Analysis of manufacturing networks and supply chains from the operation strategy perspective

Analýza zpracovatelských sítí a nabídkových řetězců z pohledu výrobních strategií

E. Smělíková

Mendel University of Agriculture and Forestry, Brno, Czech Republic

Abstract: The aim of this paper is to analyse manufacturing networks and supply chains from the operations strategy perspective. These two areas have traditionally been treated as separate research objectives, but under the conditions of the ongoing globalisation, there is a need to integrate these complementary disciplines to study the networks of facilities. In this paper, there is presented a typology for the analysis of the network system resulting in four basic network configurations. On the basis of this configuration, there is presented the coordination matrix, which distinguishes four types of the coordination activities.

Key words: supply chain, network, operation strategy, manufacturing

Abstrakt: Cílem toho příspěvku je analyzovat zpracovatelské (výrobní) sítě a nabídkové řetězce z pohledu výrobních strategií. Tyto dvě oblasti jsou tradičně vnímány odděleně, avšak v podmínkách pokračující globalizace je žádoucí tyto dvě oblasti hodnotového řetězce pro podrobnější zkoumání sloučit a zkoumat jako celek. Příspěvek klasifikuje analyzované systémy do čtyř různých typů sítí, z nichž vychází matice koordinace, která předkládá čtyři možné způsoby koordinačních činností rozčleněných na základě síťové konfigurace.

Klíčová slova: nabídkový řetězec, síť, výrobní strategie, zpracování

The fact that business today is international is indisputable. During the last decade, there has been an explosive increase in both international trade and foreign direct investments, and many markets are now really global. The role of manufacturing companies has changed from supplying domestic markets with products, via supplying international markets through export, to supplying international markets through local manufacturing. Hence, the research on international issues in manufacturing has evolved from the global sales and marketing into global manufacturing.

Globalization describes a process of increasing economic integration and can be defined as the process of converting separate national economies into an integrated world economy. The distinctive character of the globalization period which marks the difference to earlier periods of economic integration has two features: (i) deepening of economic integration and (ii) an enlargement of the number of countries taking part in economic integration.

Evolution of the *supply chain* in the last 30 years is depicted in Figure l. The supply chain has witnessed a number of major turning points as the growth (in horizontal and vertical direction) of the major retailers has impacted distribution. The grocery industry is witnessing an ever increasing pressure to maintain profits and remain competitive in a industry that has been enormous changes over the last few decades. The diagram below shows also how responsibility for the movement of goods has shifted to the retailers in

Supported by the Grant Agency of ČR (Grant No. 402/06/P294 "The Influence of Finalizing Links on Agribusiness under the Conditions of the Knowledge Economy", which is closely related with the research project the Ministry of Education, Youth and Sports of the Czech Republic (Grant No. 6215648904 "The Czech Economy in the Process of Integration and Globalisation, and the Development of Agricultural Sector and the Sector of Services under the New Conditions of the Integrated European Market").

the last 30 years. A number of factors has combined to make efficiencies in the supply chain a necessity for the major multiples. The current supply chain has to respond to the continued changing needs of the retail outlets as they strive to meet consumer demands in the most cost effective way.

As a result of globalisation, the vast majority of manufacturing in large companies is carried out in value networks. As a value network, there is regarded a network of facilities, possibly owned by different organizations, where time, place or shape utility is added to a good in various stages such that value for the ultimate customer is increased. However, the manufacturing related activities and issues in the network are viewed from different angles. This can be illustrated by two major research objectives

Evolution of supply chain in the European grocery market

1970's

The 1970's saw the beginning of the trend towards centralised distribution:

- Centralised buying and stock management began to develop with retailers using their size to bulk buy products at more favourable terms.
- Large retailers developed regional warehouses and transport facilities through the creation of regional distribution centres
- The introduction of bar codes on products allowed the development of EPOS scanning in stores.

1980's

The 1980's saw the multiple retailers opening larger stores with wider ranges and extensive product offering e.g. in store bakeries, delicatessens etc, at the expense of independent retailers.

