
Risk in Supply Chain Management

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Abstract:

Purpose: The research problem handled in this article entails the determination of the relationship between the risk and the possibility of emergence of specific interference and problems along the supply chain.

Design/Methodology/Approach: The utilised statistical analysis that is supposed to help to achieve the assumed research objective of the present article entails the identification of key interference present along the supply chain of the tested company and the identification of causes and effects of their emergence. The analysis was based on the FMEA. Tested were six types of the most common interference, negatively influencing the supply chain of the given enterprise. The analysis forms the basis for the assessment of risk related to the emergence of the individual interference types in the supply chain.

Findings: The verification of the research hypothesis in the theoretical sense was conducted using the scientific cognition method, the foundation of which was formed by non-series Polish and foreign publications as well as articles published in scientific journals. For the empirical part, the basis was formed by original material, case studies of the company Deltim concerning logistical processes, the functioning of the supply chain, and inconsistencies emerging in this area.

Practical Implications: Research results may be used by small and medium production enterprises and as teaching material at higher education facilities.

Originality/Value: Original research.

Keywords: Supply chain, supply chain management, supply chain risk, risk management.

JEL Classifications: D81, F2, F32, G32.

Paper type: Research article.

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1. Introduction

Globalisation, increased competition in economic markets and technological progress have led to an increase of significance of efficiency of logistical processes taking place within production enterprises (Piersiala, 2019). The strongly developing market of logistical services and dynamic changes within the TSL industry have provided enterprises with new opportunities on the one hand, and new challenges on the other hand. The constant struggle for the customer, significant improvements to the quality of life and progressing virtualisation are reflected in logistical processes, in particular in the area of information and material flow through supply chains. Without a doubt, one of the factors that is of key significance in terms of the creation of product added value, and hence, directly influencing a company's competitiveness, is the level of logistical services of the customer, playing a significant role in the establishment of the customer's level of satisfaction with the provided service.

The customer satisfaction level, beside the price and the individual properties of the product, is also influenced by other factors such as supply reliability, timeliness, order execution times, channels of direct contact with the enterprise, etc., meaning, factors directly defined by the supply chain management strategy adopted by the enterprise. In other words, efficient supply chain management, beside the direct influence on the efficiency of this chain, may contribute to the execution of a company's objectives, the acquisition of a competitive advantage on the market, the improvement of the image and the establishment of product added value, which is uniquely important in case of production of goods of similar properties that frequently prevent the determination of a single, best product (Kabus and Miciuła, 2019).

The above interdependencies have become the motivation for musings on the management of the supply chain, with particular focus on tests of the role of management of the supply chain in a production enterprise and research related to the identification of interference within the supply chain.

The core of management of risk within the supply chain was borne as a response to the growing market competition. Becoming participants in the supply chain, the enterprises are active globally, within diverse legal, political, or social environments. The will to reduce both production as well as supply costs had brought about the necessity to seek out ever more economical solutions in global markets, frequently choosing offshoring or outsourcing, meaning, the transfer of production abroad, to countries with decidedly lower labour costs than domestically (Małyszczek, 2016). Sadly, advantages in the form of cost reductions also bring about complications in the form of ever longer and ever more complex supply chains, leading to increases in the risk of failure in the achievement of the goals set – a form of trade-off (reduction of operating costs with a simultaneous increase of the risk of emergence of diverse types of interference). Such a situation had brought enterprises to the point, in which all kinds of interference, risk factors and interdependencies have to be factored in in terms of probability of emergence and the possible consequences (risk management) already

when designing the supply chain (Dorozik *et al.*, 2020). This shows that on the one hand integration within the supply chain brings in advantages, but on the other hand, it also influences such components of the supply chain that are considered to be raising the risk of interference.

The objective of the present paper is an analysis of the functioning of the supply chain within a selected production enterprise, and the assessment of influence of supply chain management on its efficiency. The identification of interference along the supply chain within the context of management of the entire chain became an additional (applicational) objective. The research analysis presented in this paper concerns the supply chain implemented at the production enterprise Deltim, operating in the area of children's prams.

