New Application of FMEA Analysis in the Heavy Industry Supply Chain

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Abstract:

Purpose: The purpose of the publication is to indicate the validity of building industry supply chains and to present a modified FMEA analysis for the heavy industry supply chain.

Approach/Methodology/Design: The research was carried out with reference to companies operating in the heavy metal industry between 2016 and 2020 on a European scale. The presented results concern one aspect of the conducted research related to the identification of key areas and determinants shaping industry supply chains.

Findings: The results obtained determine the specificity of the heavy industry supply chain, where social and societal aspects had the greatest impact on industry supply chains, mainly related to the lack of qualified staff, the increase in labour costs and social benefits and the need to meet staffing needs with foreign human resources.

Practical Implications: The relationships of companies operating in the heavy industry sector, the specifics of the supply chain and the risk factors affecting the companies in question are examined, as well as relating the risk elements to the heavy industry sector.

Originality/Value: The article contains important determinants for the development of the heavy industry explained along with the presentation of an innovative method combining FMEA analysis with the emergence of determinants shaping the industry.

Keywords: Supply, chain/network, management/governance, accidents (industrial, operational, etc.), failures, risk management.

JEL classification: O14, P42, P51.

Paper Type: Research study.

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1. Introduction

Contemporary economic conditions and globalisation processes influence the way a company is managed and develops. Different regional, cultural and social factors and structures determine the choice of an appropriate decision-making strategy to maintain a company's competitiveness in a given market. The dynamics of change in both cultural and economic issues determine the determinants of change in organisational management (Stajniak and Koliński, 2016). The literature on the subject abounds with many concepts of management, organisation, efficiency, effectiveness, flexibility, etc. attributed to supply chains (Leung et al., 2014; Yang et al., 2021; Christopher and Holweg, 2011). Based on these considerations, a number of contemporary concepts have emerged, such as, rigid supply chains (Gualandris and Klassen, 2018), lean supply chains (Carvalho et al., 2017; Frazzon et al., 2017; Chen et al., 2020), supply chains of continuous replenishment (Parsa et al., 2017), slimmed-down supply chain (Pawlewski, 2018), flexible supply chains (Singh et al., 2017; Radzidon et al., 2014; Kurpjuweit et al., 2021), resilient supply chains (Dubey et al., 2019; Sawyerr and Harrison, 2019; Rajesh 2019)), agile supply chains (Wu and Barnes, 2018; Bicocchi et al., 2019), hybrid supply chains (Lin et al., 2014; Tu et al., 2019), multidimensional supply chains (Dendera-Gruszka et al., 2020; Varsei et al., 2014; Panchal et al., 2015), whether triadic supply chains (Swierczek, 2019; Swierczek, 2020; Him and Henderson, 2015).

It is also worth mentioning that the supply chain is inextricably linked with the current world picture. The awareness of the advantages of the supply chain has contributed to the creation of methods supporting its management processes. Globalization forces the expansion of market activity of enterprises on a macroeconomic scale. Therefore, it is necessary to look at the structure of the supply chain from an industry perspective, which is the main idea of this publication.

The purpose of this publication is to indicate the rationale for building industry supply chains and to present an FMEA analysis for a heavy industry supply chain. The research was carried out for companies operating in the heavy metal industry between 2016 and 2020, mainly on a European scale, and covered nine major business entities, including three steel fabricators, three steel trading and manufacturing companies, and three metal products and metal processing companies. The relationships of the heavy industry companies, the specifics of the supply chain and the risk factors affecting the companies in question were examined, as well as relating the risk elements to the heavy industry.

2. Industry Supply Chain - Areas of Analysis and their Determinants

Supply chain transformation involves the adaptation of some of its elements to current market conditions. The ability to adapt to market conditions is extremely important in achieving competitive advantage. Ongoing supply chain changes are closely linked to the ability to anticipate the direction of market changes, to take
appropriate anticipatory actions and to improve supply chain management (Bentyn, 2016). In the implemented supply chain activities, one notices many elements of different concepts, mentioned in the introduction, implemented simultaneously. Managers extremely rarely consider which of the selected supply chain management concepts to apply in a given case. They need quick simple mechanisms to facilitate decision-making processes. They pay special attention to relationships with partners, information flow, flexibility and response time.

