Chapter

Supply Chain FMEA Risk Analysis for the Heavy Industry Sector

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Abstract

The discussed problem is associated with the analysis of risk factors affecting supply chain management in the heavy industry sector based on the analysis of entities operating in this industry. During the research, several aspects of key importance in supply chain management in the heavy industry sector were identified. The use of the failure mode and effects analysis (FMEA) method in research has enabled the detection of defects in supply chain management and analysis of factors that may negatively affect the flow of goods. During the research, potential design flaws and the effect of these flaws were identified, indicating the class, cause, and occurrence.

Keywords: heavy industry, supply chain, risk analysis FMEA

1. Introduction

The need for continuous improvement of processes taking place in enterprises in order to stay on the market in the era of globalization forced on organizations is requiring cooperation. Business-to-business cooperation has evolved considerably over the past few decades. It can be safely argued that the chains of service providers from the beginning of entrepreneurship. Over time, trade has appreciated the characteristics of the supply chain and its competitive advantage. They began to create conscious networks of companies for more efficient and easier loading of goods. Services related to data flow management are most often given a competitive advantage in a given market.

The term supply chain first appeared in the 1980s. The cooperation used alone was not sufficient. In order to efficiently, dynamically, and qualitatively optimize loading of goods, such as planning, decision-making, organizing, and turning over. Over time, various concepts of supply chain management were developed toward the rapid creation, which allow the flow of goods to take place in the most efficient way [1, 2].

Do business, follow the constant decision-making process that is affected by a situation that requires operations. Risk management is defined as a set of activities that include planning, organizing, flipping, controlling, and making decisions. These operations are aimed at protecting the organization against uncertain, unexpected, and dangerous events [3, 4]. Risk management is a multistage process that aims to monitor business transactions against broadly understood danger. Activities included in the risk management use also the analysis of risk sources and their elimination. It should be taken into account that it does not always mean a negative

situation and is increasingly seen as an opportunity for accessibility. Therefore, risk management may mean the elimination of the negative effects of a dangerous situation, but there may also be a chance to develop accessibility [5, 6]. The essence of risk management determines the maximum utilization of benefits by the company while minimizing possible losses [7].

The meaning of words often raises doubts, and it is impossible to change clearly. Defining keywords on the basis of various sciences and theories, such as economics, law, psychology, statistics, probability theory, systems theory, or behavioral sciences, and then explicitly worded contents of the word risk, extremely difficult tasks.

The risk mainly applies to everyone and situations that should be avoided. It is also identified with chance, courage, and fate. It is a collection of activities that cause material losses and damage to the body or cause other losses. It is primarily associated with human activity and behavior [8]. Processing the definition of risk associated with the risk of positive or negative effects, expected values, uncertainty of achieving the goal [9, 10].

The failure mode and effects analysis (FMEA) method is used to identify nonconformities together with the risk of their occurrence. The method is used to determine the risk assessment arising during production, management, organization planning, etc. of given products or processes. The FMEA method works best during implementation processes, planning processes, optimization elements, or improving unstable processes. The goal of the FMEA method is to systematically identify and recognize likely product or process incompatibilities. Then, take a step that minimizes the risks associated with them, and identify the factors that most threaten the success of the product/process [11].

2. Research goal and methodology

The FMEA method is designed to detect defects at the earliest stages of the process. The FMEA method is based on the analysis of factors that may affect the process under investigation and relate to process methods, instrumentation, and environmental impact along with the definition of control measures [12, 13].

The first stage of the FMEA method concerns the selection of operations that should be analyzed along with the definition of the scope of the analysis. The number of parts and levels of the method depends on the complexity of the process [14].

The second stage consists in specifying the activities related to the FMEA analysis. First of all, potential defects that can occur in the analyzed case should be defined. After determining the sequence of events, cause-defect-effect, each defect should be assessed with an integer ranging from 1 to 10, taking into account three criteria: risk, possible occurrence of a defect, and cause [15].

The final stage of risk analysis using the FMEA method describes the elements in which changes should be made to reduce the risk of defects.

Research is based on the use of FMEA risk analysis in supply chain management in the heavy industry sector. The research lasted from 2016 to 2019. Nine business entities involved in steel production, trade, and processing were subject to examination. The entities were divided into three groups, and each group included three economic entities. The first group concerned steel companies. The headquarters of the enterprises are located in Poland, the Netherlands, and Germany. The next group concerned enterprises dealing in steel trade in Poland. The last group of enterprises is engaged in steel processing. Based on the industry analysis and intelligence in business entities, FMEA risk analysis has been developed [14].

In the studies presented, the FMEA analysis concerns industry analysis, not the process or product so far. This is an innovative use of FMEA risk analysis. No risk analysis has yet been developed for the industry in the context of supply chain management.