- EPOS systems allowed the development of sales based product ordering system.
- Low supply chain stock also meant that there was less inventory in the supply chain to cover inefficiencies and problems such as late delivery or inaccurate orders.
- Manufacturers continued to rationalise national distribution systems whilst extending multi-national, global production. Production and distribution functions became increasingly integrated.

1990's

The 1990's saw the emergence of other store formats within the sector, such as convenience stores and forecourt shops.

- Retailers and manufacturers began to form more collaborative relationships in an attempt to find solutions along the whole supply chain.
- There was further integration between buying, stock management and distribution functions within the major multiples.
- A lot of store volumes were managed through central distribution operations.
- Electronic data interchange communication grew between companies.

2000's

Supply chain management, as a concept of strategic co-operation, has become the most recent development of integration between retailers and their downstream suppliers.

- The internet has become a low cost, reliable and secure informational channel facilitating real-time global communications as well as a new channel for home shopping.
- Multiple retailers seek to differentiate their offering through added service initiatives and non-food.
- Business to business (B2B) trading exchanges have been formed by groups of retailers and manufactures to facilitate information flow between trading partners.

Figure 1. Evolution of supply chain in the European grocery market

– manufacturing network research and supply chain research – both focusing on the value network, but using different approaches. Manufacturing network stems from the operations management field whereas the logistics management perspective dominates the supply chain theory. The aim of this paper is to analyse how the structure of value networks is treated in the two research objectives respectively.

Research on manufacturing networks has its roots in the manufacturing management of the single factory, resulting in that scholars tend to study the network as a wholly owned and internal network where all facilities are under full financial control. Conversely, research on supply chains from the logistics perspective tends to analyse the network as an external network with facilities owned by different organizations. Logistics research furthermore sets out from its roots in physical distribution and materials management and focuses on the links between the nodes (and to some extent distribution nodes), whereas manufacturing network research tend to focus on the (manufacturing) nodes themselves.

OPERATIONS STRATEGY

The essence of the operations strategy could be characterized as consisting of a pattern of decisions affecting the ability to meet the long-term objectives, market requirements, and the manufacturing task. The so-called decision covered in an operations strategy differs somewhat between the authors, but there seems to be an essential agreement on the areas that really matter. The categories, generally ranging from six to ten in number, are usually divided into structural and infra-structural decision categories.

With each decision category, a number of policies need to be addressed when formulating an operations strategy. The categories that have the greatest impact on the design of manufacturing networks and supply chains are facilities and vertical integration, two structural decision categories. These will serve as a point of reference for the analysis of manufacturing network and supply chains and for attempt to create a typology for the integration of these two types.

Facilities

The traditional policy areas related to facilities are size, location, and specialization (Hayes, Wheelwright 1984). Size basically deals with capacity issues. Size is often discussed in terms of the economies of scale. It is identified the notion of a minimal and maximal size of a facility, the maximal being the limit where diseconomies of scale starts to more than offset the economies of scale. Somewhere in between, the minimal and maximal size is the optimal size of a facility, a size that is very difficult to determine. Location deals with the general question of how to design the network of facilities, irrespective of the type of interdependence between facilities In some cases, facilities operate in sequence and are therefore dependent upon one another for inputs or outputs, whereas other facilities are fully equipped to manufacture a complete product or product range at one location, from where it is distributed to the various markets. Obviously, manufacturing location decisions cannot be formed in a vacuum, they must be taken together with marketing and logistic decisions.

Facility specialization can be of two basic types, product focus or process focus. The concept of focus was introduced by Skinner, arguing that:

– There are many ways to compete besides by producing at low costs,
– A factory cannot perform well on every yardstick,
– Simplicity and repetition breed competence.

He discussed five key characteristics of the focused factory: process technologies, market demands, product volumes, quality levels, and manufacturing tools.