The analysis of industry supply chains is an analysis of the individual actors and, above all, of the relationships between them. Four years of research have shown that managing these relationships poses the greatest difficulties for managers. The results of this research have been divided into problem areas such as technological, temporal, locational, economic, political-legal, economic, social, globalisation and ecological. While these areas can be adopted similarly across industries, the determinants that shape these areas will differ. Table 1 summarises the areas of analysis and determinants of the heavy industry supply chain.

**Table 1. Industry supply chain - areas of analysis and determinants (own study based on Polak 2009; Dendera-Gruszka et al., 2018; Dorn et al., 2018)**

| Area       | Determinants                                                                                   |
|------------|-----------------------------------------------------------------------------------------------|
| Technological | – technological progress<br>– technological developments<br>– the increasing role of telecommunications<br>– access to high-speed internet networks<br>– access to new technologies<br>– access to information<br>– quality of information flow<br>– data theft<br>– technological and technical innovation<br>– use of information systems<br>– e-banking<br>– electronic data processing<br>– cloud computing |
| Temporary   | – technological developments<br>– development of information technology<br>– information flows<br>– Development of emerging markets<br>– Speed of response to customer requests and requirements<br>– development of competition |
| Location    | – reduction of spatial barriers<br>– deterritorialisation<br>– integration<br>– reduction of state sovereignty<br>– density of transport network<br>– density of communication network<br>– access to airports/sea/interland ports |
| Category         | Examples                                                                 |
|------------------|--------------------------------------------------------------------------|
| Economical       | - access to railway stations  
                  |   - access to motorways, national roads  
                  |   - spatial mobility  
                  |   - dominance of economics  
                  |   - unpredictability of the future  
                  |   - accumulation of wealth  
                  |   - economisation of politics  
                  |   - balance of payments burden  
                  |   - increase in unemployment  
                  |   - lack of skilled labour  
                  |   - the state of world markets  
                  |   - the volume of foreign exchange turnover  
                  |   - average tariffs  
                  |   - market regulation mechanisms  
                  |   - stock exchange quotations  
                  |   - exchange rates  
                  |   - inflation  
                  |   - turbulence on energy markets  
                  |   - economic situation  
                  |   - liberalisation of the markets |
| Politico-legal   | - unpredictability of the future  
                  |   - dependence of the economic and political sphere on international  
                  |   |   capital  
                  |   - weakening of state structures  
                  |   - international legal and social relations  
                  |   - international tax regulations  
                  |   - aid received from public funds  
                  |   - policy of state authorities towards enterprises  
                  |   - changeability of legal regulations  
                  |   - legal regulations on the freedom to conduct business activities  
                  |   - effectiveness of corporate governance mechanisms  
                  |   - economic freedom  
                  |   - changes in economic conditions  
                  |   - tax rates  
                  |   - state fiscal policy  
                  |   - condition of the public finance sector  
                  |   - effectiveness of state control bodies  
                  |   - value of export  
                  |   - value of state investments  
                  |   - changes in political and economic structures of the state  
                  |   - restriction of political and economic sovereignty  
                  |   - political corruption  
                  |   - burden on the state budget  
                  |   - reforms of the tax system  
                  |   - functioning within a customs union or union of nations  |
| Business         | - standardisation  |
| - unification          |
| - integration         |
| - fragmentation       |
| - formalisation       |
| - institutionalisation|
| - innovation of the economy |
| - level of economic growth |
| - uncertainty of market position |
| - uncertainty of market identity |
| - economic volatility |
| - volatility          |
| - alignment of price/wage levels |
| - price/wage level    |
| - number of multinational corporations and subsidiaries |
| - share of intra-firm flows |
| - degree of concentration of production |
| - export rate         |
| - share of output value in global production |
| - level of foreign direct investment |
| - investment projects |
| - consolidation/ transformation of the industry |
| - implementation of strategic transactions |
| - changes in the structures of companies |
| - increase in costs   |
| - supply and demand developments |
| - competitiveness policy |
| - tightened competition policy |
| - business relationships with clients |
| - smooth communication |
| - commitment to orders |
| - information flow    |
| - payment turnover    |
| - customer insolvency |
| - payment deadlines   |
| - international flows of capital, goods, services and knowledge |
| - value of exports    |
| - value of international investments |
| - internationalisation of the company |
| - number of contractors/branches abroad |
| - fragmentation of production |
| - export capacity     |
| - international division of labour |
| - changes in production structures and product range |
| - enlargement of sales markets |
| - new jobs            |
| - access to international raw material, capital and production |
|                       |                                                                 |
|-----------------------|------------------------------------------------------------------|
| **Social**            | resources                                                        |
|                       | − access to the global labour and sales market                   |
|                       | − instability of life                                             |
|                       | − unpredictability of the future                                  |
|                       | − impoverishing cultural diversity                                |
|                       | − commercialisation of consumer culture                           |
|                       | − deterritorialisation of culture                                 |
|                       | − commercialisation of social relations                           |
|                       | − links to cultural, territorial and professional communities     |
|                       | − social disintegration                                          |
|                       | − increase in social activity                                     |
|                       | − payments for social and welfare benefits                        |
|                       | − demand and supply of skilled labour                             |
|                       | − minimum wage levels                                            |
|                       | − increase in labour costs                                        |
|                       | − population movements                                           |
|                       | − foreign language skills                                         |
| **Globalisation**     | − the growing role of non-state, unelected and undemocratic      |
|                       | centres of economic power                                         |
|                       | − the concentration of power resulting from hyper-power           |
|                       | − the separation of the financial world from the real economy    |
|                       | − increasing disparities between individual market segments       |
|                       | − uncontrolled privatisation of the sector and public space      |
|                       | − centralisation of political and economic decisions              |
|                       | − globalisation of social pathologies                             |
|                       | − social threats and terrorism                                     |
|                       | − universalisation                                                |
| **Organic**           | − rapidly increasing pressure to use green solutions              |
|                       | − legal regulations on environmental protection                   |
|                       | − environmental disasters                                         |
|                       | − natural disasters                                              |
|                       | − natural disasters                                              |