2. Literature Review

Risk and risk management can be interpreted in various ways. Risk is an ambiguous and heterogeneous category (Woźniak and Wereda, 2019), hence, it is difficult to define – causing a lack of description of its universal properties (Miciuła, 2015). Subject literature uses many diverse classifications of risk, the criteria of which correspond to the core of the event being classified (Włodarczyk and Miciuła, 2020). One may assume that risk is the probability of achievement or failure to achieve the set goal – as references to success or failure in action (Zawiła, Niedźwiedzki, and Staniec, 2008).

Every area of management within an enterprise is burdened by certain risks (Ang, 1991). The recent financial crisis unveiled the major deficiencies and weaknesses in management even in such developed structures as Eurozone (Thalassinos and Thalassinos, 2018a; 2018b). Still, within the context of the supply chain, risk has been considered only since recent time, and there is no clear indication whether this work can directly be translated to the new area of supply chain management. The supply chain, through its complexity, is exposed in a particular manner to random events and phenomena, the emergence of which cannot be fully foreseen, hence, one cannot secure themselves fully against related risks (Kulińska, 2007).

At the same time, one must notice that the risk of emergence of specific problems increases proportionally to the number of links and parameters of and within the supply chain. The concept of risk presented thus may be defined as: the hazards or dangers, the emergence of which may prevent the achievement of objectives set by an enterprise (Myszak and Sowa, 2016), the probability of emergence of unwanted situations, of negative consequences of an event (Rowe, 2007), the set of specific factors, activities and/or actions that cause material damage or loss (Kaczmarek, 2008), an event that negatively influences the operation of the supply chain, at the same time influencing its performance indicators (e.g., reaction times, customer service levels, order execution times, etc.) (Tummala, Schoenherr, 2011).

As Łupicka-Szudrowicz (2004) states, from the perspective of logistical structures, the most significance is found in terms of risk specific to supply chains, meaning, the type of risk that may occur within the supply chain, both between its individual links (participants in the supply chain) as well as within the flow of information, goods and services. Supply chain risk may be defined as the probability of choosing the wrong strategy, making the wrong decisions, configuring logistical systems in a non-optimum manner, etc., meaning, the emergence of unwanted phenomena related e. g. to the number of links within the supply chain, the availability of communication nodes or the number and types of distribution channels.

Christopher *et al.* (2003) define supply chain risk as a change/interference in the distribution of possible supply chain results, their probabilities, and their subjective values. These changes or interference influence the flow of information, materials, or products within the entire organisation. Zsidisin (2003) describes supply chain risk as the „probability of emergence of a supply-related incident caused by a breakdown in the supply market or with specific suppliers, as a result of which the enterprise loses the capacity to satisfy customer demand or creates a hazard for the life and health of customers.”

The fundamental sources responsible for the implications of risk include all kinds of processes taking place within the chain and the related suppliers, customers, service providers and the market competition (Kuzminski *et al.*, 2020). The risk within the supply chain is tightly related to phases of logistical flows within the company; three fundamental categories of risk are distinguished between supply risk (possible, unwanted events occurring in particular during the supply phase, impacting the capacity of the enterprise to fulfil and achieve customer expectations), operational risk (unwanted events that might occur during production), demand risk (unwanted events occurring during the distribution of goods/services, and which influence the probability of placement of orders and fluctuations in the volumes of the orders placed) (Małyszczek, 2016). A trait specific of the above categories are mutual relations, intertwining and reinforcement as well as exposure to unwanted phenomena, the emergence of which remains outside of the control of the participants in the supply chain (safety risk).

Broadest classifications of risks within the supply chain were suggested by Olson and Wu (2010) as in Table 1 that included categories distinguished by Chopra and Sodhi (2004), Wu *et al.* (2006), Cucchiella and Gastaldi (2006), Blackhurst *et al.* (2008), Manuj and Mentzer (2008a) and Wagner and Bode (2008).

Within the theory of risk management, defined as a kind of a decision process aimed at supporting the achievement of specific economic, social and/ or political goals, under the assumption of optimum costs (Mitek and Miciuła, 2017), with the use of procedures allowing the elimination or strongest possible reduction of all kinds of risk that could threaten the achievement of these goals (down to a level acceptable by the unit) (Zdanowski, 2000).