3. FMEA risk analysis

The FMEA analysis (**Table 1**) covers such areas of activity of the heavy industry sector as technological, time, location, political and legal, economic, social, and environmental area. Determinants affecting supply chains in the heavy industry sector were subjected to risk analysis.

Table 1 presents all aspects that may affect supply chain management in the heavy industry sector. In the table above, individual areas of activity of business entities involved in the flow of goods in the heavy industry sector have been analyzed. The potential type of defect was defined along with its effect. The probability of occurrence of a defect is determined on a scale of 1–10. The value of 1 is assigned to an unlikely situation, while 10 to a very likely situation. The details of the value assignment are set out in **Table 2**.

The next step is to determine the cause of the defect along with determining its value. Also in this case, the cause of the defect is determined on a scale of 1–10. The value of 1 is assigned to an improbable situation and 10 to a very likely situation. The details of the value assignment are set out in **Table 3**.

In the next step, you need to specify preventive measures and estimate the detection parameters, based on **Table 4**.

The final stage of FMEA analysis is the assignment of the RPN parameter. Assigning the above parameters to the FMEA spreadsheet allows you to specify the priority number of RPN risk, which is calculated according to the following formula:

$$\text{RPN} = \text{Meaning (I)} \times \text{Occurrence (P)} \times \text{Detection (D)} \tag{1}$$

RPN makes it possible to determine which threats carry the highest risk and the hierarchy in which order preventive actions should start.

FMEA analysis is a method of identifying and preventing problems related to the analyzed process before its implementation. It is focused on preventing process or product defects, increasing process security, financial security of the project, work safety, and environmental protection [14]. FMEA analysis is carried out at the design stage of the process or product to avoid the biggest threats and flaws in the implementation phase. This is an important technique for identifying and eliminating potential defects and errors in processes and products.

4. Conclusion

The research aimed to show the sources of risk in supply chain management in the heavy industry sector. During the analysis, RPN = 100 was determined below which the impact of factors on supply chain management is insignificant. For the industry studied, the greatest impact of risk on supply chain management has social aspects, primarily related to the lack of qualified staff, an increase in labor costs and social benefits, and the need to meet staffing needs with foreign personnel. Further aspects affecting supply chain risk management include an increase in energy and raw material prices, business relationships with customers, expansion of emerging markets, and reduction of spatial barriers.

Area	Potential type of defect	Potential effect of the defect	Meaning	Potential causes of the defect	Occurrence	Preventive measures	Detection	RPN
Technology	Incorrect implementation of innovations	Loss of capital	3	Difficulties with implementing innovations	2	Analysis of the current machine park and process facilities in terms of implementing innovations. Economic analysis of the implementation of innovations	7	42
				Lack of patience of the management regarding the effects of implemented innovations				
	Lack of orientation of the organization on innovative activities	Lack of technological development of the organization	3	High costs of implementing innovations	2		7	42
	Lengthening during the implementation of innovative investments			Employees' concerns related to implementing innovations				
				No interest in new technological solutions				
Time	Emerging markets expansion	Increased competition	7	More attractive supplier offer from the emerging market	5	Getting new customers. Negotiating new rates for purchasing raw material. Increasing the number of suppliers	8	280
		Loss of customers						
	Too late response to customer queries and wishes	Loss of potential customer	6	Distraction of employees. Too little employee involvement. Employee overload. Hiring employees with insufficient skills and experience	6	Getting new customers. Negotiating new rates for purchasing raw material. Increasing the number of suppliers	8	288
	No response to customer inquiries and wishes	Loss of customer	8		3		8	192
localization	Reduction of spatial barriers	Increased competition	4	Accession of the country to the economic union	6	Extending the sales and purchasing offer to other countries	7	168
	Transport network	Lack of access to seaports, river, air ports, roads, highways, rail networks	2	Location of the plant in an area underdeveloped in economic terms	7	Transfer of the workplace. Acquiring suppliers from the local enterprise environment	5	70
		Lack of adequate transport or communication network	3		4		4	48
		Bad condition of the road	2		4		4	32