Vertical integration

Vertical integration is the degree to which an organization owns the network of processes which together give goods their value and is normally discussed in terms of *direction, extent and balance*, as suggested by Hayes and Wheeelwright (1984). The fundamental concerns of *direction* and extent treat the boundaries of the firm and whether the organization should broaden or narrow the span of its operations. If increasing the span, the direction can be either forward-towards the consumer-or backward- towards the initial stages of the value network. The competencies required and the characteristics associated with forward integration differ from those of backward integration. Therefore, the choice of extending the span of operation should be carefully analysed. Narrowing the span means that some operations are outsourced at the upstream end of the span operations. Balance deals with the resulting vertically linked activities, in terms of how dependent the suppliers and customers are on the firm, relative how dependent the firm is on its suppliers and customers. In this context, Hayes and

Wheelwright refer to perfect balance as depicting the situation where only one captive supplier produce 100 percent of a firm's requirements for a given part while the firm, in turn, consumes all of the supplier's output. The question of balance applies not only to the outside consumers and suppliers but also to internal customers and suppliers along the various stages of production.

A COMPARISON OF MANUFACTURING NETWORKS AND SUPPLY CHAINS

This section describes the characteristics of manufacturing networks and supply chains in view of the operation strategy framework. The traditional perception of policy areas within the facilities and vertical integration decision categories seem somewhat restricted when applied to manufacturing networks and supply chains – involving multiple sites with various relationships. In essence, the traditional approach is that decision categories and policy areas deal with the individual facilities. Therefore, in order to capture the characteristics of a broader value network, it must be widen the perspectives of facilities and vertical integration. An initial reflection can be made that facilities is closely related to the design of manufacturing networks, and vertical integration addresses much of the supply chain structure issues.

Table 1 shows the key operations strategy issues related to manufacturing networks and supply chains. As mentioned earlier, there are distinct differences as to how manufacturing network theory view site ownership. The vast majority of he manufacturing network research assumes fully owned facilities. Research on supply chains often regards inter-firm supply chains, where relationships between the various sites are analyzed. Consequently, we assume an intra-firm focus concerning manufacturing networks and an inter-firm focus concerning supply chains. The key operation strategy issues noted in Table 1 are further explained below.

Facilities

The three policy areas within the facilities category (size, location and focus) are treated differently in each respective research objectives. As mentioned earlier, manufacturing network theory is focused in the nodes in the network, whereas the focal point f supply chain theory is the links between the nodes. In this sense, the two research areas complement each other and are both needed for the management of value networks.

Size

The traditional interpretation of size is hard to employ on manufacturing networks and supply chains, and the search for a optimal network size is likely to fail. When discussing the size of a value network it is more about finding a relevant way to measure the size, than to find an optimal size of the network. Manufacturing networks are often discussed in terms of the number of sites that the network comprises. This is of importance when the capacities, the flow of material and information, product and process

Table 1. Key operations strategy issues related to manufacturing networks and supply chains

	Manufacturing network theory (intra-firm focus)	Supply chain theory (inter-firm focus)
Facilities		
Size	No. of sites	No of organizations
Location	Corporate decisions within the network	Decision based on which collaborative partners to include in the supply chain
Specialization/focus	Vertical and/or horizontal	Mainly vertical
Vertical integration		
Direction	Both forward and backward, but mainly intra-firm perspective	Both forward and backward including inter-firm manufacturing
Extent	Narrow-only intra-firm manufacturing	Wide-focus on coordinating inter-firm relationships
Balance	External interfaces with 1st tier supplier and 1st downstream customer	Collaborative interfaces between sets of suppliers and customers

allocation, etc. are taken into consideration in the planning and execution process. Size of supply chains is, from a structural perspective, analyzed in terms of the number of different organizations that the system holds.

Location

The major distinction between the manufacturing network theory and supply chain theory concerning the location policy area is the level of control concerning the actual decision. In a intra-firm network, a site's location can be decided upon at the company's corporate headquarters in an "optimal" way relative the rest of the network.

Ferdows (1989, 1997) analyses the strategic reason for a site's location within a manufacturing network. In a study of eight international companies from the computer and electronics industry, he finds that the access to low costs production, the access to skills and knowledge, and the proximity to markets are the major areas to consider when determining a site's location.

