

Article

The Impact of Uncertainty Factors on the Decision-Making Process of Logistics Management

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Abstract: The article is a contribution to the discussion on the possibilities of effective logistic decisions under the conditions of uncertainty. Variable and unpredictable factors, which create the conditions of uncertainty, not only directly affect logistic processes (positive or negative impact), but can also be a determinant of making decisions. Logistics management, because it is referred to in the context of decision-making, is currently defined by the quality of management decisions taken, including factors which often constitute only partially quantifiable sets. The main goal of the article is to show the strength of the dependence between the occurrence of uncertainty factors and the type of decision. On the basis of decision-making theory, the types of decisions were defined, and then a set of factors that are most important for a given type of decision was selected. The results of the analysis allowed the strength of the influence of uncertainty factors on making logistics decisions to be determined. On this basis, a catalog of key decisions was selected, including decision types, and also the effects of decisions taken under uncertainty were determined. The study and the results of the analysis should be treated rather as a voice in the ongoing discussion. Due to the unpredictability of some uncertainty factors, the research field in the discussed problem remains open.

Keywords: conditions of uncertainty; logistic decisions; logistics management

1. Introduction

The unpredictable variability of the environment is now an element of the strategy. This variability determines the manager's efficiency from the perspective of decision-making effectiveness. Therefore, the question is how and when to make a decision in the field of logistic management in conditions of uncertainty. Due to the fact that the conditions of uncertainty are a set of variables, of which the source of origin is unknown and their effects are usually nonquantifiable, the answer to such a question is not straightforward. In the case of partially quantifiable variables, thus allowing to some extent to estimate the effects, it is necessary to speak about objectified conditions of uncertainty (as opposed to risk). The relations between the links and supply chain relationships with the environment are important. Globalization, networks and modern technologies force the need to look for ways of stabilizing logistic management processes.

In every process (as well as in the management of it) events occur marked by randomness. The economic instability that enterprises face is not characterized by a simple causal relationship and cannot be directly identified with the phenomenon of volatility [1,2].

The article discusses the possibility of making decisions in the field of logistic management in conditions of uncertainty. The basic purpose of the considerations is the possibility to determine the strength of the influence of specific variable factors on the type of decision.

The state of knowledge is presented in Section 2 of the article. The literature on the subject was reviewed in order to show the current scope of research, and it also indicated the research gap on the basis of which the discourse was conducted. Section 3 presents the research methodology, as well

as the analysis and its results. The discussion is in Section 4. Based on the results of the study and discussion, conclusions are made in Section 5.

The considerations and conclusions presented in the article constitute a voice in the ongoing discussion.

2. Literature Review

There are many approaches to defining conditions of uncertainty and many views in the field of decision-making. On the one hand, uncertainty is considered as the objective risk, being the consequence of the occurrence of a risk with unpredictable consequences, and on the other hand uncertainty is part of the subjective risk when the proper reaction cannot be undertaken [3]. One of the most justified views is the definition of uncertainty of A.H. Willett [4], specifying uncertainty (including conditions of uncertainty) as information shortage making it impossible to fully estimate the probability of an event and its consequences. Current studies approach the definition of uncertainty very similarly. In principle, contemporary considerations are based on studies from the 20th century. However, much more attention is paid to the attempt to measure uncertainty in both management and economics. Reflections on the quantitative approach to measurement of uncertainty have been made [5], which confirms the fact of the engineering (econometric) approach to the management of uncertainty [6].

Studies on combining the concepts of uncertainty and logistics are relatively small and are usually considered in the context of selected logistics processes. One can find studies on uncertainty and logistics networks [7], planning and logistics [8] or typical logistics operations [9]. While it should be acknowledged that all of the above areas belong to logistics management, it is difficult to find studies combining uncertainty directly with logistics management.

The theoretical scope for making effective decisions is the basis for transferring this theory to the practice of enterprises, including logistics [10]. Often, there are various methods of making decisions that are to facilitate or indicate the right decision to the manager [11]. The uncertainty in the context of decision-making is also naturally considered. It is possible to find references to both economics and management [12], in which identification of variable factors and their sources of origin play the most important role in terms of the conditions in which decisions are taken [13].

Trying to combine the problems discussed in the article in the context of searching for literature in the given area, it should again be pointed out that there are no complex studies combining uncertainty, logistics and decision-making in the holistic approach. The area of decision-making in logistics management appears in the literature through the prism of individual aspects of logistics or selected management areas. This applies in particular to forecasting and modelling uncertainty in logistics [14], logistics systems [15] or urban logistics and logistics centers [16]. It is worth noting here that making up decisions in the field of logistics is also considered from the point of view of areas resulting from the logistics environment such as disasters [17], humanitarian logistics [18] or sustainability [19].

