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DETERMINATION OF THE LEVEL OF RISK IN MANUFACTURING SUPPLY CHAIN

Abstract: *In this paper values were determined risk levels in the manufacturing supply chain. This paper considers the terms of the supply chain, risk and risk management in a manufacturing supply chain. In determining the level of the work exist real data identified risks of a manufacturing supply chain.*

Keywords: *manufacturing supply chain, risk, risk management, real data.*

1. INTRODUCTION

Modern business conditions because of constant change and require the introduction of novelties to all market participants. Therefore, it is estimated that organizations are forced to improve their business philosophy and trying to respond to the challenges and obstacles in turbulent environment. Just as such philosophy, supply chain management attracts the attention of experts and practice (*Waters, 2007*).

Supply chain in broader sense consist of two or more legally independent organizations which are related in flow of materials, information and finances. Supply chain management coordinate and integrate all activities in one process. It connects partners in the supply chain, including departments within the organization and external partners, such as suppliers of carriers, service providers and companies in the field of information systems. The subject of this work is determination of risk level in manufacturing supply chain.

The very concept of risk prediction represents the negative effects that may arise due to the action of some external or internal factors (*Peck, 2006*).

Risk management in the supply chain comprises identifying, analyzing, and satisfactory treatment of risk. Manifestations of risk in the supply chain ranging from the everyday, minor delays and downtime, to catastrophic events caused by human activities or natural processes (*Russell, 2008*).

This paper is organized in the following way follows: in Section 2, summarizes the literature from the corresponding domain. In the Section 3 provides a description of the risk and risk management in the manufacturing supply chain. The Section 4 contains the notation and the proposed algorithm. In Section 5 give an overview of illustrative example, and in the end the conclusion.

2. LITERATURE REVIEW

In the literature, there are various definitions of the structure and on the management of the supply chain that are still exposed.

Christopher (1998) in their work is based on the concept of the values in the definition of the supply chain, and explains that the supply chain is the network organizations that are connected through the upstream and downstream relationship in the different processes and activities. Thus associated create value in the form of products and services, the end user.

Christopher in his article introduces the term supply chain networks. Sam Christopher argued that what the name of the supply chain should describe, does not represent the reality of the chain, but rather network and would therefore be more correct name would be "network demand."

Paulsson (2007) in his work to define the supply chain as compared with the channel of physical distribution and the logistic chain. He says that the physical distribution channel, by which means the chain of transport and warehouse activities from initial supplier to the end user, time changed its character and

gradually developed over a two-stage chain and logistics chain to supply chain.

Ayers (2001) under the supply chain involves processes involving the flows of goods, information, and knowledge of the value, with the purpose of satisfying customer demands for products and services related to the supplier.

In a world without uncertainty, all members of the supply chain would be able to sync its activities and business processes towards achieving the full efficiency of the entire supply chain. So that all the products were available at the right time, inventories would be held at the desired minimum and demand alone would be deterministically predictable. However, in the real world ruled by principles of uncertainty, which affects the demand and sales forecasts, output deviates from the plan that produces damage during transport to complete shipments waiting for customs, etc. Therefore *Viswanadham and Gaonkar* (2008) concluded that the realization of logistic activities based on settings within the supply chain. Understanding of the importance of uncertainty, as the factor which can significantly degrade the capacity of excellence of the existing business models and logistical, strengthens the interest in determining the vulnerability and risk potential in the manufacturing supply chain.

The aforementioned definitions are unique attempts individual authors and institutions that formally describe the linguistic meaning of the supply chain. It can be concluded that the target group of the supply chain, to all the above definitions being an end user.

3. RISK AND RISK MANAGEMENT SUPPLY CHAIN

The risk is the term with the use of a very wide range which depends, above all, from their own perceptions of the concept of risk and the observed context. Most frequent mention of risk involves linking it with the likelihood of an unwanted event.

