THE USE OF THE MATRIX DIAGRAM AS A TOOL FOR THE ANALYSIS OF EFFECTIVENESS OF SUPPLY CHAIN

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ABSTRACT. The different approaches of the analyzing of the supply chain efficiency are presented. The special attention was paid to matrix methods, which enable to present both qualitative and quantitative relationships in a more communicative way. The limits of these methods were also discussed.

Key words: efficiency of supply chain, matrix method, reliability of supply chain, capacity of logistic operation.

The financial crisis, which can be observed at present in the whole world, showed once again how important is, that all elements of supply chain should be in good conditions, because the efficiency of the whole supply chain depends on the efficiency of every separated part of this chain. The nature of present crisis will be critically evaluated still many times in the future, but already today the conclusions can be made, that the structure of the supply chain of a company should enable this company to compete according to standards of the market where it operates.

The scientists noticed already quite a long time ago, that the potential inefficiency of supply chains in given environment is mainly influenced by the following conditions:

- increase of the complexity of the flow of goods and information (e.g. by the use of contemporary information technologies, etc.),

- complexity of organisational and economical structures of supply chains (as a result of a globalisation and other factors),

- lowering of stocks' levels in the supply chain as a result of implementing a "pull" system in logistic systems as well as a minimization of total costs.

Despite all these facts, the methodology of the development of a supply chain is not the independent branch of the science although such necessity was mentioned already in many scientific papers. One of the reasons of such a situation is described in the presented paper. Not all of the companies have undertaken the process of an integration of their logistic cycles, i.e. the procurement, the production and the distribution and they have not solved all their internal problems.

The starting point to formulate the methodology of the development of the supply chain should be the classical concept of the durability. It means that this concept refers to a concrete system and to lead

out its trajectory in the area around the point of the balance. The supply chains are social and economical systems, which are more similar to ecological systems than to physical or mechanical ones. Therefore the most important issue is to shown the conditions under which they keep the balance. These conditions determine the limits of the existence and the durability of supply chains, the limits which change during the process of their development. The capacity to fulfil the goals of the supply chain is the main characteristic of its vitality. The identification of these limits in the theory of the systems means the necessity to elaborate the following invariable factors:

− the existence of the fragile balance between the system and the environment and events typical for this system,

− the existence of a spatial and time "memory" of the system, which determines the risk of unforeseen results,

− unstable characteristics of the limits of this area.

Therefore the deviations of activities of participants of the supply chains from expected behaviours in the area of stability of supply chains (i.e. keeping the stability of the chain) are typical for such systems.

To estimate the possible range of these deviations the theory of the reliability of technical system is applied, in which the behaviour of each element is described as "normal work" or "refusal".

The reliability of deliveries is an essential part of the theory of the supply chains. The value of this feature characterizes the capacity of the system to fulfil its obligations. This capacity is calculated based on the distribution of quantities of deliveries with the help of statistical methods.

The same approach is applied in the process of a creation of the policy of services, offered by the company to the clients, e.g. such a parameter is used as a standard of demand satisfaction, which describes the reliability of fulfilment of clients' orders.

The possibility to estimate and evaluate the reliability of separate structures in the supply chains and their input in the whole process of chain activities, is limited. Therefore special attention should be paid to conditions which enable to function similar logistic systems.

The constructive approach to this problem is to prepare and build the common models how such systems work and economical and mathematical models for evaluation of the reliability of undertaken methods.

The most important factor, which should be taken into account in such a model of reliability is the analyse of mutual dependencies among different elements of the structure of the supply chain. The main point of this analyse should be the level of these dependencies and their importance. The model SCOR (management of the goods of supply chain) including the key functions of the supply chain, does not give the full view of the problem. The specialists admit, that the implementation of this model causes problems. One of the most important problems is the complexity of all details of the flow of processes during preparing the schema of the whole chain. Additionally according to SCM idea, the relations among the participants of the supply chains play the key role in the visualisation of internal logistic processes in the company.