An attempt was made to plot the evolution of theories related to making logistic decisions in conditions of uncertainty over the last ten years (2010–2020). Literature search and analysis was based on the following keywords for the research sought: uncertainty, decision-making, logistics management. Scientific and popular science databases were analyzed in order to find research publications in the above-mentioned scope. The analyzed literature databases are: Ebsco, Emerald and Web Of Science. The return of results from the conducted query is very high. But it mostly applies to very narrow specialties. This means that there are combinations of these keywords in the research but they are definitely not treated holistically. Usually they relate directly to a specific specialty such as disaster and logistics under uncertainty [17], decision model for cross-docking [20] or uncertainty and costs [21]. The maneuverability from the Ebsco database is over 116,000 scientific studies, but none relate directly to making logistic decisions in conditions of uncertainty from the management point of view. The maneuverability of the Emerald database is over 9000 studies. However, the database did not indicate any publication regarding research and making logistic decisions in the event of unpredictable factors. It should be noted here that both the Ebsco and Emerald databases

were analyzed using the desk research method with the use of combinations of indicated keywords, generating maneuverability of results in abstracts and the content of articles. Maneuverability in searching for research by keywords—uncertainty, decision-making, and logistics management as a research concept—is even lower. Studies on decision-making related to logistics outsourcing [22] and uncertainty in risk management [23] appear. It is surprising that the Web of Science database returns only about 300 results. To the best of my knowledge, there are no studies on making logistic decisions in conditions of uncertainty, understood from the perspective of assessing the strength of the impact of unpredictable factors on making decisions possible in conditions of uncertainty. However, the development of studies on disturbance and disaster management [24] and risk evaluation [25] is significant. There are studies on supply chain management in the context of logistics management in conditions of uncertainty, as well as making decisions in supply chain management. As indicated, the analysis of the literature query does not indicate the existence of a systemic approach to examining the relationship between unpredictable factors creating uncertainty conditions and making decisions from the point of view of logistic management. There are no publications on the methodology for the correlation of unpredictable factors and logistic decisions.

The analysis of the literature regarding the problems raised in the article showed a research gap in the area of logistic decision-making in conditions of uncertainty, from the logistic management point of view.

3. Analysis of the Correlation between Variable Factors and Decisions in Logistics Management

3.1. Methodology

Preparation for empirical research on enterprises was preceded by initial literature research using the desk research method and initial research by the Delphi method. The Delphi study on a target group of 40 people—scientists and senior managers was designed to determine the facts and variables that will be verified empirically on a group of enterprises (research sample). The result of three rounds of research using the Delphi method led to the creation of a list of unpredictable factors, a list of possible sources of their origin, and also determined a catalog of possible decisions. The preliminary study allowed the survey to be performed in businesses.

A survey was conducted among 120 companies having in their structure a unit responsible for logistics at the strategic level—logistics directors and supply chain managers (constituting a group of respondents). The responsibility for logistics is understood here through the prism of logistics processes defined in the classic way as an ordered and regulated chain of operations closely related to the flow of materials. It consists in the physical movement of products through subsequent stages of the company's operations to achieve the goal [26]. A classic definition of logistics processes was adopted. The analysis of other definitions has been omitted because they do not contribute to the content of the article. The prepared research questionnaire contains, among others a question about the level of significance attributed to relevant, listed unpredictable factors (from insignificant to most significant) Subsequently, respondents were asked to identify possible sources of unpredictable factors of origin. The selection was carried out by means of multiple selection of sources of origin for individual unpredictable factors. Then the respondents were asked about the level of significance for individual decisions (from the catalog established during the Delphi survey). The sample was random. The study was conducted with the representatives of the companies' management staff. The sampling was made up of micro, small, medium and large companies from the production and service sectors, having a logistics unit or a logistics division, located in the Bisnode Poland database. The computer-assisted telephone interviewing (CATI) method was used. A total of 4237 companies were contacted and 360 full interviews were carried out. The randomization algorithm embedded in the telephone research software provided the same chance of being in the test for each of the records in the database. Despite the fact that the sample was statistically correct, the data from 120 companies and not from 360 was analyzed (The confidence interval for the structure index has been defined in Section 3.2 "Analysis

and Result". A fraction of 120 out of 360 companies were selected for the analysis and their answers covered all research questions. Incomplete or unrelated answers were rejected. However, this does not affect the representativeness of the sample. From a statistical point of view, a random sample of 120 enterprises provides representativeness for the population. It was assumed that 120 of the enterprises questioned provided 100% maneuverability, and this is also the minimum sample size, which ensures representativeness from the statistical point of view. The aim of the study was to determine the set of factors shaping the conditions of uncertainty and to determine the effects of their occurrence in the context of the determinants of decision-making for logistics management. The analysis of the survey results was carried out using the Spearman rank correlation coefficient method. Spearman defined his coefficient as the normal Pearson correlation coefficient, calculated for variable ranks (hence the name of the rank correlation coefficient) [27,28]. It is determined by the formula [29]:

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

where:

d_i —differences between the ranks of the corresponding values of the feature x_i and the feature of y_i ($i = 1, 2, \dots, n$);

x, y —two features (X and Y), which have been given descending rank;

n —number of data pairs.

For the interpretation of the results, the J. Guilford classification was used, which is suitable for the analysis of Spearman's rank correlation coefficients, where: $|r| = 0$ —lack of correlation, $0.0 < |r| \leq 0.1$ —correlation dim, $0.1 < |r| \leq 0.3$ —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. Unconventional use of the correlation coefficient was used. It is conventionally assumed that the correlation coefficient is decimal. However, it is possible to show the range for the correlation forces in percentage using the formula $R = r^2 \cdot 100\%$ (which made it possible to determine the impact of one feature on another, in percentage terms). In the case of demonstrating the strength of the correlation, the percentage does not matter. Due to the volume limitations of the article, only the results are presented.

3.2. Analysis and Result

Taking into account the analysis of literature, it should be recognized that in the scope of some factors (the study has not identified which), a source of general origin could be identified. It is therefore possible to partially estimate the effects. Therefore, the conducted research allowed the indicating groups of variable factors as the dominant and shaping conditions of uncertainty. By nature, it is impossible to identify all variables (including unpredictable variables) qualitatively; therefore for research purposes these factors have been defined in the form of meaning. It is worth adding that the confidence interval for the structure index is determined from a large sample (independent sampling) of a particular variant of the analyzed research feature from the entire statistical population based on the formula [30,31]:

$$\frac{m}{n} - u_\alpha \sqrt{\frac{\frac{m}{n}(1 - \frac{m}{n})}{n}} < p < \frac{m}{n} + u_\alpha \sqrt{\frac{\frac{m}{n}(1 - \frac{m}{n})}{n}} \quad (2)$$

where:

m —the number of elements highlighted in the sample;

n —the sample size.

Based on the probability level of 0.95, it can be concluded that the determined confidence intervals contain an unknown share of all companies identifying themselves with the indicated factors. The result is shown in the Table 1.

Table 1. Factors shaping the uncertainty conditions identified by the surveyed entities.

Factor	Participation in the Sample	Confidence Interval
External factors of unknown origin, the occurrence of which was unpredictable	57.21%	$47.80 < p < 65.54$
Internal factors of unknown origin, the occurrence of which was unpredictable	17.45%	$10.70 < p < 24.30$
External factors of unknown origin, the occurrence of which was partially predictable	16.32%	$10.00 < p < 23.34$
Internal factors of unknown origin, the occurrence of which was partially predictable	9.02%	$4.01 < p < 14.33$

Source: own study based on a survey.

The value of the statistics u_{α} is read from normal distribution tables for $1 - \frac{\alpha}{2}$.

Because the research sample was correctly selected, the results indicated (confidence intervals set for the level of significance $1 - \alpha = 0.95$) can be generalized. For clarity of discourse, the aggregation process was omitted here (as it is unnecessary for further analysis).

In order to maintain the clarity of the analysis of the study, factor and decision designations were introduced for factor F and decision D, as shown in Tables 2 and 3. It should be noted here that the types of decisions contained in Table 3 were determined by means of a preliminary examination using the Delphi method. Discussion of the preliminary study was excluded from the considerations in this article, due to its lack of relevance to the conducted analysis, but also to maintain the purity of the considerations.

Table 2. Determination of factors shaping the conditions of uncertainty.

No.	Factors Shaping the Conditions of Uncertainty	Designation
1.	External factors of unknown origin, the occurrence of which was unpredictable	F1
2.	Internal factors of unknown origin, the occurrence of which was unpredictable	F2
3.	External factors of unknown origin, the occurrence of which was partially predictable	F3
4.	Internal factors of unknown origin, the occurrence of which was partially predictable	F4

Source: own study.

Table 3. Decision marking in the field of logistics management.