		network						
	Limited spatial mobility	Lack of suitable transport rolling stock	4	No business entity investment in transport means	2	Using the services of shipping companies	9	72
Economic	Lack of qualified labor force	Staff shortages	7	Unemployment. Migration of population. High level of emigration. Aging of the society. Lack of labor in working age	8	Employment of foreigners	2	112
		Lack of appropriate staff	7		10		1	70
		Hiring employees with insufficient qualifications, experience and skills	7		9		3	189
	Changes in global markets	Financial crisis	5	International economic situation. Conflicts between countries	2	Transfer production to stable areas of the world	3	30
	Changes in the stock exchange listing	Loss of potential shareholders	4	Crisis on global stock exchanges. Company bankruptcy. Speculative bubble	3	---	2	24
	Exchange rate changes	A drop in the value of shares	2		2		6	24
		The inflow of external capital	3		3		5	45
		Inflation	3		2		5	30
Political and legal	Changes in legal and social relations	Unfavorable legal and social relations	4	Professional groups strikes. Social policy of the state	5	---	4	80
	Changes in tax rates	Unfavorable tax regulations Lack of funds for enterprise development	5	Income load	7	---	3	105
	Changes in tax regulations							
	No possibility of assistance from public funds	Rejection of the application for investment co-financing	2	No public funds for the area. Lack of classification of the entity to obtain assistance from public funds. Insufficient pool of public funds. Insufficient reasoning in requesting assistance. No proper support program available	5	Acquiring new contractors, new production orders	5	50
		Insufficient funds for the investment	1		7		7	49
		Lack of adequate transport or communication network	1		9		8	72
	Changes in economic conditions	Lack of creditworthiness	4	Other credit obligations. Loss of production orders. Enterprise debt	6		2	48
		Inability to repay the loan	3		2		2	12
		The need to introduce foreign capital	1		1		2	2
	Unfavorable policy of state authorities towards enterprises	No help from public administration	1	Lack of understanding of the situation by state administration offices. Handling specific and rigid procedures	8	Joining the business association	6	48
		Complicated and time-consuming administrative procedures	2		9		3	54

	Export Value	Lack of international competitiveness	8	Difficulties in getting international clients. Not very attractive company offer for foreign contractors	7	Searching for new markets	7	392
Economic	Low innovation of the economy	Lack of support from government institutions for scientific research and production development	4	Low attractiveness of enterprises abroad	6	Starting cooperation with new suppliers	2	48
	Degree of concentration of production	Increased competition	3	100% production in one place	4	Use of outsourcing. Signing a contract with a subcontractor	2	24
	Export Rate	Low export rate	6	Sales regress	4	---	1	24
	The level of strategic transaction execution	No strategic transactions carried out	2	Directing production only to one specific type of product and cooperation with only one final customer	2	Acquiring strategic investment and implementing smaller production orders	3	12
	Costs increase	Low level of profitability of production	9	Increase in prices of energy, raw materials, labor costs	10	---	4	360
	Competitiveness Policy	Unfair commercial practices	4	Competition development, globalization	9	Breaking cooperation	4	144
	Business relations with clients	Loss of customer	4	Disregarding the customer, improper customer service, lack of developed and implemented customer service standards	8	Development of customer service standards. Hiring the right people to contact customers. Staff training	9	288
	The quality of communication	Loss of employees	7	Lack of communication between the management and the lowest level employees	7	Analyzing projects with department managers and production employees	2	98
	Information flow quality	Bad quality of information flow	6	Interference during the information flow	7	Improving the information flow process	3	126
	Customer insolvency	No payment within the prescribed period Counterparty's bankruptcy Too much debt of the organization Payment period too long	3	Too much trade credit	5	Confirmation of payment and economic credibility of the customer	3	45
	The quality of purchased goods and services	Breaking relations with the supplier No supply source	3	Poor quality of purchased goods and services Poor quality of goods and services sold	4	Checking the quality of delivered goods. Change of supplier	3	36
	Quality of goods and services sold	Loss of customer	7	The impact of globalization, a decrease in the share of international investments, the long-term nature of investments, changes in international economic conditions	3	Control of manufactured products	5	105

	The value of international investment	No participation in international investments	6	Globalization, imperfection of manufacturing processes, low quality of manufactured components, various cultural conditions affecting the production process, communication problem and changing time zones, long transport time	7	---	5	210
	Production fragmentation capacity	No possibility for fragmentation of production	3	Poor quality of purchased goods and services	4	Cooperation with international contractors who are able to provide the required quality of goods	4	48
		No international division of labor is possible	4		2		4	32
	Access to international raw materials, capital and production resources	Lack of access to the global labor market and sales market	6		5		2	60
	The degree of storage of the raw material	Too large inventory	8	Global steel overproduction	7	---	6	336
	Steel supply	Steel oversupply	7		6		4	168
		Volatility of energy and transport prices	8		10		2	160
	Degree of production profitability	Price discrepancy between steel and raw material price	2	High level of raw material prices. Steel unprofitability.	6	---	2	24
	Low efficiency of mining activities	Inability to meet demand	3	Low level of deposits	3	Searching for new deposits of raw material	4	36
	Inaccurate estimates of mine life	Depletion of resources	1		1		3	3
	Drilling failure	Loss of raw material	2	Errors during drilling processes	2	Failure analysis. Implementing corrective actions	3	12
	Errors during production processes	Failure to complete the order	2	Loss of capital. Loss of customer	2		2	8
	Export Capabilities	Changes in the steel mill's trade policy	8	Lack of conviction to export goods. Too much competition. Temporary or permanent ban on the export of goods	4	Verification of foreign contractors. Acquiring opinions about a contractor in the environment	2	64
		Embargo	5		6		2	60
	Steel Import	Material losses	4	Increasing costs of raw material extraction. Too low prices for steel and iron ore. Chronic	7	---	3	84
		Increase in transport costs	3		8		3	72