The actual location decisions are much harder to execute in an inter-firm supply chain, since the sites within the system are owned by different (collaborative) organizations. The only way to determine, or change, the location of a site outside a specific organization's control is by choosing one or another supplier or customer that the organization wishes to collaborate with. If this is not a possibility, the location must be taken as given.

Specialization (focus)

Skinner introduced the concept of focus for a manufacturing factory, but the specialization (focus) variable is distinctly different for a network than it is for the single plant. Basically, the specialization policy area can be described as a continuum, where two endpoints are vertically focused and horizontally focused. The choice between the two is not of simplistic "either-or" type of decision, but the two options can, to varying degrees, co-exist within one network.

There are no direct contingences determining if a manufacturing network should be vertically or horizontally focused, it can be of any type. In general, a horizontal focus tends to be present when market proximity is important, whereas a vertical focus is more frequently found in networks focusing on low cost and hence getting access to low cost and hence getting access to low cost production. As opposed to manufacturing networks, the very nature of inter-firm supply chains leads to the major focus being vertical.

Vertical integration

Since vertical integration as a decision category in an operations strategy treats the ownership of, and the relations between, the successive stages in the value network, be it internal or external to an organization, it applies to both intra-firm and inter-firm environment. The policy areas (direction, extent and balance) are described in more details below.

Direction

The direction of expanding vertically can be both forward and backward in both manufacturing networks and supply chains. In the former environment, the considerations are mainly intra-firm, since the vertical actors are constituted by the various stages of production plus the immediate suppliers and customers. Consequently, the internal production stages are likely to dominate in number. An issue of concern with respect to direction is whether the value-adding activities should be re-distributed vertically. In a supply chain, inter-firm relations include the coordination of manufacturing activities between different sets of firms. Then, the issue of vertical direction relates to the distribution of value-adding activities between organizations – a question that may be dealt with between two parties along the supply chain or from an overall supply chain perspective, provided that the firms cooperate in order to maximize the effectiveness of the entire chain. In such cases, Pareto optimal or win-win solutions need to be found. In essence, both forward and backward integration initiatives can be applied to both manufacturing networks and supply chains, the difference being that internal operations dominate in manufacturing networks, whereas external relations dominate in supply chains.

Extent

The extent of the vertical integration ranges from one manufacturing stage to ownership of all operations along the entire value network. Tannous and Mangiameli (1993) deal with the issue of determining the extent of the internal span of operations and its impact on the firm's risk and value. If one organization owns the entire chain, which corresponds to full integration, the issue of extent dominates the decision category of vertical integration, since the firm cannot integrate either forwards or backwards, nor can it balance its relationships with external suppliers. In a manufacturing network governing the facilities of one organization, the extent is concerned with intra-firm manufacturing. This concern is narrower

in perspective when compared to the supply chain, which by definition would include both upstream and downstream operations. In a supply chain perspective, all operations (procurement, production and distribution) constituting the supply chain need to be considered simultaneously.

Balance

The relationships with other firms – suppliers, distributors, and customers – differ between the intra-firm focused networks and the inter-firm focused supply chains. Porter (1985) makes a distinction between linkages within a firm's value network and those between a firm and suppliers and customers. The latter type is termed vertical linkages (upstream) and so-called channel linkages (downstream), arguing that there are differences as well as similarities. For example, supplier linkages are a function of the suppliers' bargaining power and are reflected in the suppliers' margins. In the intra-firm network, vertical linkages are typically bi-party arrangements or contracts. The external interfaces are limited to 1st tier suppliers and 1st downstream customers. In a supply chain, the real challenge and opportunity is to create balance among all parties along the chain, e.g. by using frameworks and platforms for collaboration and cooperation.

CONFIGURATION AND COORDINATION

Value networks are often analyzed using two dimensions: the configurations and the coordination of the network (Rudberg, Olhager 2003). In the following it will be discussed configuration and coordination in a general manner and shown how the two schools of thought, manufacturing network (operations management) and supply chain (logistics management) are complementary .