No.	Decision	Designation
1.	Stop the logistics process and start after the problems have ended	D1
2.	Slow down the logistic process in anticipation of problems	D2
3.	Absorb the occurring changes and react in accordance with the change of pace and direction in real time	D3
4.	Do not react—run a logistics process	D4
5.	Run a logistics process in a completely hermetic way (not requiring a change)	D5
6.	Respond ex-post (after the occurrence of effects), eliminate the effects	D6
7.	Increase resource consumption to keep up the pace of the logistics process	D7
8.	Reduce resource consumption to keep up the pace of the logistics process	D8
9.	Increase the pace of the logistics process and increase resource consumption	D9
10.	Reduce the pace of the logistics process and increase resource consumption	D10
11.	Increase the pace of the logistics process and reduce resource consumption	D11
12.	Reduce the pace of the logistics process and reduce resource consumption	D12

Source: own study.

Using the correlation coefficient, it was possible to determine the strength of this correlation from the point of view of logistic management. The determination of the relationship between the factors and logistic decisions allows not only the dominant variable factors to be noticed, but also determines the dominant logistics decisions taken in the event of conditions of uncertainty. The correlation strength between the mentioned elements is presented in Table 4.

Table 4. The strength of correlation between variable factors and logistics decisions.

Factors Shaping the Conditions of Uncertainty	Decision in the Field of Logistics Management	Correlation Coefficient	Strength of Correlation
F1	D1	0.7463	very high
	D2	0.6301	high
	D3	0.6562	high
	D4	0.5014	high
	D5	0.6236	high
	D6	0.6441	high
	D7	0.7349	very high
	D8	0.5361	high
	D9	0.5504	high
	D10	0.8112	very high
	D11	0.7281	very high
	D12	0.6107	high
F2	D1	0.6538	high
	D2	0.6101	high
	D3	0.5018	high
	D4	0.5352	high
	D5	0.4522	average
	D6	0.4537	average
	D7	0.6145	high
	D8	0.3872	average
	D9	0.3539	average
	D10	0.6544	high
	D11	0.6642	high
	D12	0.6301	high
F3	D1	0.5101	high
	D2	0.3781	average
	D3	0.3289	average
	D4	0.3818	average
	D5	0.3294	average
	D6	0.334	average
	D7	0.4741	average
	D8	0.2498	weak
	D9	0.2564	weak
	D10	0.569	high
	D11	0.5103	high
	D12	0.3747	average
F4	D1	0.6627	high
	D2	0.5191	high
	D3	0.506	high
	D4	0.5498	high
	D5	0.4601	average
	D6	0.4612	average
	D7	0.6397	high
	D8	0.3785	average
	D9	0.3897	average
	D10	0.3852	average
	D11	0.6637	high
	D12	0.6504	high

Source: own study based on the results of a survey.

As the analysis has shown, the factors that shape uncertainty, recognized as dominant, have a different impact on the decisions made. The different impact force indicated by the correlation coefficient allows the conclusion that the decision catalog cannot be closed. There is a high amplitude

of the discrepancy between the forces of influence in the particular groups of factors and decisions. Considering the fact that the factors are inherently unpredictable, there is no possibility of indicating a closed catalog of effects.

In the group of F1 factors, in an occurrence that is completely unpredictable and of which the origin is unidentifiable, it should be pointed out that logistic decisions are shaped as follows:

- (D2) Slow down the logistic process in anticipation of problems;
- (D7) Increase resource consumption to keep up the pace of the logistics process;
- (D10) Reduce the pace of the logistics process and increase resource consumption;
- (D11) Increase the pace of the logistics process and reduce resource consumption.

Very high correlation strength between F1 factors and indicated decisions was demonstrated. However, the study did not verify the determinants of dependence. Only the type of decisions to be taken by the logistics manager (variant) is indicated when conditions of uncertainty occur as the result of F1 variable factors.

The group of factors F2 determines the widest scope of decisions indicated in the conducted study. It is a confirmation that the awareness of the factors of internal variables of origin is the greatest among logistics managers. High correlation decisions include:

- (D1) Stopping the logistics process and starting after the problems have ended;
- (D2) Slowing down the logistic process in anticipation of problems;
- (D3) Absorbing the occurring changes and reacting in accordance with the change of pace and direction in real time;
- (D4) Not reacting—running a logistics process;
- (D7) Increasing resource consumption to keep up the pace of the logistics process;
- (D10) Reducing the pace of the logistics process and increasing resource consumption;
- (D11) Increasing the pace of the logistics process and reducing resource consumption;
- (D12) Reducing the pace of the logistics process and reducing resource consumption.