		Steel price increase	4	low steel and iron ore prices	9		3	108
	Decrease in steel demand	The use of steel substitutes	6	Development of competition of other materials. Price and technological attractiveness of other materials	8	Acquiring new customers. Assortment flexibility. The rate at which primary production is transformed	2	96
		Loss of customers	9		8		2	144
	Seasonality of sales	Limited cooperation with a potential supplier Production stoppages	1	Loss of standing production orders	7		5	35
	Addiction to suppliers			Supplier's bankruptcy. Delays in the implementation of supply orders. No constant flow of raw material. Supply order execution problem with a potential new supplier		Securing the source of supply from several suppliers		
		Loss of production orders	1		3		4	12
	Relationship with entities	Loss of a key customer	3	Too much trust. No loyalty. Business fraud	1	---	6	18
		Loss of subcontractor						
		Transfer of production to Asian markets						
	The impact of globalization	Loss of regular customers	6	Global steel overproduction. The inflow of raw material from Asian markets. Low price level. Low quality	10	---	2	120
		Price drop	2		2		2	8
		Material losses	3		4		3	36
Social	The amount of the minimum wage	Increase in transport costs	9	Loss of price attractiveness on the international and national arena. Increase in prices of manufactured products	10	---	6	540
Environmental	Environmental degradation	Labor cost increase	2	Steel cost increase. The need to modernize the workplace to meet environmental standards. High investment costs. Lack of government programs supporting the adaptation of workplaces to environmental conditions.	6	Gradual adaptation of the workplace to environmental standards	3	36
		Adaptation of production plants to strict restrictions and environmental regulations						
		High penalties for non-compliance with environmental regulations						
		Inability to adapt production plants to environmental requirements						

Table 1.
FMEA analysis sheet for the industry studied [own study].

I	Importance	FMEA services/constructions
1	Unbelievable	An imperceptible impact on the service
2–3	Little	The defect is small and has little impact on customer satisfaction
4–6	Average	Average defect, felt customer dissatisfaction
7–8	Important	The defect happens cyclically and has a big impact on customer dissatisfaction
9–10	Extremely important	An extremely important defect, which affects further work, safety and is contrary to the law

Table 2.
Determining the significance of the occurrence of a defect [own study].

P	Probability of occurrence of a defect	FMEA service/construction/process
1	Unbelievable	No defect can occur
2	Very low	Very low probability of occurrence of a defect. Defects occur individually and very rarely
3	Low	Low probability of occurrence of individual defects
4–6	Average	Defects occur on average in small quantities
7–8	High	Disadvantages occur very often
9–10	Very high	Very high probability of a defect

Table 3.
Determining the probability of occurrence of a defect [own study].

D	Detection	FMEA service/construction/process
1–2	Very big	Some defect detection
3–4	Large	The chances of detecting a defect are high, a test or functional check is used
5–6	Average	Defect control can detect average detectability
7–8	Small	Defect detection difficult
9–10	Very small	Detection of a defect is difficult or impossible to detect

Table 4.
Determining the probability of detection [own study].

Risk analysis has been created for a specific industry. Based on the analysis, the values included in **Table 1** have emerged. The RPN value presented in **Table 1** identifies the greatest threats to the process under study. A detailed analysis of all RPN values above 100 identifies the greatest threat to supply chain management in the heavy industry sector. At the same time, analyzing the results contained in **Table 1**, you can simultaneously create and implement appropriate preventive measures described in the column "Current preventive measures in the process." Disregarding the results of risk analysis using the FMEA method may lead to negative effects on the functioning of enterprises operating within the analyzed supply chain.

The FMEA risk analysis itself can be used for different cases. The studied problem concerns threats and uncertainty in the supply chain in the heavy industry sector. Each risk analysis based on a given problem is individual. Risk factors may vary on each enterprise that is technologically similar, and it is not possible to use risk analysis prepared for entity A for entity B. Even more, the risk analysis

considered in the context of one industry may differ for other industries. The impact of risk factors may be the same in some respects, but it will be different even if it is personal or environmental. Risk analysis is always created with a specific enterprise, process, product, or industry in mind. The scheme of risk analysis using the FMEA method can be used for each individual problem.

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