
The Impact of Unpredictable Factors on the Uncertainty's Structure in the Management of Logistics Processes

Submitted 05/08/20, 1st revision 17/09/20, 2nd revision 20/10/20, accepted 06/11/20

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Abstract:

Purpose: The aim of the study is to determine whether and how unpredictable factors impact on the uncertainty structure in the management of logistics processes.

Methodology: The Delphi method was used in the first phase of the study. 40 experts in the field of logistics management, supply chain management, risk and efficiency of logistics processes were selected. In the second phase of the study, the structure of experts' responses was analysed and the Spearman rank correlation indicators between the indicated unpredictable factors and the consequences for the management of the logistics processes were determined.

Findings: During the study, unpredictable factors were identified that had the greatest impact on the structure of uncertainty in the management of logistics processes. In terms of probabilistic uncertainty, randomness was primarily indicated. In terms of stochastic uncertainty, most indications were reported for an unknown source of origin. The main sources of unpredictable factors from outside and inside the process were then identified. The most important uncertainty from the point of view of the logistics process was also determined. The uncertainty has been found to have implications for the management of the logistics process in terms of cost, time, and quality.

Practical Implications: The obtained results identify unpredictable factors determining the uncertainty structure in the management of logistics processes. Respondents identified the most common internal and external sources of unpredictable factors. Additionally, uncertainty was found to have implications for the management of the logistics process in three key decision areas - cost, time, and quality.

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Originality/Value: *The added value of the paper is the identification of the key unpredictable factors impacting on the uncertainty structure in the management of logistics processes.*

Keywords: *Management of logistics processes, uncertainty structure.*

JEL classification: *M21, L91.*

Paper Type: *Research Paper.*

1. Introduction

The growing dynamics and unpredictability of market changes result in an increased rate of absorption of variable factors into the enterprise management processes. In the classical sense, the behaviour of enterprises can follow two paths. Enterprises can react to the changes in a way that encapsulates their processes, trying to create a situation of their undisturbed course, or a situation of the least destructive impact. They can also react to changes, thus demonstrating a flexible attitude, the ability to adapt to the environment and the ability to "learn", absorbing external and internal variables into their business environment, while realizing that such behaviour determines various advantages of processes, such as structure, costs, quality, time, directions and level of changes, effects. This reaction often implies re-engineering of processes.

Whenever process management is mentioned, the basic element of process evaluation is effectiveness, and consequently the efficacy and abilities (and competencies) of the manager. At the same time, when considering management efficiency and process productivity, it is necessary to determine the level of risk. Risk taking in the management process has two dimensions in terms of determining its effects. Positive risk, considered from the point of view of the possibility of predicting its occurrence and the possibility of estimating its effects (mathematical probability) – that is, subject to standard management methods. At the opposite extreme, negative risk should be considered when it is known that it will occur, but the set of effects consists of an error that cannot be estimated or has a high probability of error, as well as those that are partially non-quantifiable. In such a case, the variables that cannot be predicted are called unpredictable factors. On the other hand, an increased set of unpredictable factors is commonly called uncertainty. From this perspective, it should be assumed that due to the occurrence of unpredictable factors, the course of the process is run and managed under conditions of uncertainty.

The growing importance of the issue of unpredictability and uncertainty in the area of process management encouraged the authors of the paper to research the problem in the field of logistics processes, where the research gap was diagnosed. Therefore, the aim of the study is to assess the impact of the identified unpredictable factors on the structure of uncertainty in the management of logistics processes. The following research questions support the achievement of the main goal:

- What are the sources of variable unpredictable factors?
- What unpredictable factors shape the structure of uncertainty?
- What is the extent of the relationship between the conditions of uncertainty and the management of the logistics process?

The aim adopted in the study and the research questions posed were carried out by means of a qualitative survey conducted with the Delphi method among 40 participants. A quantitative approach was used in the analysis of the study results. The structure of the answers was analysed and the correlation indicators between unpredictable factors and the consequences of their occurrence for the management of logistics processes were determined. Qualitative and quantitative research was preceded by the literature review. This research methodology is reflected in the design of the article, which contributes to a wider discussion on the identification and description of the meaning of uncertainty in management.