*Source:* Own study based on Polak 2009; Dendera-Gruszka et al., 2018; Dorn et al., 2018.

Determinants influencing the industry supply chains concern each area of activity of the economic entity. Starting from the closest environment of the links comprising the supply chain, through social conditions, ending with the geopolitical situation of the world and globalisation processes. Table 1 presents factors influencing industry supply chains. In an industry supply chain, social factors are extremely important, as extremely culturally different employees may operate the supply chain at different stages of the business. Another important issue is the location of each element of the industry supply chain and its access to transport infrastructure. The operation of industry supply chains depends not only on national legal and fiscal frameworks, but also on international legal, tax and customs standards. The operation of industry supply chains is directly affected by the situation on global markets. The transformation of industry supply chains also takes place in connection with
exchange rate fluctuations and inflation. The pressure from international organisations to protect the environment is also increasingly important in this area.

The research conducted also allowed for the identification of determinants shaping the industry supply chain. The management of the studied business entities indicated the most significant, in their opinion, key elements influencing changes in the industry supply chain. On this basis, an analysis of the dependence between the influence of each factor on the functioning of the studied business entities and an exploration of the dependence of the factors in the perspective of each enterprise was carried out. For this purpose, the dependency graph method was used. In order to develop a risk management model of the industry supply chains, a decision table was drawn up based on the developed dependency graphs. The decision table showed the relationship between the determinants affecting the transformation of supply chains and the corresponding risk factors. These areas of research will be described in another publication.

The identified risk factors were used to carry out a risk management model of transforming supply chains, which is based on FMEA analysis. As is well known, FMEA analysis is used to analyse products or processes. FMEA analysis is a method of identifying and preventing problems related to the analysed process before its execution. It focuses on the prevention of process or product defects, increasing the safety of the process implementation, the financial security of the project, the safety of work and environmental protection (Wyrębek, 2012). FMEA analysis is carried out in the design phase of a process or product in order to avoid major risks and defects in the implementation phase. It is an important technique for identifying and eliminating potential defects and errors in processes and products. The authors decided to use it in a slightly different way.