Małyśzek (2016) states, four fundamental dimensions of risk are differentiated between: probability of emergence of risk, potential losses and consequences arising from the risk, the velocity of the risk considered as the speed of development of the threatening event, the speed of emergence of negative consequences; the speed of detection of risk-bearing events, risk frequency (Stępień and Miciuła, 2017).

Table 1. Categories of risk within the supply chain, according to Olson and Wu

External risk factors	
nature	<ul style="list-style-type: none"> • natural disasters: floods, fires, earthquakes, epidemics
political system	<ul style="list-style-type: none"> • war, terrorism, strikes, legal provisions, customs duties
market competition and	<ul style="list-style-type: none"> • economic crisis • price fluctuations • new technologies • alternatives in substitution • exchange rate fluctuations • payments • demand fluctuations • competition and domination changes • product ageing
External risks	
available capacity	<ul style="list-style-type: none"> • structural capacities • possibility of increase in production capacity • costs of maintenance of production capacity • supplier bankruptcy • financial capacities
internal operations	<ul style="list-style-type: none"> • on-time deliveries • flexibility • quality • security and safety • wrong prognoses • trade-off between stock keeping and orders • forester effect
information systems	<ul style="list-style-type: none"> • outside influences – viruses, hackers, worms • information deformation • breakdown of information systems

Source: Own work quoted from (Olson and Wu, 2010).

The objective of management of risk within supply chains is, beside the identification of risk sources, also quite precise determination of its levels, allowing one to undertake in the future work towards the prevention of emergence of risk events.

Sadly, the usage of a suitable supply chain management strategy that would directly consider supply chain risk does not guarantee the achievement of the objective of identification of the type and level of risk. Problems with efficiency of processes

related to risk reduction can hence be influenced by barriers against risk management within the supply chain, directly including: the globalisation of the supply chain, wrong management of outsourcing processes, centralisation of distribution, undertaking actions aimed at the reduction of costs, failure to consider a suitable level of their effectiveness, focusing the company on just one, fundamental product (no diversification), excessive dependence of the manufacturer on supplier efficiency, seasonal demand fluctuations, incomplete, inefficient access to information, errors within the information management system, failure to use assessment procedures and action control (Myszak and Sowa, 2016).

3. Research

In recent years, Poland has become a force in the production of children's prams. The core region for companies from this industry is the area around Częstochowa. This closely related to the history of the region. We read in the *Dziennik Zachodni*: „After World War II, Poraj, in the county of Myszków, saw the establishment of one of three factories of prams in the eastern bloc. People working at the „Poraj” plant left the facility one by one, to establish their own workshops. This was facilitated by the atmosphere in Częstochowa, which, in times of the Republic of Poland, was the cradle of so-called private initiative. The region had many more private companies and workshops than other areas of Poland. The core region of Częstochowa has become smaller. Nowadays, we see but several dozen companies dealing with pram production, of which once there were 150.” (*Dziennik Zachodni*). Data from Statistics Poland shows that export in 2018 exceeded half a billion PLN. Children's prams are primarily exported to Germany, Russia, Ukraine, Great Britain, Ireland, Spain or Scandinavia.

Pursuant to the Polish Classification of Activity (Pl. PKD), the children's pram production sector, found within sector C – Manufacturing under the following sections:

- 30 – production of other transport equipment,
- 30.92.Z – production of bicycles and prams.

The pram industry, be it in Poland or worldwide, is not characterised by any specific formal or legal conditions that would apply to this industry in particular. No particular licences or permits are required of entrepreneurs. The specifics of the sector, however, require manufacturers to adapt production both to environmental standards as well as execution of activity in line with OHS provisions. Entrepreneurs active in the pram production sector are subordinate to general provisions of industrial processing (manufacture).

In Poland, the furniture industry is a significant part of domestic industry. Since the 1990s, the furniture sector is one of the main branches both of the economy as well as of export. The pram industry of Poland is a sector doubtless characterised by good

perspectives of development and many still undiscovered opportunities. The driving forces behind the industry include:

- production automation and robotisation,
- consolidations, takeovers, and fusions,
- material, design, and functional innovations,
- development – service personalisation and individualisation.