The analysed flow diagram is the typical method of the presentation of objects of different types, being the elements of net structures (especially of systems spread over big territories, e.g. information, transport and energetic ones, etc.). The diagram is prepared during the process of a synthesizing and analysing of these objects. It really helps to describe in a more communicative way the nature of such technical and economical communication nets, especially when the "weight" values are assigned to the different elements of such structures. These assigned values are very helpful specially when describing the lost possibilities and needs (production capacities).

This approach is implemented in the theory of the flow programming, connected with management of series of tasks, e.g. in the process of production planning, work and time scheduling, minimization of needed resources for handling operations, optimization of transport, etc.

The presentation of the supply chain as a flow diagram shows the correlations among elements of this chain, but do not give the qualitative explanations of these dependencies. Additionally when the presented supply chain consists of many elements, the graphic presentation is not very clear to understand. At this point it is useful to give more attention to two other methods of analyse, i.e. the matrix approach to this problem.

One of these methods is used to describe the documents flow, connected with material and technical supplies in the production companies and plants. The biggest advantage of this method is its ability to present the connections among different elements of the structure (material and technical) in both quantitative and qualitative ways as well as to set up limits in the process of designing of data exchange systems.

The second of mentioned above methods is oriented more on the optimization of the structure of energetic systems during the process of analyzing the mutual correlations and dependencies inside the chain and among its elements.

These both methods enable to present logistic systems as structural and flow graphs in a concentrated form. The later one applies the multiple transformations of tasks belonging to designing logistic system of the company within the given limits (Fig. 1).

Flow type		Structure and flow schema of a logistic system of the company					
		elements of a logistic system (according to functional areas of logistics)					
		procurement		production		distribution	
		goal	provided	goal	provided	goal	provided
		1	j	…	…	…	N
outgoing	1						
ingoing	i		r_{ij}				

Fig. 1. The mutual dependencies in logistic system of the company
Rys. 1. Wzajemne zależności w obrębie systemu logistycznego przedsiębiorstwa

The model shown at the figure 1 is presented in the form of the matrix $\{r_{ij}\}$, where its columns are the elements of the logistic system (e.g. of a production plant) and rows are the flows (outgoing, internal and ingoing). The matrix is filled up with integers +1 and -1, according to the rule:

$$r_{ij} = \pm 1 \quad \text{if } j \text{ element requires } i \text{ flow}$$

The empty cell of the matrix ($r_{ij}=0$) means, that the i flow is not connected with j element. If the element of logistic system is able to create and use a given flow, then two signs "+" and "-" are put before the integer.

The matrix is filled up in a few steps. The first step is to identify the internal flows (of goods, etc). Then the elements of logistic system connected with its main goals are identified and the columns from 1 to N are filled out. The last step is to identify other flows and their correlations with elements of the logistic system.

This process is concentrated mainly on the determination of other flows and their itinerary of flows as well as their correlations with other elements of logistic system.

The process of the identification of elements of a logistic system is based on the decomposition of functional areas of the logistics on the existed processes and tasks. The advantage of this model is the ability to identify and describe the character of the correlations among elements of logistic system and to show the whole structure of this system. Therefore the quantitative evaluation of the flow balance is possible.

The above described methods can be used in the analysis of the supply chains. At this point it is worth to mention, that according to SCM idea, the optimization of processes in such structure is strongly connected with the idea of a lean company (i.e. logistic centre).

typology of flows		Structural and flow schema of the supply chain						
		elements of supply chain						
		suppliers		lean company	logistic distributors		consumers/ clients	
		goal	provided		goal	provided	VIP	others
		1	j	…	…	N	…	R
outgoing	1							
ingoing	i		r_{ij}					

Fig. 2. The mutual dependencies in supply chain
Rys. 2. Wzajemne zależności w obrębie łańcucha dostaw

The analysis of the configuration of the supply chain according to SCM method enables to use such category like the capacity of logistic operation. This capacity is understood as the possibility of the system to run the flow.

The three types of this capacity are recognized:

- designed capacity – the maximal one in ideal conditions,

- effective capacity – the maximal one in real conditions, taking into account time limitations,

- real capacity – achieved in real conditions and usually lower then effective one.