The research decided to extend its application to the supply chain analysis of a specific industry. The developed FMEA model of industry supply chains includes areas that were selected from all the factors affecting changes in the management of the flow of goods and services. Based on the previously conducted analysis and selection of determinants, an FMEA analysis was conducted for the industry under study. The FMEA analysis covers the previously mentioned areas. The determinants affecting the industry supply chain in the heavy industry were analysed. The FMEA analysis was prepared on the basis of data obtained from the researched business entities - Table 2.

**Table 2. FMEA analysis sheet for the industry under study**

| Area | Potential type of defect | Potential effect of the defect | Importance | Potential causes of the defect | Occurrence | Preventive measures | Detection | RPN |
|------|--------------------------|-------------------------------|------------|-------------------------------|------------|---------------------|-----------|-----|

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| Category                        | Issue Description                                                                 | Impact Score | Impact Score Impact Score Impact Score | Impact Score |
|--------------------------------|----------------------------------------------------------------------------------|--------------|----------------------------------------|--------------|
| Technological                   | Incorrect implementation of innovations                                          | Loss of capital | 3                                      | 2            |
|                                | Lack of focus of the organisation on innovation activities                       | Loss of capital | 3                                      | 2            |
|                                | Extension in time of the implementation of innovative investments              | Lack of interest in new technological solutions | 2                                      | 7            |
|                                | Expansion of emerging markets                                                   | More attractive offer from an emerging market supplier | 5                                      | 8 280        |
|                                | Late response to customer enquiries and requests                                 | Loss of a potential customer | 6                                      | 6            |
|                                | Lack of response to customer queries and requests                              | Customer loss | 8                                      | 3            |
|                                | Reduction of spatial barriers                                                   | Increased competition | 4                                      | 6            |
|                                | Transport network                                                               | Lack of access to sea, river and air ports, roads, motorways, railway networks | 2                                      | 7            |
|                                | Lack of an adequate transport or communication network                          | Location of plant in an economically undeveloped area. | 4                                      | 5 70         |
|                                | Lack of a suitable transport fleet                                              | Lack of investment by the operator in transport equipment | 2                                      | 9 72         |
|                                | Poor condition of road network                                                  | Use of forwarding companies | 4                                      | 32           |
|                                | Limited spatial mobility                                                        | Employment of foreigners | 8                                      | 2 112        |
|                                | Lack of skilled labour                                                          | Unemployment. Migration of | 8                                      | 10           |
| Economic                        | Staff shortages                                                                 |                          |                                        |              |
|                                | Lack of suitable                                                                |                          |                                        |              |
### New Application of FMEA Analysis in the Heavy Industry Supply Chain

#### Changes in global markets
- **Financial crisis**: High level of emigration. Conflicts between countries. 5
- **Relocation of production to stable areas of the world**: 3

#### Changes in stock exchange quotations
- **Loss of potential shareholders**: 4
- **Crisis on world stock exchanges. Company bankruptcy.**: 2
- **Speculative bubble**: 3

#### Changes in exchange rates
- **Inflow of external capital**: 3
- **Speculative bubble**: 3
- **Inflation**: 2

#### Changes in legal and social relations
- **Unfavourable legal and social relations**: 4
- **Strikes of professional groups. Social policy of the state**: 5
- **Lack of funds for enterprise development**: 2
- **Lack of public funds for a given area. Lack of classification of entity to receive assistance from public funds. Insufficient pool of public funds. Insufficient argumentation in applying for aid. Lack of an adequate aid scheme.**: 9
- **Lack of credit capacity**: 4
- **Other credit commitments. Loss of production orders. Company indebtedness**: 6

#### Changes in tax regulations
- **Unfavourable tax regulations**: 5
- **Burden on the earned income**: 7

#### Polio-

#### Value of exports
- **Lack of competitiveness in the international arena**: 8
- **Difficulty in gaining international customers. Unattractive offer of the company for foreign contractors**: 7