To summarise, this is one of the most important branches of the Polish industry, beside the furniture branch, production of amber jewellery, window profiles and yachts. In recent years, in Poland, the pram production sector has become one of the most dynamically developing branches of the economy.

A company that is known in the pram sector is Deltim. Deltim is a Polish family company active on the market for four generations. The main profile of activity focuses on the production of children's prams and seats. Since the beginnings of the facility, the idea and mission of the company were the creation of products fully corresponding to customer expectations (Deltim). An advantage of the company is, without a doubt, its owner, who over the last 25 years of activity in the children's pram production industry had gathered the necessary experience and ability to recognise customer needs, developed a strong competitive position within their closest environment and learned to adapt to changing market trends and requirements. Since its foundation, the company Deltim, continues to expand and develop its offer, upgrade production facilities, and gain new skills (Deltim). The key advantages defining the company's success are (Deltim):

- professional service,
- an individual approach to every customer,
- creation of designs,
- advisory services spanning the selection of materials, dimensioning, the selection of furniture,
- functional analyses,
- creation of visualisations,
- following changing trends,
- timeliness,
- high quality.

The main production facility of the company is found in Częstochowa, in the Silesian voivodeship. Its professional, modernly-equipped machine park allows the fulfilment of needs of even the most demanding customers. The key product of Deltim are two brands, Navington and X-lander – classic brands that do not compromise on quality, entirely subordinated to the comfort of the child and the parent. Production technology, top material quality, the experience and professionalism of the employees are the key factors behind the robustness, durability, precision, functionality,

resistance to humidity and high temperatures, modern looks, and aesthetic design of the products. In its offer, Deltim also has a broad range of pram bags, umbrellas, hand muffs or baby sleeping bags, made-to-order according to individual Customer designs, characterised by perfect functionality, high production quality and elegant designs.

Contemporaneously, in particular within the context of interdisciplinary risk management, probability is determined much more frequently on the basis of the rule of reasonable probability, possibility (as in – the level of certainty) of the emergence of a given event. Some tools used in risk management, e. g. the FMEA (failure mode effects analysis) concerning types and effects of possible errors – use more complex analysis methods of probability and more beside its level.

The analysis of key interference emerging along the supply chain of a given company, and the indication of the causes of their emergence and their effects is based on FMEA method. This tool allows both the identification of emerging interference, as well as the development of a real programme to eliminate them by way of an analysis of the efficacy of suggested remedial actions. Tested were six of the most commonly emerging types of interference that negatively impact the supply chain of the tested enterprise. These are: production inconsistencies, breakdowns of equipment and machinery, errors in packing, insufficient production resources, wrong project interpretation, wrong identification of customer needs. The effects of interference may arise with a delay or immediately. This influence may be short- or long-term, depending on the intensity of interference and the capacity of the company to stabilise the situation (Sheffi and Rice, 2005).

The analysis constitutes an attempt to assess the risk related to the emergence of the individual types of interference along the supply chain. Considered is the weight of the risk and its detectability, through calculation of the risk priority number (RPN) being the product of $S \cdot P \cdot D$, where S – severity if impact on the supply chain; P – probability of emergence; D – probability of detection of the interference.

For each of the above factors, a scale of 1-10 is used. Detailed descriptions of the assessment of the individual factors are presented in the following tables.

Table 2. Significance assessment criteria (S)

S factor	
1	No effect
2	Negligible interference along the supply chain
3-4	Minor interference along the supply chain
5-6	Moderate interference along the supply chain
7	Significant interference
8	Grave interference
9-10	Failure to adhere to environmental and OHS standards

Source: Own work based on (Hamrol, 2017).

Table 2 presents the criteria of assessment of the severity of the given type of interference, meaning, what the level of severity of its influence on the correct functioning of the supply chain of the enterprise. Value 1 is assigned to types of interference that do not influence the supply chain, whereby values 9-10 are assigned to types of interference that constitute a hazard for any participants of the logistical process along the supply chain.