2. Literature Review

Uncertainty and unpredictability relate to many areas, including philosophy, statistics, economics, finance, psychology and, increasingly, to management. These terms describe certain situations, certain states of affairs. From the perspective of process management, nowadays, when we observe large dynamics of changes, the need to make quick decisions, access to an increasing number of information sources, often leading to the illusion of reality, both of these situations should be seen as an inherent element of the company's functioning. Today, logical thinking seems to be not enough, the ability to predict the future becomes essential, and in this case intuition towards the conditions of uncertainty and unpredictability becomes valuable.

In management, uncertainty is one of the three conditions for making decisions, along with certainty and risk. It was first noticed by Willett at the beginning of the 20th century (1901). Author considered uncertainty in the aspect of correlation with risk, noting that the level of uncertainty increased along with the increase in risk, emphasizing at the same time its attribute of subjectivism, and arguing that it resulted mainly from incomplete data and insufficient knowledge of the decision maker about the surrounding reality. In subsequent studies on the essence of uncertainty, Knight (1921) made the statement that it is a factor distinguishing the desired state from the existing state and defined two types of uncertainty: quantified uncertainty and non-quantified uncertainty. He calls the quantified (countable) uncertainty a risk, while the non-quantified (uncountable) uncertainty is defined as uncertainty in the strict sense (Knight, 1921). In such a way, he made it clear that risk must not be confused with uncertainty, as has often been done.

Further analysing the development of the uncertainty paradigm, one should recall the work of the Commission on Insurance Terminology of the American Risk and Insurance Terminology, which in the 1960s (Head, 1967) supplemented Knight's thesis by stating that risk is uncertainty about a specific event under conditions of two

or more possibilities. This statement confirmed the measurability of uncertainty as a risk in the context of the problem of whether the intended objective of the action will be achieved. In fact, these three approaches prompted the separation of the definitions of risk and uncertainty. Nevertheless, the breadth of understanding of risk and uncertainty means that they are still not perceived in a uniform and unambiguous way. A certain facilitation of the semantic delimitation of both concepts is drawing attention to the objective and measurable nature of risk and the subjective and non-quantifiable nature of uncertainty. Pasieczny (1981) provides a broad definition of uncertainty. Author says that this is a situation for which it is impossible to determine what elements constitute it, what their value is or what is the probability of their occurrence. This situation often occurs with problems that have not arisen in the past but are characterized by a high degree of complexity. Therefore, it is not possible to rely on the manager's experience and knowledge when making decisions. Thus, management consists in the need to consider the specificity and conditions of the indeterminacy of uncertainty that the manager subjectively feels, and on the basis of these feelings, i.e. intuition, decides.

Uncertainty makes the future unknown and unpredictable. Therefore, neither the probability of an event nor its possible outcomes can be reliably calculated. As a result, any economic system can be perceived as moving in historical time from the irrevocable past to the uncertain, statistically indescribable future (Bludnik, 2014). As stated by Davidson (1988; 2009), the real world is non-ergodic, meaning past and present results may not necessarily repeat in subsequent periods. The future cannot therefore be reduced to quantifiable risk, calculated on the basis of existing market data. In recent years, Taleb's publications (2001; 2008) have been an elementary reading on uncertainty, laying the foundations for the "black swan" theory, in which, in general, risk calculations based on sophisticated mathematical models have been criticized. Referring to the chaos theory, Taleb shows the power of uncertainty, noting that from the point of view of risk, it is important to manage uncertainty or unlikely events, and that in making business decisions the so-called "blind luck" plays a significant role. Acting in the role of a sceptical empiricist, Taleb believes that scientists, economists, historians, political decision makers and managers are in fact illusionists because they overestimate the value of the observed data, thus underestimating the occurrence of undefined events. In his discourse, Taleb makes a comparative analysis of "white swans" – predictable events, with "black swans", that is, unpredictable events.

According to Taleb, "black swan" is the force of the most unreal, unlikely events; these are events that are improbable, almost unreal, but still occur. These events are very unlikely and occur unexpectedly, although after the fact, after their occurrence, they are very easy to explain. In terms of management, managers who see an orderly and understandable world, that is, they see only "white swans", are unable to prepare the company for events or situations that are difficult to predict, showing a specific strategic handicap. It is necessary not only to be able to identify "black swans", but also to accurately diagnose the situation and quickly develop effective response

scenarios. Until recently, the theory of probability was used to describe uncertainty. However, the assumptions underlying this theory are increasingly considered controversial (Kyburg, 1978; Daston, 1994; Ferson, 1996), the implication of which is the development of alternative or derivative methods of describing uncertainty useful in the decision-making process, including interval analysis (Moore, 1966), the evidence theory, the Dempster-Shafer theory (Dempster, 1967; Shafer, 1976), the possibility theory (Zadeh, 1978), the fuzzy sets theory (Zadeh, 1965; 1973) or the credibility theory (Liu, 2004; 2006; 2009).