The concept of risk is closely linked to the concept of uncertainty, and only the origin of the word "risk" is not certain. According *Paulsson* (2007), a possible source terms are Arabic word "risqué" or Greek word that was later taken over and in Latin "riscum". Paulsson (2007) states that the term risk through literature add different meanings and are a threat or danger, evaluation of the likelihood and size effects.

Risk is usually seen as a product or function of several components and the probability that some unexpected event harm the business organization and is defined as a function of the level of uncertainty and the size of the impact of a given event (*Waters, 2007*). Uncertainty is an integral part of the risk and means that it is possible to draw up a list of events that may occur in the future, but without any idea as to which of them will actually be realized. Risk is defined through three types of questions and they are (*Paulsson, 2007*):

- What can happen?
- How likely is that to happen?
- If it happens, what are the consequences?

Risk management involves the identification of threats and the implementation of measures aimed at reducing the probability of realization of the given threats and minimizing the effects on the reporting process. This includes the implementation of cost-effective procedures to risks or reduce to an acceptable level or completely eliminated.

Risk management in supply chains is a new concept, which includes both operational and financial aspects of the decision making process and is based on the timely reaction to changes (*Blos and others, 2009*).

Risk management in supply chains has a background in risk management concept that began to be applied in business organizations middle of the last century.
According of others, in the definition of supply chain management stated that there are three basic management strategy (*Brendell, 2004*):

- risk taking,
- avoiding risks and
- transfer of risk.

Supply chain management, as well have very complex functions, which faces challenges of a wide variety of risks, which may be a consequence from a minimum delay to a complete interruption of flow in the supply chain.

Under the risk in the supply chain usually implies (*Wagner and Bode, 2009*):

- variability and distribution of possible outcomes in the supply chain - the uncertainty,
- Events that can cause a deviation from the planned outcomes and performance targets,
- potential incidents associated with problems of individual suppliers or disturbance on the market procurement, whose outcomes lead to the inability of the company that supplies goods to meet consumer demands and
- damage, defined by a probability of realization, which negatively affects the business processes within the supply chain

The concept of risk in the supply chain can be defined as exposure to risk events that negatively affect the supply chain, and therefore its performance such as service levels to costs or the possibility of a quick response.

3.1 Risk identification

Theoretically, risk identification represents the logical continuation of the first phase of process management in supply chains. However, in practice, a large number of risks already identified in the initial stage of the process, or substantial risk identification is possible only after the completion of the first phase and a precise determination of the observed structure of the supply chain. The basic framework for the identification of a combination of risk adopted the concept of risk and the mapped structure of the supply chain

The importance of the identification phase of risk is that the quality of the execution of this phase depends on the success of the entire risk management process.

Methods for the identification of risk in the supply chain can be the following (*Brendell, 2004*):

- Identification of risk through self-evaluation through appropriate questionnaire,
- risk identification through organizing workshops and
- risk identification based on the review of business processes.

In this paper, we identified the following risks:

In order to make effective risk reduction strategies, it is necessary to understand the diversity and coherence of risk in the supply chain. The task of identifying potential risk factors and their negative effects belonging to the management team (table 1).

Table 1. *Risk identification in the supply chain*

Risk factors of SSCM		
Risk factors		
Operation risk factors		
i_1	*Demand and supply uncertain*	**8**
i_2	*Failure to select the right suppliers*	**5**
i_3	*Lower responsiveness perfomance*	**6**
i_4	*Inflexibility of supply source*	**4**
i_5	*Poor quality or process yield at supply source*	**2**
i_6	*Coordination complexity/effort*	**3**
i_7	*IT and information sharing risk*	**4**
i_8	*Lack of sustainable knowledge/technology*	**7**
Economic risk factors		
i_9	*Vollatilily of price and cost*	**9**
i_{10}	*Inflation and currency exchange rates*	**3**
i_{11}	*Market share reduction*	**11**
i_{12}	*Reputation loss or brand damage*	**6**
Environmetal risk factors		
i_{13}	*Natural disasters*	**1**
i_{14}	*Inefficient use of resources*	**6**
i_{15}	*Environmental pollution*	**7**
i_{16}	*Hazardous waste generation*	**3**
Social risk factors		
i_{17}	*Unhealthy/dangerous working environment*	**6**
i_{18}	*Violation of human rights*	**3**
i_{19}	*Failure to fulfill social commitment*	**4**
i_{20}	*Violation of business ethics*	**2**

Each of the listed risk has its own specific consequences, which are shown in table 2.