Table 3. Emergence probability criteria (P)

P factor	
1	Very low probability of emergence of interference
2-3	Low probability of emergence of interference
4-6	Moderate probability of emergence of interference
7-9	High frequency of emergence of interference
10	Very high frequency of emergence of interference

Source: Own work based on (Hamrol, 2017, p. 314).

The assessment of probability of emergence uses a scale, in which interference along the supply chain, emerging very rarely, are assigned a score of 1, while interference emerging very frequently is assigned a score of 10.

Table 4. Detection capacity criteria (D)

D factor	
1-2	The probability of detection of interference during a control inspection is almost certain
3-4	The probability of detection of interference during a control inspection is high
5-6	The probability of detection of interference during a control inspection is moderate
7-8	The probability of detection of interference during a control inspection is low
9-10	The detection of the interference in course of an inspection is almost impossible

Source: Own work based on (Hamrol, 2017, p. 314).

The last factor, D, shows the probability of detection of interference along the company's supply chain. The score of 1-2 is assigned to interference, the detection of which is almost certain, whereby the score of 10 is assigned to interference, the detection of which is practically impossible. Detailed results of the conducted analysis are included in Table 5.

The subsequent stage involved an assessment of the individual indicators. The risk priority number is calculated. It can take the score between 1 and 1000. The higher the RPN, the greater the risk related to the hazard. High indicator scores mean that the mode of procedure at that stage of the process is accompanied by high risk related to the very high significance of that risk, its high emergence frequency or high difficulty to detect it (Burduk and Lubczyńska, 2017).

The first part of Table 5 shows selected interference along the supply chain, their possible causes and effects, along with an assessment of the individual factors against any type of interference. The second part shows suggestions of corrective actions that could positively influence the reduction of prevalence of a certain type of interference

and/ or influence its higher detectability (e. g. more frequent control inspections). The RPN is calculated twice for every indicator. The first RPN score represents the present state of the supply chain at the company and the related risk. The second in turn reflects the RPN value following the implementation of the suggested remedial actions.

Table 5. FMEA for interference along the supply chain for the analysed company

Area of activity	Potential interference	Potential effects	Potential causes	S	P	D	SPD	Result of action				
								Preventive measures	S	P	D	SPD
production	Production inconsistencies	Low product quality	No set quality standards	5	10	3	150	Continuous quality control of ready goods; introduction of quality standards	5	9	2	90
production	Breakdowns of machines and equipment	Unforeseen machinery repair costs	No regular maintenance	7	5	3	105	Regular maintenance	7	3	2	42
warehousing	Errors in packaging of orders	Errors in the order	Errors in the descriptions of ready goods	4	8	4	128	Verification of warehouse stock levels; introduction of warehouse sheets	4	6	3	72
supply	Insufficient volume of production factors	Production delays	Errors during production planning	3	9	2	54	Increase of warehouse stock levels; inspection of supply levels	3	7	2	42
production	Erroneous interpretation of the project	Inconsistency between order and product	Wrong qualifications	8	3	2	48	Additional training for production department staff	8	2	2	32
sales	Erroneous interpretation of customer needs	Customer cancellation of the order	No training in recognition of customer needs	1	3	1	3	Additional training for sales department staff	1	2	1	2

Source: Own work.

4. Conclusions

The results of the conducted FMEA in terms of the individual types of interference in the supply chain allow the following conclusions, that the most common interference

along the supply chain of the studied company include: production inconsistencies, insufficient production resources, errors in order packing, equipment and machine breakdowns. The interference related to the highest risk for the correct functioning of the supply chain include: production inconsistencies (RPN score of 150), errors in order packing (RPN score of 128), equipment and machine breakdowns (RPN score of 105), insufficient production resources (RPN score of 54). The applied method indicated four basic types of interference that bring about consequences for the enterprise (both in terms of image as well as finances), however, their order for interference type three and four varies.