#### Business

#### Low innovativeness of government
- **Lack of attractiveness of the company abroad**: 6

#### Data

| Category                                  | Event Description                                                                 | Score | Total |
|-------------------------------------------|-----------------------------------------------------------------------------------|-------|-------|
| Financial crisis                          | High level of emigration. Conflicts between countries                              | 5     |       |
| Relocation of production to stable areas  | of the world                                                                       | 3     |       |
| Loss of potential shareholders            |                                                                                  | 4     |       |
| Crisis on world stock exchanges. Company  | bankruptcy.                                                                        | 2     | 24    |
| Speculative bubble                        |                                                                                  | 3     |       |
| Inflow of external capital                |                                                                                  | 3     | 45    |
| Inflation                                 |                                                                                  | 2     | 30    |
| Unfavourable legal and social relations   |                                                                                  | 4     |       |
| Strikes of professional groups. Social    | policy of the state                                                                | 5     | 80    |
| Lack of funds for enterprise development  |                                                                                  | 2     | 50    |
| Rejection of an application for funding of | investment                                                                         | 1     |       |
| an investment                             |                                                                                  |       |       |
| Insufficient funds to carry out the       | investment                                                                         | 1     |       |
| investment                                |                                                                                  |       |       |
| Acquisition of new customers, new         | production orders                                                                   | 8     | 72    |
| Lack of credit capacity                   |                                                                                  | 4     | 48    |
| Inability to repay credit                |                                                                                  | 3     | 12    |
| Necessity to introduce foreign capital    |                                                                                  | 1     | 2     |
| Lack of assistance from public administration |                                                                                  | 1     |       |
| Lack of understanding of the situation by | government offices. Following specific and rigid procedures                        | 8     |       |
| Joining a business association            |                                                                                  | 6     | 48    |
| Complicated and time-consuming administrative procedures |                                                  | 2     | 54    |
| Difficulty in gaining international       | customers. Unattractive offer of the company for foreign contractors              | 7     | 392   |
| Finding new markets                      |                                                                                  | 7     |       |
| Starting to work with new suppliers       |                                                                                  | 2     | 48    |
| Lack of competitiveness in the international arena |                                                 | 8     |       |
| Low attractiveness of the company abroad  |                                                                                  | 6     |       |
| Lack of government                        |                                                                                  | 4     |       |
| Category                                      | Cause                                                                 | Degree of Impact | Effect                                                                 | Degree of Impact |
|----------------------------------------------|-----------------------------------------------------------------------|------------------|------------------------------------------------------------------------|------------------|
| The economy                                  | Support for research and production development                       |                  |                                                                        |                  |
| Degree of concentration of production        | Increase in competition                                               | 3                | Use of outsourcing. Signing a contract with a subcontractor            | 2 24             |
| Export rate                                  | Low export rate                                                       | 6                | Regress of sales markets                                               | 4 ---            |
| Level of execution of strategic transactions | Lack of executed strategic transactions                              | 2                | Focusing the production only on one specific type of products and cooperation with only one final customer | 2 12             |
| Increase in costs                           | Low level of production profitability                                 | 9                | Increase in the prices of energy, raw materials and labour costs       | 10 ---           |
| Competitiveness policy                       | Unfair trade practices                                               | 4                | Development of competition, globalisation                              | 9                |
| Business relations with clients              | Loss of client                                                        | 4                | Disregard for clients, improper customer service, lack of developed and implemented standards of customer service | 8 288            |
| Quality of communication                     | Loss of employees                                                     | 7                | Lack of communication between the management and employees at the lowest level | 7                |
| Quality of information flow                  | Poor quality of information flow                                      | 6                | Disruptions in the flow of information                                 | 7                |