Configuration

The previous section indicated that the manufacturing network theory assumes ownership of the facilities within the network, i.e. intra-firm, whereas the supply chain theory has a focal point on inter-firm networks, i.e. more than one organization have be considered. Therefore, to enable the study of a general value network, there is a need to determine the number of organization involved in the analyzed system. Another important feature of a network's configuration is the number of sites that each organization controls. The actual planning and execution of material and information flows between sites are dependent on site ownership. The transactions between sites differ between the inter-firm networks and the intra-firm environment. Hence, it is useful to examine value networks based on two dimensions: the number of organizations within the system analyzed, and the number of sites within each organization in the system. Based on these two dimensions, four different types of networks are discussed in the following part (Figure 2).

Type 1 called Plant is the simplest form of a value-adding entity and the transactional operations strategy theory concerning facilities and vertical integration applies. However, when we turn to the type 2 network- the Intra-firm network- multi-site planning is viewed as the development of a set of facilities that will provide the specific capabilities required by the organization over the long term. Since there is only one organization, but with many sites this

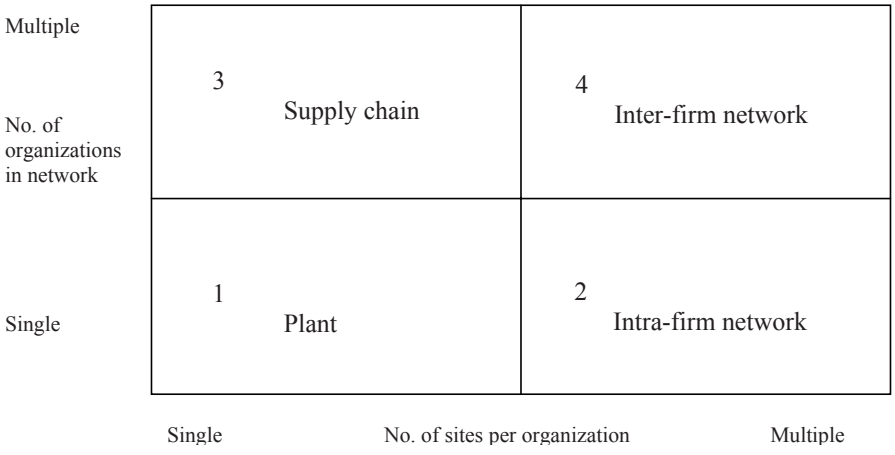

Figure 2. Classifying the analyzed system into different types of networks

type is very similar to the theory developed in the manufacturing network area. Hence, the attributes listed under the facilities and the vertical integration category, respectively, in Table 1 are relevant to this kind of network. In some instances, vertically focused intra-firm networks are called supply chains. The supply chain theory attributes listed in Table 1 are, on the other hand, more related to the type 3 network. Here, there is basically only one (or a few) site(s) per organization, and the ownership of the sites is distributed among a number of organizations. Finally, the type 4, which can be seen as a combination of types 2 and 3, is termed Inter-firm network. For this type, the attributes in each respective column in Table 1 have to be combined to describe the two decision categories for the network. Both the number of organizations and the total number of sites within the system determine the size of the network. The location of the sites within each respective organization can be decided by the organization's corporate headquarters, but the location of collaborative partners' sites have to be taken into consideration. The focus of the complex network is most likely a combination of the vertical and horizontal focus, resulting in an "unfocused" network. Concerning vertical integration issues, the extent is both narrow and wide; narrow for the part of the system that is under the direct control, and wide on the collaborative basis. Depending on how the system is set up, an internal interface, external interface, or combinations of both can be present. The actual balance is determined by the "collaborative maturity" of the inter-firm network system.

In summery, there where identified four typical kinds of value networks, each containing varying degrees of complexity. It can also be noticed that the networks of types 1 and 2 emphasize the issues contained in the facilities decisions category, contrary to the type 3 network that puts an emphasis on the vertical integration category. It is expected, that type 1 and 2 are more concerned with the nodes in the network, while type 3 concentrates on the links. However, type 4 is a combination of types 2 and 3, and hence it must consider both nodes and links jointly.