The lowest risk for the operation of the supply chain is associated with erroneous identification of customer needs. Such a low risk level is related to the character of the interference, which emerges at the beginning of the supply chain (in its first link), e. g. the moment the customer places their order. An error at this stage does not cause grave consequences for the supply chain, as the subsequent logistical processes are stopped, however, erroneous identification of customer needs is frequently related to customer loss, hence, reduction of revenue and a change of the company image for the worse from the perspective of the market. Suggested remedial work was chosen so as to bring about as low costs for the enterprise as possible; all suggested remedial work influence the reduction of the RPN to a greater or smaller extent. The greatest change of the RPN was noted for the following types of interference: breakdowns of equipment and machinery – the introduction of regular maintenance could reduce the possible risks for supply chain operation by ca. 60%; errors in order packaging – the introduction warehousing sheets and verifications of stock could reduce the risk of this interference by close to 44%; production inconsistencies – introduction of continuous inspections of the quality of individual furniture components and the determination of quality standards could reduce this risk by ca. 40%.

Along with globalisation and dynamic technological progress, the significance of efficiency of logistical processes taking place at production enterprises increases. Changes in the area of customer in terms of transport and forwarding, with the strongly developing logistical services market, provide enterprises both with new opportunities, but at the same time determine further challenges (Kabus and Miciuła, 2019).

Improvements to quality of life, progressing virtualisation, the chase for the customer and development of ICT significantly improve logistical processes in terms of material and information flow between the various enterprises (chain links), an unavoidable effect of which were increases in the complexity of the supply chain (Kabus and Miciuła, 2019). A factor without a doubt influencing the competitiveness of a company on the market is the provision of a suitably high level of customer service, in particular in the area of product flow between the enterprise and the customer. The customer satisfaction level, or rather their subjective opinion about the quality of services offered by the enterprise, is influenced, beside the price, by the execution time of the order and the precision of delivery, or factors defined largely by the supply

chain management strategy. In other words, on the basis of the above, one can conclude that supply chain management may contribute to the achievement of company objectives and influence its functioning, leading (in terms of efficient management) to the optimisation of costs and improvements of advantages from the conducted business. The empirical part of the present paper shows the results of studies covering:

- a description of the fundamental tasks and the role that logistics plays in a production enterprise,
- an analysis of functioning of the supply chain in logistical processes,
- tests of the influence of supply chain management on company operations,
- determination of the relationship between the risk and the possibility of emergence of specific interference and errors along the supply chain,
- an assessment of risk for the supply chain.

Both the main objectives as well as the above detailed objectives indicate the subjective scope of the conducted research, taking the form of supply chain management at a production company, using the example of Deltim, a company operating in the children's pram industry.

For the conducted research, the following research hypothesis was to be verified: supply chain management influences the company's operations, contributing to the achievement of advantages in terms of costs, quality, customer service and risk. The theoretical verification of the research hypothesis was conducted using the method of scientific cognition, the basis for which was Polish and foreign non-series literature as well as articles published in scientific journals. For the empirical part, the basis was original material in the form of case studies of the company Deltim concerning logistical processes, the operation of the supply chain and the inconsistencies emerging in its area.

The utilised method of the FMEA is an efficient tool allowing the identification of causes and effects of the most common inconsistencies in the analysed process. The usage of the FMEA contributed to the efficient interpretation of data acquired from Deltim. On the basis of the conducted study, it was concluded that a FMEA constitutes the basis for determination of preventive and corrective measures in course of the production process, and the proposed actions shall allow the future prevention and removal of possible effects of flaws and errors that arose in the supply chain. In the group of all kinds of interference, those were highlighted that bring about the highest risk for the correct functioning of the supply chain, at the same time negatively impacting its efficiency. In addition, suggested were sample corrective measures, the possible efficiency of which is confirmed by an analysis of the value of the RPN score for the interference before and after application of the remedial measures.

Besides sample remedial work suggested in table no. 5 (in the FMEA results), the company owner should undertake actions improving management efficiency and motivation of employees, in particular production workers. In addition, the current company warehousing also needs some remedial activities. One must remember that losses in revenue stemming from supply interruptions may stem from the inability to satisfy demand, loss in stock volumes, aged equipment, additional transactions, overtime, additional storage and transport, penalties from failure to adhere to deadlines, driven by higher operating costs (Hendricks and Singhal, 2003).

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