Table 2. *The consequences of risk factors*

r.f.	CONSEQUENCE
i_1	decrease in revenue per order – 5, layoff – 4, discontinuation of investment in development – 3, termination of cooperation with subcontractors - 2
i_2	involvement of existing suppliers – 4, engaging new suppliers - 6
i_3	reducing the performance of the production process – 5, reducing the performance of the sales process – 6,reducing performance process research and development – 4, reducing the performance management process - 6
i_4	reducing the flexibility of the production process – 5,reducing the flexibility of the sales process – 4,reducing the flexibility of the research and development – 3, reducing the flexibility of the management process - 4
i_5	reducing the quality of the production process - 7, reducing the quality of the sales process – 5. reducing the quality of research and development – 2, reducing the complexity of management - 4
i_6	reducing the complexity of the manufacturing process -3, reducing the complexity of the sales process – 5, reducing the complexity of the process of research and development – 2, reducing the complexity of management - 4
i_7	strategic risk – 5, risk management -4, operational risk – 6
i_8	reducing technological knowledge – 7, reduction of marketing knowledge – 8, reduction in management and leadership skills – 4, reduction of knowledge on maintenance - 3
i_9	reduction in liquidity – 8, reducing the profit 6,reduction of development – 4, reducing competitiveness - 9
i_{10}	reduction in liquidity – 5,reducing the profit – 4,reduction in development – 3,reducing competitiveness - 6
i_{11}	reduction in liquidity – 4,reducing the profit – 3,reduction of development – 2,reducing competitiveness - 6
i_{12}	reduction in liquidity – 4,reducing the profit – 5,reduction in development – 3, reducing competitiveness - 9
i_{13}	the consequences of the eartquake -1, the consequences of a fire -6, consequences of flooding -5, hurricane force winds -1.
i_{14}	lack of energy – 6, lack of metal – 4, lack of wood -5,lack of water -6
i_{15}	soil contamination -3, air pollution - 4 contaminated food –5,weather pollution - 6
i_{16}	soil pollution – 9, air pollution - 5,contaminated food – 4, weather pollution - 2
i_{17}	inappropriately fixed lighting – 3, increased noise – 4, elevated concentrations of dust – 5, dispersion of working fluid in the working area - 3
i_{18}	inadequate lighting - 3
i_{19}	lack of continuing education - 4
i_{20}	unethical behavior of employees - 2

4. SUGGESTED MODEL

4.1 Notation

In this head has been described by using the model that is performed by assessment of risk in the production and supply chain that is determined by the observed level of risk of the supply chain.

Identification of the risk factors in the supply chain was performed according to the literature *(Wagner 2007; Chopra et.all, 2004; Hofman, 2011)* which is shown in section 3.1. All risk factors can be classified into various groups, $\boldsymbol{g}$, $\boldsymbol{g}$ = 1,... G. Total number of groups is referred to as $\boldsymbol{G}$, a group index is labeled as $\boldsymbol{g}$, $\boldsymbol{g}$ = 1,... G.

The management team is determined by the frequency of occurrence of the identified risk factors on the basis of data from the records. This decision was made by consensus. Let this value is designated $\boldsymbol{F}_i$, i = 1, ... I. The management team of its assessment mapping the set of real numbers. The relative value of the frequency is characterized $\boldsymbol{f}_i$, i = 1 ... I, and this value belongs to the set of real numbers in the interval [0-1]. If the frequency of any risk factor equal to 0, it can be considered that this risk factor in the observed period did not materialize. Similarly, if the value of the frequency of risk factors is equal to

1, then it can be considered a risk factor that is associated with a value appeared in each measurement.