| Customer insolvency                          | Non-payment in due time                                               | 3                | Improving the information flow process                                 | 3 126            |
| Bankruptcy of a business partner             |                                                                       |                  | Confirming the customer's payment and business reliability             | 5 45             |
| Too much debt of the organisation           |                                                                       |                  |                                                                       |                  |
| Too long payment period                      |                                                                       |                  |                                                                       |                  |
| Quality of purchased goods and services      | Breaking off relations with the supplier                             | 3                | Poor quality of purchased goods and services                           | 4                |
| Lack of source of supply                    |                                                                       |                  | Checking the quality of supplied goods. Change of supplier             | 3                |
| Quality of goods and services sold           | Loss of client                                                        | 7                | Inspection of manufactured products                                    | 5                |
| Value of international investments          | Lack of participation in international investments                    | 6                | Impact of globalisation, decrease in the share of international investments, long-term nature of investments, changes | 7 ---            |
|                                               |                                                                       |                  |                                                                       | 5 210            |
| Category                                      | Description                                                                 | Severity | Likelihood | Impact   |
|-----------------------------------------------|------------------------------------------------------------------------------|----------|------------|----------|
| **Capacity for fragmentation of production** | Lack of opportunities for fragmentation of production                        | 3        | 4          | 48       |
|                                               | Globalisation, imperfect production processes, low quality of manufactured    |          |            |          |
|                                               | components, different cultural backgrounds influencing the production process |          |            |          |
|                                               | problem with communication and changing time zones, long transport times      |          |            |          |
| **Access to international raw material, capital and production resources** | Lack of access to the global labour and sales market                         | 6        | 5          | 60       |
|                                               | Global steel overproduction                                                 | 6        | 10         |          |
| **Degree of raw material storage**            | Excessive stocks                                                            | 8        | 7          | 336      |
| **Supply of steel**                           | Over-supply of steel                                                        | 7        | 6          | 168      |
|                                               | Global steel overproduction                                                 | 6        | 10         |          |
| **Degree of production profitability**        | Price discrepancy between steel and raw material                           | 2        | 6          | 24       |
|                                               | High level of raw material prices. Unprofitability of steel production.      |          |            |          |
| **Low efficiency of mining operations**       | Inability to meet demand                                                    | 3        | 3          | 36       |
| **Inaccurate mine life estimates**            | Exhaustion of resources                                                     | 1        | 1          | 3        |
| **Drilling failure**                          | Loss of raw material                                                        | 2        | 2          | 12       |
| **Errors during production processes**        | Failure to meet orders                                                      | 2        | 2          | 8        |
| **Export capacity**                           | Changes in the commercial policy of steel mills                             | 8        | 4          | 64       |
|                                               | Lack of conviction to export goods. Too much competition.                   |          |            |          |
|                                               | Temporary or permanent ban on export of goods.                               |          |            |          |
| **Steel imports**                             | Loss of material                                                            | 4        | 7          | 84       |
|                                               | Rising costs of raw material extraction. Steel and iron ore prices too low.|          |            |          |
|                                               | Persistently low steel and iron ore prices.                                 |          |            |          |
| **Decrease in demand for steel**              | Use of steel substitutes                                                    | 6        | 8          | 96       |
|                                               | Development of competition from other materials. Price and technologica      |          |            |          |
|                                               | and technological attractiveness of other materials                         |          |            |          |
| **Seasonality of sales**                      | Limited cooperation with a                                                 | 1        | 7          | 35       |
|                                               | Loss of regular production orders                                           |          |            |          |
Table 2 shows the key aspects that can affect the heavy industry supply chain. Table 2 analyses the different business areas of the operators involved in the flow of goods and services in the heavy industry industry. The potential type of defect is defined together with its effect. The probability of a defect occurrence is determined on a scale of 1 to 10. A value of 1 is assigned to an improbable situation, while 10 - to a very probable situation. Details of the value assignment are given in Table 3.
**Table 3. Determination of the significance of the occurrence of the defect**