A contribution to the theory of uncertainty was also accidentally made by Defence Secretary Donald Rumsfeld with his famous quote from a press conference in 2002. He presented an opinion in which he distinguished two types of unknowns: unknowns which we know we do not know and unknowns which we do not know we do not know. The first is the known unknowns, the second is the unknown unknowns.

Uncertainty is a situation that implies incomplete or unknown information (data). The problems of granularity, inconsistency, ambiguity, information obsolescence, etc. are also important in the analysed subject. The element of uncertainty is unpredictability. The concept of unpredictability should be identified with the aspect of the occurrence of unique events, causing unintended situations, creating different scenarios of impact on the functionality of a given system or process. There are many approaches to defining the concept of unpredictability. The definitions of selected authors are presented in Marzantowicz (2017). They show that unpredictability is usually a set of unforeseen events that affect structural changes and their dynamics, and therefore the possibility of unexpected and incidental events should be included in the management strategy (Jedliński and Marzantowicz, 2017; Marzantowicz and Dembińska, 2019a; Marzantowicz and Dembińska, 2019b).

Looking at the issues of undertaken research, Marzantowicz (2020) made an important theoretical observation. Analysing the literature from the last decade (2010-2020) in the Ebsco, Emerald and Web of Science databases based on a set of such keywords as: uncertainty, decision making, logistic management, he came to the conclusion that there is a shortage of elaborations of a holistic and systematising approach to studies of the relationship between unpredictable factors that create uncertainty conditions and decision making from the point of view of logistics management. This gap is an important argument to carry out such research and to disseminate its results, especially since they are of great importance not only theoretically but also in practice.

3. Results of an Empirical Study

3.1 Methodology of Research

The study was carried out using the Delphi method. It is one of the methods of qualitative heuristic research that uses the knowledge, opinions and experience of experts and specialists. The Delphi method is used to study complex problems that

are, in principle, difficult to quantify. Using electronic correspondence techniques, the survey was conducted in 3 research rounds. The last round revealed a convergence and a differential in the experts' answers. All concurrent responses were used for further analysis. The entire study was conducted on the basis of the principle of diversity of experts in terms of education and professional practice. The experts were selected in terms of having positive personality traits, such as independent thinking. The principle of freedom of discussion and the confidentiality of experts' statements were also maintained (Sudoł, 2016). It should be recognized that the Delphi method as a tool for researching unique phenomena is appropriate due to the level of complexity of the problem and the subjectivity in the perception of unpredictable phenomena, and is also related to the possibility of predicting future events (Stone Fish and Busby, 2005). In a situation where there is a widespread lack of knowledge in the field of unique phenomena (as well as in the field of predicting the effects of their occurrence), the Delphi method allows to select experts' opinions and on their basis to build a basis for solutions to the given problem (Fischer, 1978). The following study scheme was adopted:

Stage 1. Conceptual work.

The research problem was specified, and the research goal was set.

Stage 2. Research assumptions and procedure.

The following assumptions were made in the field of research areas:

1. In terms of the structure of uncertainty, the following types of uncertainty are identified: probabilistic uncertainty, stochastic uncertainty, strategic uncertainty.
2. In terms of the impact on logistics processes, the following unpredictable factors are identified incidentally, randomness, unknown source of origin, partially known source of origin, difficulty in estimating the effects, sudden appearance, possibility of partial estimation of effects, uniqueness.

During the research process, 40 experts in the field of logistics management, supply chain management, risk and efficiency of logistics processes were selected. The experts included 20 scientists (10 with the title of professor, 10 with the Ph.D. degree), 10 employees representing the strategic level of company management, 10 managers of logistics management in the company. The selection of experts (as a qualitative research sample) was made based on the criteria qualifying the participant as an expert. In the Delphi study, the research sample is not selected randomly.

3.2 Description of Statistical Methods

As part of the study, the structure of the responses was analysed and the Spearman rank correlation indicators between the indicated unpredictable factors and the consequences for the management of the logistics process were determined. In statistical terms, correlation is a method of assessing a possible two-way linear association between two continuous variables. Correlation is measured by a statistic

called the correlation coefficient, which represents the strength of the putative linear association between the variables in question (Mukaka, 2012).