It is known that the materialization of any risk factors leads to the formation of one or more effects. In general, the weight of the result is different. The weight of the result estimate management team based on their knowledge and experience. Decision makers use a standardized scale measures [1-9] to express their assessment of the gravity of the consequences. Decision makers have the same importance. In this work it is assumed that the total weight consequence, C_i, i = 1 ... I, which is associated with a risk factor i, i = 1 ... I, was prepared using the mean value of the operator.

The total value of the risks resulting from the materialization of the risk factor i, i = 1 ... I, wherein R_i is as calculated as the product of the total consequences and the relative frequency values that are associated with a risk factor.

The relative importance of the group of risk is not equal depending on a kind of the supply chain. Many authors believe that it is easier and therefore more accurate decision-makers to observe the relative importance of each pair of considered group *(Saaty, 1990).*

In other words, the relative importance of the group of risk is given by using the comparison of pairs of values of the matrix elements of the matrix belong to the set of real numbers which belong to the interval [0-9]. A value of 1 indicates that the importance of g and g ', if the group g, is of greater importance compared to the group g, then the value of the elements in the array is described in reciprocal numbers.

Elements constructed a matrix comparing the relative importance must be consistent. Checking a was carried out using the method of the vector (*Yager, 1996*).

The weight of each risk group, w_g, g = 1..G, ordinal numbers are described and set are normalized. It is believed that each identified risk factor within a group have the same weight as the group to which it belongs.

Difficulties in risks at the level of the value of the group R_g, is calculated as product: 1) weight value of the group, 2) the sum of the aggregated values of the risk level of the group. In order to determine the level of risk of the product supply chain, it is necessary to determine the total risk factor at the level of the supply chain R.

Using the rules of mathematical logic and calculate the total value of the risk factors can determine the level of risk. In this paper, it is assumed that there are three levels of risk: low, medium and high levels of risks. Limit each discussed the level of risk is determined on the basis of an assessment of the management team. That means that they have very subjective views of decision makers and this can be considered as a weak point of the developed method.

4.2 Suggested algorithm

Taking into account the selection of 4.1, was analyzed the influence of risk factors in the production supply chain, which is realized through the following steps:

Step 1. After identification risk factors and their consequences, its weight and the consequences of C_i, i = 1 ... I, and the level risk of factors, RF_i, i = 1 ... I.

$$C_i = \frac{1}{C_{ij}} \cdot \sum_{j=1}^{C_{ij}} C_{ij}$$

Step 2. To compute the weight of the consequences of C_i, i = 1 ... I and at the level of risk factors, RF_i, i = 1 ... I. To determine the value of each risk factor and R_i, i = 1 ... I.

$$R_i = C_i \cdot f_i$$

Step 3. Calculate the relative risk values r_i., i = 1, ... I .

$$r_i = \frac{R_i}{\sum R_i}$$

Step 4. We develop matrix to calculate the weights of risk factors w_g, g = 1, ... 4. Calculating the weight of each risk factor w g, g = 1, ... 4 was carried out using the AHP methods.

$$\begin{pmatrix} 1 & 3 & 6 & 8 \\ - & 1 & 4 & 5 \\ - & - & 1 & 2 \\ - & - & - & 1 \end{pmatrix}$$

Step 5. Calculating value difficulty on the level of every group of risk factor R_g, *g = 1, ... 4*

$$\boldsymbol{R_g} = w_g \cdot \sum_{i=1}^{I_g} R_i$$

Step 6. Total factor of risks on supply chain level ***R.***

$$\boldsymbol{R} = \sum_{g=1}^{4} w_g \cdot R_g$$

Step 7. Determination of risk factors level $\mathbf{R_g}$, g = 1, ... 4 and total factor of risks **R** on supply chain level..

