Supply Chain FMEA Risk Analysis for the Heavy Industry Sector

Małgorzata Dendera-Gruszka and Ewa Kulińska

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 non-conformities 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:

$$RPN = \text{Meaning (I)} \times \text{Occurrence (P)} \times \text{Detection (D)}$$  \hspace{1cm} (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                                                                 | Occurrence | Preventive measures                                                                 | Detection | RPN |
|---------------------------|------------------------------------------------|------------------------------|-------------------------------------------------------------------------|------------|------------------------------------------------------------------------------------|-----------|-----|
| Technology                | Incorrect implementation of innovations       | Loss of capital              | Difficulties with implementing innovations                              | 3          | 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 orientation of the organization on innovative activities | Lack of technological development of the organization | Lack of patience of the management regarding the effects of implemented innovations | 2          |                                                                                   |           |     |
|                           | Lengthening during the implementation of innovative investments |                           | High costs of implementing innovations                                   | 3          |                                                                                   |           |     |
|                           |                                               |                              | Employees’ concerns related to implementing innovations                   |            |                                                                                   |           |     |
|                           |                                               |                              | No interest in new technological solutions                                 |            |                                                                                   |           |     |
| Time                      | Emerging markets expansion                    | Increased competition        | More attractive supplier offer from the emerging market                   | 7          | 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   | 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 |
|                           |                                               | Loss of customer             |                                                                              | 8          |                                                                                   | 8         | 192 |
|                           | No response to customer inquiries and wishes  |                                |                                                                              | 3          |                                                                                   |           |     |
|                           | Reduction of spatial barriers                 | Increased competition        | Accession of the country to the economic union                             | 4          | Extending the sales and purchasing offer to other countries                       | 7         | 168 |
| Localization              | Transport network                              | Lack of access to seaports, river, air ports, roads, highways, rail networks | Location of the plant in an area underdeveloped in economic terms          | 2          | Transfer of the workplace. Acquiring suppliers from the local enterprise environment | 5         | 70  |
|                           |                                               | Lack of adequate transport or communication network |                                                                         | 3          |                                                                                   | 4         | 48  |
|                           |                                               | Bad condition of the road    |                                                                         | 2          |                                                                                   | 4         | 32  |
| Network | Limited spatial mobility | Lack of suitable transport rolling stock | 4 | No business entity investment in transport means | Using the services of shipping companies | 2 | 9 | 72 |
|---|---|---|---|---|---|---|---|---|
| Lack of qualified labor force | Staff shortages | 7 | Unemployment. Migration of population. High level of emigration. Aging of the society. | 8 | Employment of foreigners | 2 | 112 |
| | Lack of appropriate staff | 7 | Lack of labor in working age | 10 | | 1 | 70 |
| | Hiring employees with insufficient qualifications, experience and skills | 7 | | | | 9 | | |
| Economic | Changes in global markets | Financial crisis | 5 | International economic situation. Conflicts between countries | Transfer production to stable areas of the world | 2 | 3 | 30 |
| | Changes in the stock exchange listing | Loss of potential shareholders | 4 | Crisis on global stock exchanges. Company bankruptcy. Speculative bubble | | 3 | | |
| | | A drop in the value of shares | 2 | | | 2 | 24 |
| | | The inflow of external capital | 3 | | | 6 | 24 |
| | Exchange rate changes | Inflation | 3 | | | 5 | 45 |
| | | | | | | 5 | 30 |
| | 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 | 4 | Lack of funds for enterprise development | Income load | 5 | | 105 |
| | Changes in tax regulations | Lack of funds for enterprise development | 5 | | | 7 | | |
| | 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 | | 50 |
| | | Insufficient funds for the investment | 1 | | | 7 | 49 |
| | | Lack of adequate transport or communication network | 1 | | | 9 | | 72 |
| Political and legal | Changes in economic conditions | Lack of creditworthiness | 4 | | | 6 | 2 | 48 |
| | | Inability to repay the loan | 3 | | | 2 | 12 |
| | | The need to introduce foreign capital | 1 | | | 1 | 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 | | 48 |
| | | Complicated and time-consuming administrative procedures | 2 | Joining the business association | | 9 | 3 | 54 |