The study used the Spearman's rank correlation coefficient. It has been defined as the Pearson correlation coefficient calculated for the variable ranks (Spearman, 1904; Chook, 2010) (the rank is the number that corresponds to the place in the order of each feature). The difference also applies to the fact that it measures any monotonous dependence (Rebekić *et al.*, 2015), including if the features are qualitative. In other words, The Spearman correlation coefficient is the comparable non-parametric ranking statistic for data where at least one of the variables is measured on an ordinal scale or does not form an approximate normal distribution on an interval scale. A correlation coefficient gives an indication of the closeness of the relationship (Porter, 1999). It is designated by the formula (Zimmerman *et. al.*, 2003):

$$r = 1 - \frac{6 \sum_{i=1}^n D_i^2}{n(n^2-1)} \quad (1)$$

where:

D_i^2 – the difference between the ranks of the corresponding variable features.
Spearman's correlation coefficient varies from -1 to +1 and the absolute value of (...) describes the strength of the monotonic relationship. The closer the absolute value of (...) to 0, the weaker is the monotonic relationship between the two variables (Chok, 2010). When interpreting the obtained results, the classification according to J. Guilford was used, where:

$|r|=0$ - lack of correlation
 $0,0<|r|\leq 0,1$ - dim correlation
 $0,1<|r|\leq 0,3$ - weak correlation
 $0,3<|r|\leq 0,5$ - average correlation
 $0,5<|r|\leq 0,7$ - high correlation
 $0,7<|r|\leq 0,9$ - very high correlation
 $0,9<|r|<1,0$ - almost full correlation
 $|r|=1$ - full correlation.

This classification is suitable for use in the analysis of Spearman's rank correlation coefficients.

In order to verify the hypothesis about a monotonic relationship between the studied characteristics of the population, a significance test was performed for the Spearman's rank correlation coefficient. The following hypotheses were formulated:

- *Main hypothesis: $H_0: r = 0$ saying that the features are not correlated (statistically significant),*
- *Alternative hypothesis: $H_1: r \neq 0$ saying that there is a correlation between features (statistically insignificant).*

The test statistics have the form:

$$p = \frac{r}{\sqrt{\frac{1-r^2}{n-2}}} \quad (2)$$

The statistics have a Student's t distribution at $n - 2$ degrees of freedom. Comparing the results of the statistics obtained with the assumed level of significance ($\alpha = 0.05$), one should decide whether to accept or reject the main hypothesis. The hypothesis H_0 should be rejected in favor of the alternative hypothesis (statistically significant) if $p \leq \alpha$. However, if $p > \alpha$ there are no grounds to reject the H_0 hypothesis (statistically insignificant) (Barczak *et al.*, 2019).

3.3 Study Results

During the Delphi study, unpredictable factors were pointed, which are identified as those having the greatest impact on the structure of uncertainty in the management of logistics processes. In terms of probabilistic uncertainty, 42.0% of respondents indicated fortuitousness, only 24.0% - partially known source of its origin, and 14.0% - difficulty in estimating its effects. Much less indications in this regard were given to the following responses: the ability of partial estimation of the effects (8.0%), incidence and suddenness of appearance (4.0% respectively) and unknown source origin and uniqueness (2.0% respectively).

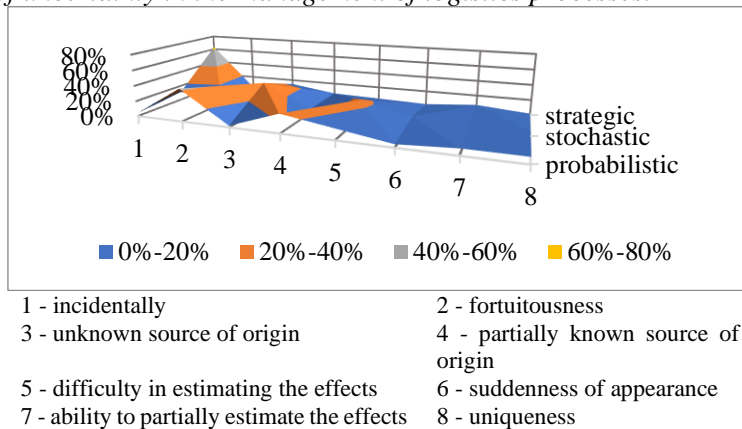
In terms of stochastic uncertainty, 35.19% of respondents emphasized an unknown source of origin, 24.06% - difficulty in estimating the effects, 9.26% - sudden appearance and incidentally - 11.11%. Partially known source of origin, the possibility of partial estimation of the effects and uniqueness were indicated by 5.56% of the respondents.