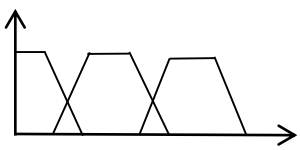

Diagram 1. *Determination of risk factors level*

5. ILLUSTRATED EXAMPLE

In this head, it will be shown developed analysis of influence of risk factors, in which the real data exist at the level of the production of the production supply chain.

Based on experience, the data obtained from the literature and the results of good practice, the members of the management team present their estimates of the frequency and severity of risks and their consequences. The management team uses a scale rate [1-9].

The method which is shown in section 4 (step 1-step 7), it is further illustrated in the case of difficulty in the determination of total risk at the level of the manufacturing supply chain.

In step 1, the specific weight and consequently also to the $\boldsymbol{C_i}$ on the level risk factors for $\boldsymbol{RF_i}$, i = 1, .. I. Weight is determined by the consequences of using the method and the mean value and thier values are shown in Table 5. The calculation of the consequences of each individual, by means of step 1 is shown in the example., shown on exemple C_1.

$$C_1 = \frac{1}{4} \cdot (5 + 4 + 3 + 2) = 3.5$$

After determining the weight of consequence $\boldsymbol{C_i}$ we determined the value of each risk defined by $\boldsymbol{R_i}$ (step 2). The values obtained are shown in table 3.

$$R_1 = 3.5 \cdot 8 = 28$$

Table 3. *The values of each risk defined by R_i, i=1,...I*

r.f.	*The aggregated value of the risk to the group C_i*	*Frequencies risk f_i*	R_i
i_1	3.5	8	**28**
i_2	5	5	**25**
i_3	5.3	6	**31.8**
i_4	4	4	**16**
i_5	4.5	2	**9**
i_6	3.5	3	**10.5**
i_7	5	4	**20**
i_8	5.5	7	**38.5**
i_9	6.8	9	**61.2**
i_{10}	4.5	3	**13.5**
i_{11}	3.8	11	**41.8**
i_{12}	3.5	6	**21**
i_{13}	3.3	1	**3.3**
i_{14}	5.3	6	**31.8**
i_{15}	4.5	7	**31.5**
i_{16}	5	3	**15**
i_{17}	3.8	6	**22.8**
i_{18}	3	3	**9**
i_{19}	4	4	**16**
i_{20}	2	2	**4**

When a particular value of each risk factor, in step 4, we determines the relative importance of each of the risk factors. Determination of packaging on the basis of the applied pattern that is defined in the step 4. In Table 4, the values shown were obtained.

Table 4. *Determination of the relative risk value r_i*

r.f.	R_i	*Relative risk value* r_i
i_1	28	**0.062**
i_2	25	**0.055**
i_3	31.8	**0.070**
i_4	16	**0.036**
i_5	9	**0.020**
i_6	10.5	**0.023**
i_7	20	**0.044**
i_8	38.5	**0.086**
i_9	61.2	**0.136**
i_{10}	13.5	**0.030**
i_{11}	41.8	**0.093**
i_{12}	21	**0.047**
i_{13}	3.3	**0.007**
i_{14}	31.8	**0.071**
i_{15}	31.5	**0.070**
i_{16}	15	**0.033**
i_{17}	22.8	**0.051**
i_{18}	9	**0.020**
i_{19}	16	**0.036**
i_{20}	4	**0.009**
Σ	449.7	**1**

In step 5, and 6, calculated as difficulty level value in each group of risk factors R_g. Difficulties and risks at the level of the value of the group R_g, is calculated as the product: 1) weight value of the group, 2) the sum of the aggregated values of the risk level of the group. In order to determine the level of risk of the product supply chain, it is necessary to determine the total risk factor at the level of the production supply chain ***R***.
Weight of risk are calculated based on a matrix using methods AHP (step 5):

