, it will foster and improve the competitive capability of manufacturing in the global competition [15]. E-mfg can be determined as IT-based manufacturing model, optimizing resource handling over entire enterprise and extended supply chain [16]. Using Internet and tools that support commerce functions, one can find new customers, reduce the costs of managing orders and interacting with a wide range of suppliers and trading partners, and even develop new types of informationa-based products, such as remote monitoring and control software and other online services [17]. The emphasis is on the aspect that decisions made by implementing e-mfg affect the whole supply chain and they must always be made to benefit the entire supply chain, not just an individual manufacturing company.

Outsourcing single parts of an order presumes risk assessment and making certain decisions (Fig. 3).



SO – places, where it is decided whether to perform an action by itself or to outsource
D – decision about performing by oneself or outsourcing
1 – risk assessment (what are the risks when performing by oneself or outsourcing)
2 – analysis of technological capabilities of a partner
3 – outsource is more effective than performing an action by oneself
4 – performing an action is more effective than outsourcing

Fig. 3. Generalized scheme of network manufacturing.

It is possible to determine the basis for creating a network of possible partners by collecting and analysing data that can be used for outsourcing part of the orders. Mainly three types of risk factors exist for outsourcing an order to possible partners:

- partner's location;
- technological capability of the partner;
- trustworthiness of the partner.

When planning to use several partners for order fulfilment, the transport routes should be optimized and minimum length of transport routes should be determined:

$$\min \sum_{i=1} \sum_{j=1} f_{ij} d_{ij} p(j), \tag{15}$$

where f_{ij} is the flow matrix F, whose (i, j) element (part of product) represents the flow between facilities i and j, d_{ij} is the distance matrix $D\ (i, j)$, the elements of which represent the distance between locations i and j, and $p\ (j)$ is the location to which the facility (partner j) is assigned.

Risk assessment consists of an objective evaluation of risk, in which assumptions and uncertainties are clearly considered and presented. Part of the difficulty of risk assessment is that both quantities, in which risk assessment is concerned, potential loss and probability of occurrence, can be difficult to measure. This problem and extent of faults can be decreased by creating empirical information basis in the company. Parameters, forming the information base, are the following:

- nature of orders (parametrical and functional description of products);
- evaluation of company's technological capabilities (utilization rate index);
- analysis of company's performance in order fulfilment (Table 1);
- lengths of transport routes in case of network manufacturing;
- index of technological capabilities of partner companies;
- index of trustworthiness of partner companies.

On the basis of these expert estimations, it is possible to evaluate the risk R_{total} of outsourcing parts of the order to partner companies:

$$R_{\text{total}} = \sum L_i P(L_i), \tag{16}$$

where L_i is the magnitude of the potential loss when the risk of type i occurs and $P(L_i)$ is the probability that the risk of type i occurs.

Types of the risk i may be different, for example, delayed delivery time for product assembly, work does not respond to quality requirements, fluctuation in the product price, etc.

Estimation of the total risk that may occur in case of network manufacturing helps to minimize potential losses to the company that arise because of overestimating the partners' capabilities. Presuming that technological processes are becoming more and more complicated and installing all of them economically inefficient, network manufacturing becomes more perspective.

6. CONCLUSIONS

The key factors that can influence the company's production capability have been investigated. Technological possibilities play an important role in designing operational and route technologies but also in management of the whole production process. Framework of the technological resources management system and network manufacturing with the aim to optimize the use of technological capabilities and to increase efficiency through extended use and exchange of technological resources were presented. Information system for resource management inside one company as well as in the network of companies can be one part of the more wide e-manufacturing system. For smooth performance of the resource management system as a part of more wide e-manufacturing system, unified ontology and semantics are needed. Ontology model is important from two aspects:

1) explaining products flow through the production process with the aim to optimize production costs and analyse other parameters that can help to minimize the lead time;
2) building up architecture for e-manufacturing system software.

The results of this phase are used for further development of the database and system for controlling, managing and exchanging manufacturing services, based on technological resources of the companies in the network.

Standardization is important not only regarding exchange of information in the manufacturing network within and between the companies, but also regarding working methods, etc. It will increase quality and productivity and decrease cost, making cooperation more efficient.