The smallest number of respondents - 2.0%, indicated the uniqueness of the stochastic uncertainty. Strategic uncertainty, in the opinion of 63.16% of respondents, is characterized by incidentally, as well as an unknown source of origin - 14.04% participating in the interview. The possibility of partial estimation of effects was also indicated - 7.02%, partially known source of origin - 5.26%, as well as fortuitousness and difficulty in estimating the effects - 3.51% each, as well as suddenness of appearance and uniqueness - 1.75% of indications each (Figure 1).

The next stage of the research was to identify the main sources of factors that are unpredictable due to their origin from outside or inside the process. According to the respondents, the process environment is related to incidentally - 23.91% of indications, uniqueness - 19.57%, sudden appearance - 17.39% and unknown source of origin and difficulty in estimating the effects - 13.04% of indications each. The fewest indications - 4.35% each, were given to: fortuitousness, partially known source of origin and the possibility of partial estimation of effects. From the outside of the

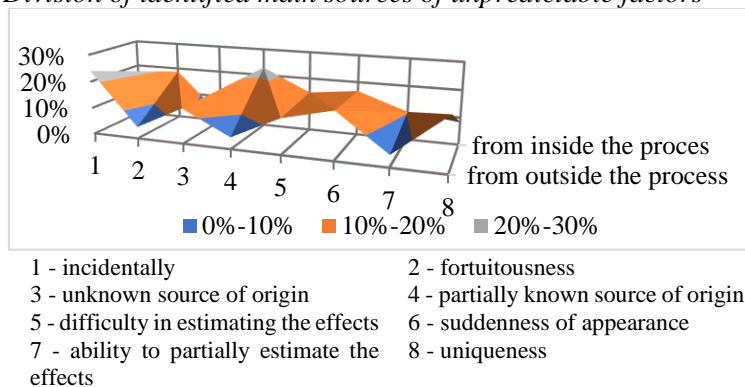
process come: partially known source of origin - 22.92% of indications, fortuitousness - 18.75%, sudden appearance - 16.67%, difficulty in estimating the effects - 14.58% and the possibility of partial estimation of effects - 10.42% indications. In addition to the above, the participants of the interview indicated: uniqueness (8.33%), incidentally (6.25%) and unknown source of origin (2.08%) (Figure 2).

Figure 1. *Unpredictable factors identified as those with the greatest impact on the structure of uncertainty in the management of logistics processes.*



Source: *Own elaboration on Delphi research results.*

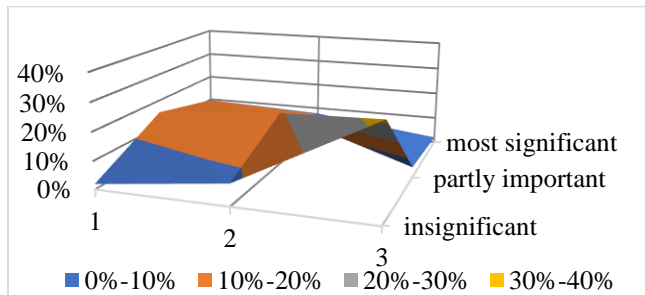
Figure 2. *Division of identified main sources of unpredictable factors*



Source: *Own elaboration on Delphi research results.*

The next part of the interview concerned the determination of the most important uncertainty from the point of view of the logistics process, previously categorized. The stochastic uncertainty - 15.38% of responses, strategic - 9.62%, and probabilistic - 1.92% of responses was considered insignificant. Partly important is the stochastic uncertainty - 19.24% of indications and 7.69% of probabilistic and strategic uncertainty. The most significant uncertainty was probabilistic - 32.69%, stochastic - 3.85% and strategic - 1.92% (Figure 3).