$\boldsymbol{w_1} = {}^{18}/_{33.57} = \mathbf{0.54}$
$\boldsymbol{w_2} = {}^{10.33}/_{33.57} = \mathbf{0.31}$
$\boldsymbol{w_3} = {}^{3.41}/_{33.57} = \mathbf{0.10}$
$\boldsymbol{w_4} = {}^{1.825}/_{33.57} = \mathbf{0.05}$

After a certain weight of each risk factor $\mathbf{w_g}$, g = 1, .. 4, is calculated by the total value of each risk factor $\boldsymbol{R_g}$ and the value of the risk level of supply chain ***R***.
$R_1 = 0.54 \cdot \sum 0.062 + 0.055 + 0.070 + 0.036 + 0.020 + 0.023 + 0.044 + 0.086$
$\boldsymbol{R_1} = 0.214 \approx \mathbf{0.21}$
$R_2 = 0.31 \cdot \sum 0.136 + 0.030 + 0.093 + 0.047$
$\boldsymbol{R_2} = 0.095 \approx \mathbf{0.10}$
$R_3 = 0.10 \cdot \sum 0.007 + 0.071 + 0.070 + 0.033$
$\boldsymbol{R_3} = 0.018 \approx \mathbf{0.02}$
$R_4 = 0.05 \cdot \sum 0.051 + 0.020 + 0.036 + 0.009$
$\mathbf{R_4} = 0.005 \approx \mathbf{0.01}$
$R = \sum 0.54 \cdot 0.396 + 0.31 \cdot 0.306 + 0.10 \cdot 0.181 + 0.05 * 0.116$
$\mathbf{R} = 0.333 \approx \mathbf{0.33}$

In step 7 is shown the definition of the level according to the previously obtained values (step 5 and step 6) of each individual risk factors, $\boldsymbol{R_g}$ and the total risk of the production at the level of the supply chain ***R***.

μ ($\boldsymbol{R_1} = 0.21$) → the level of operational risk factors is secondary
μ ($\boldsymbol{R_2} = 0.10$) → level of economic risk factors is secondary.
μ ($\boldsymbol{R_3} = 0.02$) → the level of risk factors that affect the environment is low.
μ ($\mathbf{R_4} = 0.01$) → level of social risk factors is low.
μ ($\mathbf{R} = \mathbf{0.33}$) → overall level of risk is high.

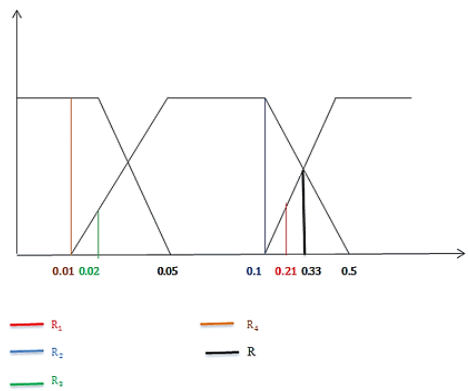

Diagram 2. *Determination of risk factors level*

On the basis of a certain level of risk of an individual R_g and the total risk R, it can be concluded that a ***high*** level of risk has a total risk of the production at the level of the supply chain **R**, and the ***lowest*** risk levels are risk factors that affect the environment and social risk factors,.

5. CONCLUSION

In this paper determined the level of risk in the manufacturing supply chain. We are identified 20 risk factors, which are, based on their meaning that is divided into 4 groups. The group consists of risk factors: operational factors of risk, economic risk factors, risk factors that affect the environment and the social factor of risk.

Each of the enumerated risks has its consequences and frequency poms which determine their value. Also, each risk group has its own weight.

Based on the proposed model, certain levels of risk. The paper gives a diagrammatic representation. On the diagram, it can be concluded that the level of operational and economic risk factors middle. While the level of risk factors that affect the environment and social risk factors low. We determine the overall risk level and at the level of the manufacturing supply chain. The level of overall risk on the level of the manufacturing chain of supply is high.

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