Each logistic operation is limited by some conditions, therefore different elements of the supply chain have different capacities. It leads very often to bottlenecks in the supply chain and limits the capacity of the whole system. Therefore the identification of correlations inside the supply chain is recommended to be proceeded by the use of the additional matrix, as shown at the figure 3.

typology of flows		Structural and flow schema of the supply chain			
		1	j	…	S
type of the flow			$r_{ij\ (designed)}$		
			$r_{ij\ (effective)}$		
			$r_{ij\ (real)}$		

Fig. 3. The correlations between the elements of supply chain and the flows according to their logistic capacity
Rys. 3. Wzajemne zależności między elementami łańcucha dostaw i przepływami według kryterium ich zdolności
    logistycznej

It is worth to mention that in the period of the time, the designed logistic activities become more and more inert. It means, the possibility to change their parameters becomes lower. Therefore it is important to secure the possibility of the future development of the supply chain and to enable the higher flexibility of the system.

The flexibility of the supply chain is the possibility to change its structure in response to market demands. The economical flexibility depends on the availability of resources such as: stock levels, financial resources, free production capacities and organizational structure of the supply chain. The last mentioned resource enables the economical changes, which are connected with the origin of the partial functional units inside the supply chain.

The necessity of such movements shows of course the character of the probability. But the inertia of the supply chain is of the objective character and therefore there is a need to estimate the level of the flexibility of resources and to determine the available limits of the economic flexibility. The surplus of elements and connections in the supply chain allows of course to compensate the unexpected events.

But the requirements mainly concerning planned investments restrain the available variants, which facilitate their formal presentation. The last mentioned condition together with the highest priority of the adjustment of goods assortments according to clients' demands could make the matrix (shown at Fig. 4) less useful.

The elements of the supply chains are divided in this matrix into the flexible and inert ones in regard to objective conditions. The matrix enables also to determine the potential participants of the chain because of the strategical goals. Such approach makes possible to react and adjust the supply chain according to the changing environment. It should be remarked, that the big problem is to coordinate operative and strategic goals of the supply chain. Usually it is accepted, that the long-term development of the supply chain should be aimed at achieving the maximal possible profit, but the activities of the supply chain in shorter periods of time should be aimed at obtaining the approved level of profits.

Elements of supply chain			Range of assortments					
			real		potential alternative variants			
			1		…		n	
			T_1	…	T_j	…	T_m	…	T_p
			1	…	j	…	m	…	p
real	goal (secured)	i			r_{ij}				
possible	goal (secured)	k							

Fig. 4. Continuity of assortments changes in supply chain
Rys. 4. Ciągłość zmian asortymentowych w łańcuchu dostaw

The above describe approach to the presentation of relationships among the elements of the supply chain enables to ensure their structure stability. Although this method shows also some disadvantages. The most important one is not taking into consideration the time requirements in regard to flow process although their index interpretation is possible.

The next step of this process should be the determination of limits for the stability of the supply chain taking into accounts both material flow as well as information and financial ones.

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ZASTOSOWANIE DIAGRAMU MACIERZY JAKO METODY ANALIZY EFEKTYWNOŚCI ŁAŃCUCHA DOSTAW

STRESZCZENIE. Przedstawiono różne metody analizy efektywności łańcucha dostaw. Szczególną uwagę zwrócono na metody macierzowe, umożliwiające prezentację zarówno jakościowych jak i ilościowych zależności w bardziej przystępnej formie. Poddano dyskusji ograniczenia stosowania tych metod.

Słowa kluczowe: efektywność łańcucha dostaw, metody macierzowe, niezawodność łańcucha dostaw, zdolność operacji logistycznej.

DIE VERWENDUNG DER MATRIX DIAGRAMM ALS WERKZEUG FÜR DIE ANALYSE DER LIEFERKETTENEFFEKTIVITÄT

ZUSAMMENFASSUNG. Verschiedene Methode der Analyse der Leistungsfähigkeit der Lieferkette. Besondere Beachtung wurde die Matrix Methode geschenkt, die die Darstellung der qualitativen und quantitativen Abhängigkeiten in eine zugängliche Form ermöglichen. Die Verwendung dieser Methoden wurde also diskutiert.

Codewörter: Lieferketteneffektivität, Matrix Methode, Lieferkettezuverlässigkeit, Fähigkeit der logistischen Wirkungen

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