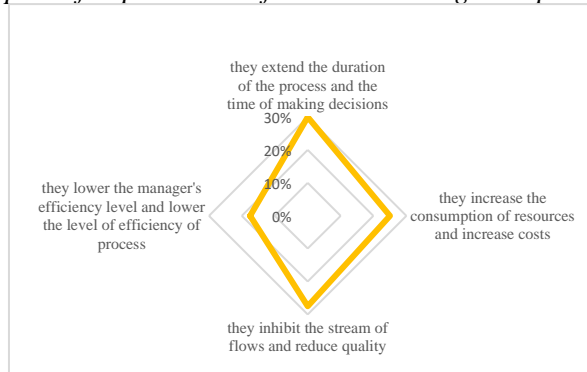
Figure 3. Most important from the point of view of the logistics process categorized uncertainty



Source: Own elaboration on Delphi research results.

An important part of the interview was to characterize the impact of unpredictable factors on the logistics process. The largest number of responses - 30% - concerns the extension of the process duration and the time of deciding. On the other hand, 27.5% of respondents believe that this impact has a negative effect on flows and reduces quality, and 25% of respondents indicate increasing resource consumption and increasing costs. The smallest number of respondents - 17.5% believe that unpredictable factors lower the manager's efficiency level and the level of process efficiency (Figure 4).

Figure 4. The impact of unpredictable factors on the logistics process

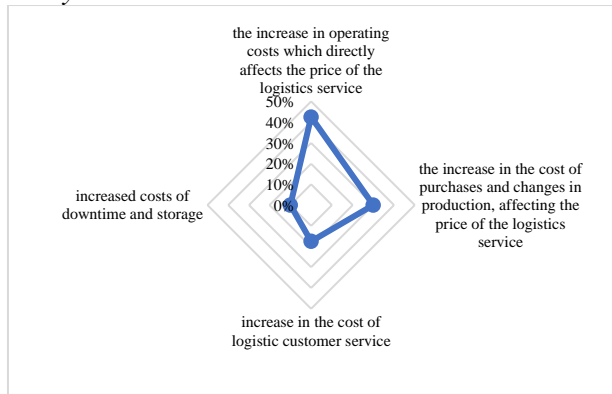


Source: Own elaboration on Delphi research results.

Uncertainty has implications for the management of the logistics process in terms of cost, time, and quality. Figure 5 shows the cost impact. Interview participants indicated that there was an increase in:

- operating costs - 42.5% of responses,
- costs of purchasing and production changeovers - 30.0% of responses,
- costs of logistic customer service - 17.5% of responses,
- downtime and storage costs - 10.0% of responses.

Figure 5. The effects, in terms of cost, for the management of the logistic process caused by uncertainty

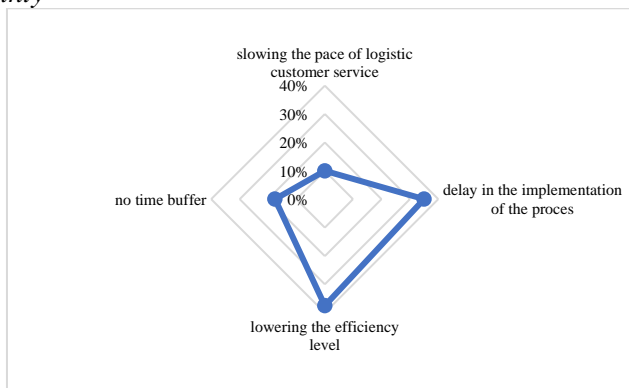


Source: Own elaboration on Delphi research results.

In the case of the time factor, the interview participants indicated such effects as the occurrence (Figure 6):

- reduction in the level of efficiency - 37.5% of responses,
- delays in the implementation of the process - 35.0% of responses,
- no time buffer - 17.5% of responses,
- lowering the level of logistics customer service - 10.0% responses.

Figure 6. The effects, in terms of time, for the management of the logistic process that causes uncertainty



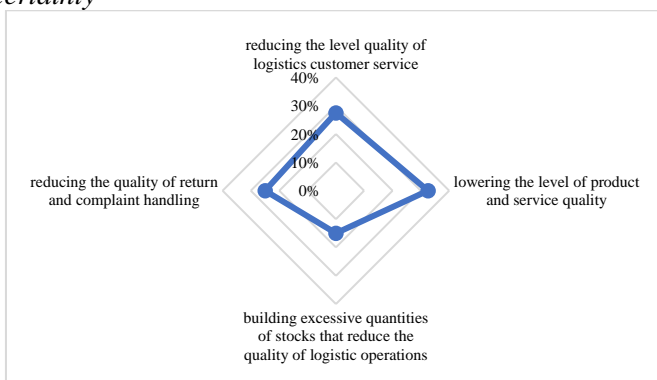
Source: Own elaboration on Delphi research results.