| R    | Importance          | FMEA service/structure                                      |
|------|---------------------|-------------------------------------------------------------|
| 1    | unlikely            | Imperceptible impact on service delivery                    |
| 2–3  | small               | The defect is minor and has little impact on customer satisfaction |
| 4–6  | medium              | Medium defect, noticeable customer dissatisfaction           |
| 7–8  | important           | The defect occurs cyclically and has a major impact on customer dissatisfaction |
| 9–10 | extremely important | Extremely important defect that affects further operation, safety and is contrary to law |

Source: Own study.

The next step was to determine the cause of the defect with its value. Again, the cause of the defect was determined on a scale of 1 to 10. A value of 1 is assigned to an unlikely situation and 10 to a very likely situation. Details of the value assignment are given in Table 4.

**Table 4. Determination of probability of defect**

| W    | Probability of defect | FMEA service/structure/process                                |
|------|-----------------------|---------------------------------------------------------------|
| 1    | unlikely              | No possibility of defect                                      |
| 2    | very low              | Very low probability of defect occurrence. Defects occur singly and very rarely |
| 3    | low                   | Low probability of individual defects                          |
| 4–6  | average               | Defects occur in small quantities on average                  |
| 7–8  | high                  | Defects are very common                                       |
| 9–10 | very high             | Very high probability of defect                                |

Source: Own study.

In the next step, preventive measures were specified and detection parameters were estimated, Table 5.

**Table 5. Determination of probability of detection**

| D    | Significance of the defect | FMEA service/structure/process                               |
|------|----------------------------|---------------------------------------------------------------|
| 1–2  | very large                | Reliable detection of a defect                                |
| 3–4  | large                     | Chances of detecting a defect are high, a test or functional check is used |
| 5–6  | medium                    | Defect inspection may detect an average detection              |
| 7–8  | small                     | Difficulty in detecting a defect                              |
| 9–10 | very small                | Detection of the defect is difficult or impossible             |

Source: Own study.

The final stage of the FMEA analysis was to assign the RPN parameter. Assigning the above parameters to the FMEA sheet allowed us to determine the RPN risk priority number, which was calculated according to formula 1.

\[
RPN = \text{Importance (R)} \times \text{Occurrence (P)} \times \text{Detection (D)}
\]  

(1)
The RPN makes it possible to identify which hazards carry the greatest risk and to prioritise in which order the different determinants are analysed.

The industry supply chain FMEA aimed to demonstrate the relationship between the determinants shaping the areas of industry supply chain materiality for the heavy industry sector. During the analysis a value of RPN = 100 was set, below this value the influence of the factors on the industry supply chain was insignificant, while above this value it had a very significant influence on it.

For the industry studied, social and societal aspects had the greatest impact on industry supply chains, mainly related to the lack of skilled staff, rising labour costs and social benefits, and the need to meet staffing needs with foreign human resources. Other aspects influencing the formation of industry supply chains were rising energy and raw material prices, business relationships with customers, expansion of emerging markets and reduction of spatial barriers.

3. Conclusion

Supply chains are among the structures that are susceptible to the influence of external factors, and thus are conducive to creating conditions for the transformation of supply network structures. As supply chains are directed towards the achievement of specific economic, organisational and quality objectives, they are influenced by the paradigm of reducing costs and increasing benefits for the final customer.

The industry supply chain involves the adaptation, relevant at a given point in time, of its elements to current market conditions. The ability to adapt to market conditions is critical to achieving competitive advantage.

Industry supply chains are primarily target-driven. In the face of increasing change, logistics partnerships, relationships formed, have a significant impact on supply chain management.

The verification of the industry supply chain model was carried out on the basis of an analysis of business entities. The analysis covered the determinants within the distinguished areas that condition effective cooperation according to the studied entities. On the basis of the indicated determinants influencing the industry supply chain, an analysis of the dependence of selected factors on business entities operating within the industry supply chain was conducted. The results obtained after a modified FMEA analysis made it possible to identify the key determinants for the industry supply chain of heavy industry.

The results obtained determine the specificity of the supply chain for the heavy industry industry. For the industry under study, social and societal aspects had the greatest impact on the industry supply chain, mainly related to the lack of qualified staff, the increase in labour costs and social benefits and the need to meet staffing
needs with foreign human resources. Other aspects influencing the formation of industry supply chains were rising energy and raw material prices, business relationships with customers, the expansion of emerging markets and the reduction of spatial barriers.

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