| Risk Assessment | Export Value | Low innovation of the economy | Degree of concentration of production | Export Rate | The level of strategic transaction execution | Costs increase | Competitiveness Policy | Business relations with clients | The quality of communication | Information flow quality | Customer insolvency | The quality of purchased goods and services | Quality of goods and services sold |
|----------------|-------------|-------------------------------|--------------------------------------|-------------|-----------------------------------------------|---------------|-----------------------|-----------------------------|-----------------------------|--------------------------|-------------------|--------------------------------------|--------------------------|
|               | Lack of international competitiveness | Lack of support from government institutions for scientific research and production development | Increased competition | Low export rate | No strategic transactions carried out | Low level of profitability of production | Unfair commercial practices | Loss of customer | Loss of employees | Bad quality of information flow | No payment within the prescribed period | Breaking relations with the supplier |
|               | Difficulties in getting international clients. Not very attractive company offer for foreign contractors | Low attractiveness of enterprises abroad | 100% production in one place | Low export rate | Directing production only to one specific type of product and cooperation with only one final customer | Increase in prices of energy, raw materials, labor costs | Competition development, globalization | Disregarding the customer, improper customer service, lack of developed and implemented customer service standards | Disregarding the customer, improper customer service, lack of developed and implemented customer service standards | Lack of communication between the management and the lowest level employees | Too much trade credit | Poor quality of purchased goods and services |
|               | Searching for new markets | Starting cooperation with new suppliers | Use of outsourcing. Signing a contract with a subcontractor | 4 Sales regress | Acquiring strategic investment and implementing smaller production orders | --- | Breaking cooperation | Development of customer service standards. Hiring the right people to contact customers. Staff training | --- | Analyzing projects with department managers and production employees | --- | Confirmation of payment and economic credibility of the customer |
|               | 7 392 | 2 48 | 2 24 | 4 24 | 3 12 | 10 360 | 4 144 | 9 288 | 2 98 | 7 126 | 3 45 | 3 36 | 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 |
| Access to international raw materials, capital and production resources | 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 | -- | 7 | -- | 6 | 336 |
| Steel supply | Steel oversupply | 7 | Global steel overproduction | 6 | --- | 4 | 168 |
| Steel supply | 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 | -- | 3 | -- | 4 | 36 |
| Inaccurate estimates of mine life | Depletion of resources | 1 | Low level of deposits | 3 | -- | 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 |
| Steel Import | Embargo | 5 | -- | 6 | -- | 2 | 60 |
| Steel Import | Material losses | 4 | Increasing costs of raw material extraction. | 7 | --- | 3 | 84 |
| Steel Import | Increase in transport costs | 3 | Too low prices for steel and iron ore. Chronic | 8 | --- | 3 | 72 |
| Category                        | Event                                                                 | Risk Assessment | Impact | Severity |
|--------------------------------|----------------------------------------------------------------------|-----------------|--------|----------|
| **Steel price increase**       | 4 low steel and iron ore prices                                       | 9               | 3      | 108      |
| **Decrease in steel demand**   | 6 The use of steel substitutes                                         | 6               | 8      | 96       |
|                                | 9 Loss of customers                                                   | 8               | 8      | 144      |
| **Seasonality of sales**       | 1 Limited cooperation with a potential supplier                       | 1               | 7      | 35       |
|                                | Production stoppages                                                  | 7               | 5      | 35       |
| **Addiction to suppliers**     | 1 Loss of production orders                                           | 3               | 4      | 12       |
| **Relationship with entities** | 3 Loss of a key customer                                              | 1               | ---    | 6        |
|                                | 4 Transfer of production to Asian markets                             | 6               | 2      | 120      |
| **The impact of globalization**| 6 Loss of regular customers                                           | 10              | 2      | 8        |
|                                | 2 Price drop                                                          | 2               | 2      | 8        |
|                                | 3 Material losses                                                     | 4               | 3      | 36       |
| **Social**                     | 9 Increase in transport costs                                          | 10              | 6      | 540      |
| **Environmental degradation**  | 2 Adaptation of production plants to strict restrictions and environmental regulations | 6              | 3      | 36       |
|                                | 2 High penalties for non-compliance with environmental regulations    |                 |        |          |
|                                | 2 Inability to adapt production plants to environmental requirements  |                 |        |          |
|                                | 2 Steel cost increase. The need to modernize the workplace to meet environmental standards. | 6              | 3      | 36       |
|                                | 2 Gradual adaptation of the workplace to environmental standards      |                 |        |          |

Table 1.
FMEA analysis sheet for the industry studied [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

| 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.