Coordination

The next step in this analysis is the coordination of the system. It is clear that the type of coordination required is contingent upon how the network is configured in terms of the number of sites per organization and the number of organizations. In Figure 3, there is depicted the level of coordination that is characteristic to each respective configuration.

In the type 1 network (single organization, single-site environment), the need for coordination is extremely limited. Rather it is a question of utilizing the existing resources. Thus, it is a special case of optimization, reduced to the utilization of a single facility. This quadrant is also applicable to the individual plants that treat their manufacturing facility as a complete system and where its environment is considered peripheral to the system.

In a multi-site environment for a single organization, the term optimization is more appropriate. Multiple sites that cooperate in sequence or in parallel, with a vertically or horizontally focused network, need to be optimized in order for the intra-firm network to reach its true competitive potential, i.e. to be fully productive. Questions that need to be addressed include the allocation of products and volumes to

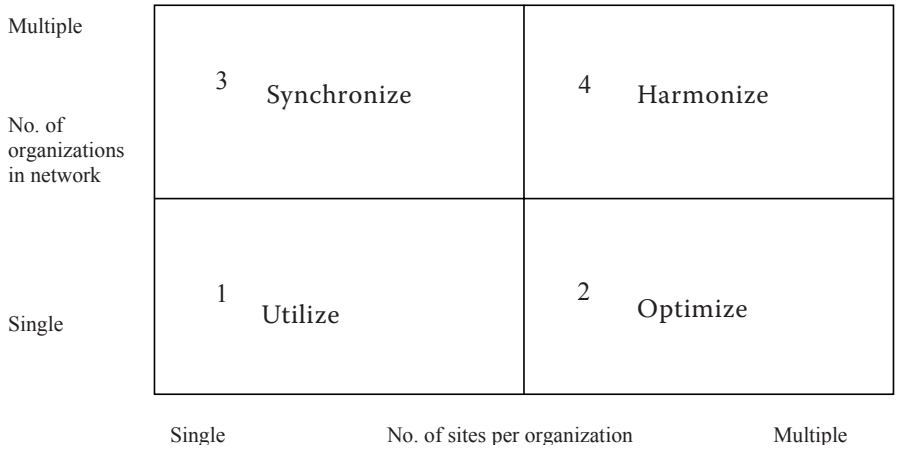

Figure 3. Coordination is contingent upon the network configuration

plants, and the production and distribution of products and orders within the network.

Coordination is an important issue in a supply chain with multiple organizations, each participating with a single site. The typical coordination approach to supply chains is synchronization.

In the most complex environment, dealing with multiple organizations with multiple sites, the coordination problems are "beyond" optimization, and even synchronization. The level of coordination in such an inter-firm network is typically reduced to harmonization, dealing with the coordination of the use of facilities, people, finance, and system. This is especially true in an unfocused network, containing both horizontal and vertical focuses.

In general, multiplicity of sites and organizations adds complexity to the network, leading to different types of coordination problems, contingent upon the configuration of the value network. The coordination has to be dealt with within a single organization or by a set of organizations. The possibility to optimize the coordination of the value network is better in the single-organization environment, whereas the multi-organization environment focus on collaboration and feasible, but not optimal, ways to coordinate the network.

The possibility to effectively manage a value network is also dependent on the quality of the available information presented to the decision-makers. As such, the recent evolution of information systems and information technology greatly impact the effectiveness of the coordination within each quadrant. Yet, even though the continual evolution of IS/IT offers improvement in coordination of value networks, it does not change the basic types of coordination required for each respective type of configuration. The possible type of coordination remains the same since coordination is still dependent upon the underlying configuration of the value network.

Strategic and managerial implications

Some issues concerning strategic and managerial implications can be raised, with respect to the design and control of the value network. From the perspective of individual plant, it must be easier to operate in one quadrant only, thus avoiding mixed flows from different types of networks and with different coordination approaches. Mixing the flows in one plant will lead to problems of how to prioritize between different products belonging to different networks. This can potentially be solved with a plant-within-a-plant approach, separating the flows from different quadrants into physically separated manufacturing entities, i.e. different plants within the plant. These issues are closely related to the structural decision categories of capacity and process technology.