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REFERENCES

1. Riives, J., Lõun, K. and Otto, T. Framework for extended use of technological resources in the network of enterprises. In *Proc. 7th International DAAAM Baltic Conference "Industrial Engineering"*, Tallinn, 2010.

2. Riives, J., Otto, T. and Papstel, J. Monitoring of technological resources for extended usage. In *Proc. 4th International DAAAM Conference "Industrial Engineering – Innovation as Competitive Edge for SME"*, Tallinn, 2004.
3. Lõun, K. *Enhancement of Company's Competitiveness by Using Process Approach*. LAP Lambert Academic Publishing, 2010.
4. Askin, R. G. and Stanridge, S. R. *Modeling and Analysis of Manufacturing Systems*. Wiley, 1993.
5. Porter, M. E. *Competitive Strategy: Techniques for Analyzing Industries and Competitors*. Free Press, New York, 1980.
6. Huang, G. Q., Lee, S. W. and Mak, K. L. Synchronized web applications for product development in the 21st century. *Int. J. Adv. Manufact. Technol.*, 2001, **18**, 605–613.
7. Lin, H. K. and Harding, J. A. A manufacturing system engineering ontology model on the semantic web for inter-enterprise collaboration. *Computers in Industry*, 2007, **58**, 428–437.
8. Lin, H. K., Harding, J. A. and Shahbaz, M. Manufacturing system engineering ontology for semantic interoperability across extended project teams. *Int. J. Production Res.*, 2004, **42**, 5099–5118.
9. Zhao, J., Cheung, W. M., Young, R. I. and Bell, R. An object oriented manufacturing data model for a global enterprise. In *Proc. 15th International Conference on Computer Aided Production Engineering (CAPE'99)*, Durham, UK, 1999, 582–588.
10. Gaševiic, M., Djuric, D. and Devedžic, V. *Model Driven Engineering and Ontology Development*. Springer, 2009.
11. Allemang, D. and Hendler, J. *Semantic Web for the Working Ontologist*. Elsevier, 2007.
12. Otto, T., Riives, J. and Lõun, K. Productivity improvement through monitoring of human resources competence level. In *DAAAM International Scientific Book*, Vienna, 2008, 565–576.
13. Bell, S. *Lean Enterprise Systems. Using IT for Continuous Improvement*. Wiley, 2006.
14. Riives, J. and Otto, T. (eds). *Innovative Development of Human Resources in Enterprise and Society*. TUT Press, Tallinn, 2007.
15. Wang, L. D. An information-integrated framework to support e-Manufacturing. *Int. J. Adv. Manufact. Technol.*, 2007, **32**, 625–630.
16. Lee, J. E-manufacturing – fundamental, tools, and transformation. *Robotics Computer Integrated Manufact.*, 2003, **19**, 501–507.
17. Worthington, S. L. S. and Boyes, W. *E-business in Manufacturing: Putting the Internet to Work in the Industrial Enterprise*. ISA, The Instrumentation, Systems, and Automation Society, 2002.

Tehnoloogiliste ressursside kasutamise otstarbekuse hindamine tootmisvõrgustikus

Kaia Lõun, Jüri Riives ja Tauno Otto

Tänapäeva tootmist iseloomustavad põhimärksõnad on kuluefektiivne tootmine ja tehnoloogial põhinev tootmine. Efektiivsuse ja tootlikkuse saavutamine eeldab väga head töökorraldust, ressursside ning kompetentsi täpset vastavust tootmisnõuetele ja kõigi võimalike raiskamiste ning lisakulutuste pidevat jälgimist ja kohest reageerimist nendele ehk parendamisprotsessi pidevat reaalset toimimist. Käesolevas artiklis on lähtutud tootmissüsteemi esitluse ontoloogiast ja kirjeldatud tootmisressursside ning tootmiskompetentsi haldamise metoodikat nii tellimuse täitmise eelses kui ka järgses staadiumis. Samuti on esitatud ressursside

jaotuse ja tellimuse osade väljamüümise otstarbekuse ning vastavate riskide haldamise üldised põhimõtted. Kirjeldatud põhimõtete järgimine ettevõttes võimaldab tootmisressursse ratsionaalsemalt kasutada ja hinnata olemasoleva kompetentsi ning seadmete tehnoloogiliste võimaluste mõju tootlikkusele ja ettevõtte efektiivsusele.