**Fundings**

Research financed by a research project NCN nr UMO-12/05/B/HS4/04139.

**Author details**

Małgorzata Dendera-Gruszka* and Ewa Kulińska
Faculty of Production Engineering and Logistics, Opole University of Technology, Poland

*Address all correspondence to: m.dendera-gruszka@po.edu.pl

**IntechOpen**

© 2020 The Author(s). Licensee IntechOpen. This chapter is distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/3.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.
References

[1] Tarasewicz R. Jak mierzyć efektywność łańcuchów dostaw? Warszawa: Oficyna Wydawnicza Szkoły Głównej Handlowej w Warszawie; 2014. pp. 11-14

[2] Rogowski W, Michalczewski A. Zarządzanie ryzykiem w przedsiębiorstwach inwestycyjnych. Kraków: Wyd. Oficyna Ekonomiczna; 2005. p. 7

[3] Kulińska E, Dornfeld A. Zarządzanie ryzykiem procesów, identyfikacja—modelowanie—zastosowanie. Opole: Oficyna Wydawnicza Politechniki Opolskiej; 2009. p. 9

[4] Dendera-Gruszka M, Kulińska E, Mastowski D. Mapa ryzyka jako narzędzie analityczne wspomagające zarządzanie ryzykiem. In: Studia i Materiały Wydziału Zarządzania i Administracji Wyższej Szkoly Pedagogicznej im. Jana Kochanowskiego w Kielcach. Zarządzanie kryzysowe i bezpieczeństwo, 21. 2017;1(4):533-546

[5] Kulińska E. Metody analizy ryzyka w procesach logistycznych. Logistyka. 2011;2:385-390

[6] Szymonik A. Logistyka w bezpieczeństwie–bezpieczeństwo w logistyce. Wybrane zagadnienia, Innowacje w zarządzaniu i inżynierii produkcji, T. I, red. R. Knoasała. Oficyna Opole: wydawnicza PTZP; 2016. pp. 1033-1044

[7] Dendera-Gruszka M, Kulińska E, Masłowski D. Mapa ryzyka jako narzędzie analityczne wspomagające zarządzanie ryzykiem. Zarządzanie kryzysowe i bezpieczeństwo: Studia i Materiały, R. 21 Wydziału Zarządzania i Administracji Wyższej Szkoly Pedagogicznej im. Jana Kochanowskiego w Kielcach. 2017;1(4):533-546

[8] Kaczmarek TT. Ryzyko i zarządzanie ryzykiem, ujęcie interdyscyplinarne. Warszawa: Wyd. Difin; 2008. pp. 51-53

[9] Šotić A, Rajić R. The review of the definition of risk. Online Journal of Applied Knowledge Management. 2015; 3(3):17-19

[10] Dendera-Gruszka M, Kulińska E, Wojtynek L. Analiza ryzyka usług logistycznych w oparciu o audyt logistyczny na podstawie wybranego przedsiębiorstwa. Zeszyty Naukowe SGGW. 2017;2(1):17-30

[11] Rusecki A. Praktyczne zastosowanie metody FMEA na przykładzie produkcji koła pasowego w wybranym przedsiębiorstwie. Quality Production Improvement. 2018;8(1):7-18

[12] Folejewska A. Analiza FMEA – zasady, komentarze, arkusze, Wyd. Warszawa: Verlag Dashofer; 2010

[13] Pałubicki S, Kuśielka K. Zarządzanie jakością w wybranym procesie produkcyjnym z zastosowaniem metody FMEA. Autobusy. 2017;7–8:90-96

[14] Wyrębek H. Znaczenie metody FMEA w zarządzaniu jakością w przedsiębiorstwach. Zeszyty Naukowe Uniwersytetu Przyrodniczo – Humanistycznego w Siedlcach. 2012;92: 151-165

[15] Huber Z. Analiza FMEA procesu. Gliwice: Wyd. Złote Myśli; 2007. pp. 11-32

Supply Chain FMEA Risk Analysis for the Heavy Industry Sector
DOI: http://dx.doi.org/10.5772/intechopen.91042