In choosing the type of control mechanism, it is important to acknowledge the level of coordination that typically can be reached. However, the coordination approaches in Figure 3 are rather of a descriptive than perspective nature. A proactive approach would therefore strive for a higher level of coordination than the one depicted for the value network at hand. The important question is then: How far can we go from harmonizing to synchronizing to utilizing to optimizing?

Furthermore, Figure 2 and 3 shed some light on the concept of the outsourcing parts of an operation network. The outsourcing of a manufacturing stage in a previously internally controlled chain of operations implies a move from quadrant two to three. What was previously an intra-firm network is now an inter-firm chain or network. When handing over parts of the network to an external party, the coordination problem is no longer "owned" by the firm. Consequently, the ambition regarding the level of coordination is reduced from optimizing to synchronizing, i.e. a certain level of coordination imperfection is expected. Thus, it is likely that one or more competitive priorities, such as quality, delivery speed and reliability, cost and flexibility will experience reduced performance. Even though a contract manufacturer, taking care of the outsourced operations, may offer improvements in some areas, a holistic approach would imply that the total solution would not be as good as if the firm itself could improve its own operations and maintain an intra-firm network, since outsourcing per se leads to a reduction in the level of coordination.

CONCLUSIONS

This paper has analyzed the manufacturing networks theory and the supply chain theory from an operation strategy perspective. A difference in focus of each respective perspective was identified. Research on manufacturing networks has used an intra-firm operations management perspective, focusing on the configuration and coordination of manufacturing sites in terms of general strategy, process technology, information systems, transfer of knowledge, etc. Suppliers and customers are only considered with an external interface concerning material and information flows. In other words, manufacturing network research is mainly interested in the manufacturing nodes in the network and not necessarily in the trans-

actions between them. Logistics research on supply chains has, on the other hand, mainly focused on managing material and information flows, as well as financial flows, between sites. Supply chain research is mainly interested in the links between the nodes in the value network.

In the analysis of differences and similarities between manufacturing network and supply chain theory from the operation strategy, there were taken into account two structural decisions categories –facilities and vertical integration. The facility issues are closely related to the manufacturing networks theory and the configuration of networks, whereas vertical integration policy areas correspond to supply chain theory and the coordination issues of the network. The coordination of the network is contingent upon the network configuration. It exemplified this relationship with two matrices, one showing the typical configuration of value networks and the other showing the corresponding type of coordination.

In summary, there was highlighted the difference between the manufacturing network and the supply chain theory, and a way to integrate the two research areas was suggested. Interesting areas for future research are, for example, to further analyze the issues of configuration and coordination of networks, to analyze network hierarchies (network, organization, sites, plants, production processes), and to develop inter-firm network strategies.

REFERENCES

Hayes R.H., Wheelwright S.C. (1984): Restoring our Competitive Edge-Competing through Manufacturing. NY Wiley, New York.

Ferdows K. (1997): Making the most of foreign factories. Harvard Business Review, *75* (2):73–88.

Ferrous K. (1989): Managing International Manufacturing. North-Holland, Amsterdam.

Porter M.E. (1985): Competitive Advantage. The Free Press/Macmillan, New York.

Rudberg M., Olhager J. (2003): Manufacturing networks and supply chains: an operations strategy perspective. The International Journal of Management Science, Omega, *31* (1): 29–39.

Skinner W. (1974): The focused factory. Harvard Business Review, *52* (3): 113–121.

Tannous G.F., Mangiameli P.M. (1993) : A microeconomic model of the focused factory – vertical integration strategic decision problem. Decision Sciences, *24* (1): 209–217.

Arrived on 3rd July 2006

Contact address:

Edita Smělíková, Mendel University of Agriculture and Forestry in Brno, Zemědělská 1, 613 00 Brno, Czech Republic
e-mail: veselska@mendelu.cz