Figure 7 shows the effects on the management of a logistics process as a result of uncertainties in quality. According to the respondents, these effects include the occurrence:

- the possibility of lowering the quality level of a product or service - 32.5% of responses,

- the possibility of reducing the quality level of logistic customer service elements - 27.5% responses,
- lowering the quality of handling returns and complaints - 25.0% of responses,
- tendency to create excessive amounts of inventories - 15.0% of responses.

Figure 7. The effects, in terms of quality, for the management of the logistics process caused by uncertainty



Source: Own elaboration on Delphi research results.

Interesting conclusions can be provided by the analysis of correlation coefficients by means of which the strength of dependence has been surveyed between unforeseeable factors and the effects of their occurrence, and between the effects themselves. For greater clarity of the obtained results, the determined correlation coefficients are presented in Table 1.

Table 1. Correlation coefficients between the indicated unpredictable factors and the consequences for the management of the logistics process

	unpredictable factors	cost effects	time effects	quality effects
unpredictable factors	1.0000	0.7829*	0.0576**	-0.1048****
cost effects		1.0000	-0.3377***	0.4953*****
time effects			1.0000	-0.2961*****
quality effects				1.0000

Note: *Significance Level < 0.0001, **Significance Level = 0.7241, ***Significance Level = 0.0331, ****Significance Level = 0.5199, *****Significance Level = 0.0012, *****Significance Level = 0.0636.

Source: Own elaboration on Delphi research results.

In order to verify the statistical significance of the determined correlation indicators, significance tests were carried out for the obtained values. At the significance level $\alpha = 0.05$, it can be concluded that the dependencies characterized by low strength are statistically insignificant, i.e. dim, and weak correlation.

The occurrence of unpredictable factors is characterized by a very high correlation with effects on logistics management in terms of costs (Figure 5). For time and quality effects, only dim and weak correlation were noted (Table 1).

4. Conclusions and Discussion

The aim of the research was to demonstrate the relationship between unpredictable factors and the structure of uncertainty in the management of logistics processes. The hypothesis concerning unpredictable factors influencing the structure of uncertainty in the management of logistics processes was positively verified. It was proved that incidence with stochastic uncertainty was indicated by a larger number of managers than with probabilistic uncertainty. On the other hand, the difficulty in estimating the effects was noticed by the managers the least in the presence of strategic uncertainty. It is worth emphasizing that in the general approach to these three types of uncertainty, a relatively small number of answers indicated problems with estimating the effects of uncertainty, which may suggest that managers feel quite confident in this matter or have access to appropriate quantitative tools. According to the respondents, the most common internal sources of unpredictable factors were incidentally and uniqueness.

On the other hand, as external sources, unpredictable factors were most often indicated as the source of origin, randomness and suddenness of appearance. During the study, unpredictable factors were also identified that determine the structure of uncertainty in the management of logistics processes to the greatest extent. In terms of probabilistic uncertainty, randomness was primarily indicated. With regard to the stochastic uncertainty, the most indications were the unknown source of origin. The most important uncertainty from the point of view of the logistics process was also determined. The probabilistic uncertainty was indicated as the most significant, while the most significant answers were noted for the stochastic uncertainty. Uncertainty was found to have implications for the management of the logistics process in three key decision areas - cost, time, and quality.

The assumption that the future will be similar to the past, embedded in the essence of most forecasts, raises more and more doubts, especially with regard to issues of economics and management sciences. An inherent feature of modern economic activity is the necessity to make decision-making choices. Depending on the conditions, making decisions is characterized by a varying degree of difficulty. The basis for decisions made in deterministic conditions are therefore the differences between uncertainty and risk. Understanding the essence of deterministic conditions allows to adjust appropriate techniques supporting the decision-making process.

Contemporary logistics processes in the face of uncertainty need agility, learning way of thinking and focusing on the environment. Ensuring the resilience of logistics systems to unforeseen events and implementing processes for identifying early warning indicators is the best approach to managing uncertainty.

Bearing in mind the complexity of the issues undertaken for the analysis, the authors see the need to continue the research both in terms of its deepening and broadening the spectrum of unpredictable factors determining the uncertainty structure in the management of logistics processes. It would also be important to pay attention to the role of digital technologies (especially artificial intelligence) in reducing uncertainty, its structure, as well as the role in shaping unpredictable factors. These aspects were excluded from the presented study due to the need to keep the considerations clear.

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