In the case of the F3 variable factors group, the scope of decisions is the smallest. The results of the questionnaire showed that there are situations in which the occurrence of incidental variables is partially predictable is subject to partial forecasting, although the sources of these factors may be different and their identification is often impossible. The high correlation force of F3 factors applies to the following decisions:

- (D1) Stop the logistics process and start after the problems have ended;
- (D10) Reduce the pace of the logistics process and increase resource consumption;
- (D11) Increase the pace of the logistics process and reduce resource consumption.

The variable factors F4 show high correlations with the following decisions:

- (D1) Stop the logistics process and start after the problems have ended;
- (D3) Absorb the occurring changes and react in accordance with the change of pace and direction in real time;
- (D4) Do not react—run a logistics process;
- (D7) Increase resource consumption to keep up the pace of the logistics process;
- (D11) Increase the pace of the logistics process and reduce resource consumption;
- (D12) Reduce the pace of the logistics process and reduce resource consumption.

The indicated relations and the power of influence illustrate the possible and most likely scenarios for making decisions. This means that the indicated solution (decision) may vary depending on other additional factors related to competences, qualifications, instruments provided, as well as the market environment and demand in the supply chain. Therefore, the catalog of possible decisions in the field of logistic management in uncertainty is not closed.

4. Discussion

Decision-making in the field of logistic management in uncertain conditions is particularly problematic to determine the operating patterns in a given situation. This is understandable because unpredictable factors that create uncertainty conditions are nonquantifiable. The effects of their occurrence cannot be fully estimated. Making effective decisions in real time is nowadays a requirement of a changing market. Sudden variability results in the interruption of the cause and effect chain of the logistics management process. It can be assumed that a completely stable logistic process is hermetically resistant to predictable and unpredictable variables [2]. The logistics management process is also stable. Taking into account the assumption that unpredictable conditions occur due to unpredictable changes, it should be assumed that the variable (but quantifiable) factor will belong to the part of the uncertainty conditions, which partly allow estimating the effects of uncertainty. The group of variable factors indicated in the study, the content of which depends on the degree of recognition of their sources of origin and subsequent effects. For even an unknown source, there may be variable factors predictable in terms of their occurrence but characterized by a broad set of consequences, of which only those with the highest value (as a result of forecasting) are an element of *ex ante* and *ex post* management. In the described context one should speak about the negative effects, but also the chances that, by identifying the source of the variables, one can take an adequate, effective reaction—a decision.

The analysis showed that in the case of variable factors of unknown origin, the most likely decision is the one of which the result is to be limited use of resources and at the same time an attempt to increase the pace of the process (D11). Increasing the pace of the process in the event of conditions of uncertainty is justified when the impact cannot be estimated. The wide spectrum of decisions that result from the analysis of the conducted research prompts the transfer of the considerations towards the effectiveness of these decisions. When the source of the occurrence of variable factors is known, it is necessary to talk about risk and not about conditions of uncertainty. Going in this direction, one may state that the risk is part of the uncertainty conditions. While the article does not address the issue of the management model under conditions of uncertainty, the conducted analysis can be treated as a starting point for the basic assumptions for shaping logistic management models in conditions of uncertainty.

From the point of view of logistics process management, the most important is the result of high and very high correlation between unpredictable factors and logistic decisions. Although it is not possible to determine the full catalog of the effects of decisions made, a high and very high correlation determines which of the decisions may be most likely. It can therefore be assumed that these decisions will be most effective in the event of uncertainty conditions and measured in relation to the desired effects. It is worth noting that the analysis presented for obvious reasons does not indicate only one decision that should be made in a given situation, because then one should talk about the risk associated with mathematical probability.

The discussion on the possibilities of shaping the catalog of management decisions in logistics related to reacting to the occurrence of uncertainty conditions remains open. It requires deeper research and searching for appropriate and usable methods of possible measurement. The difficulty is to measure phenomena or situations that by their nature are nonquantifiable. For obvious reasons, the indicated catalog should not be understood as a closed set of characteristics. While, in the theory of decision-making, their type, manner of implementation and final effectiveness depends on the manager's skills and tools available to him, in the context of logistics management in the conditions of uncertainty and possible risk, the effectiveness of a decision and its level also depend on the ability to forecast and analyze the future effects of both the volatility factor and the effects of the decision itself.

5. Conclusions

Conditions of uncertainty are shaped by unpredictable events, the effects of which are largely unpredictable. A management decision cannot be made directly in relation to the existing variable

factors, because the source of these factors is not identifiable. It is possible to define groups of variable factors shaping uncertainty, taking into account the directions of their origin. It becomes possible to select an open catalog of the most likely management decisions under conditions of uncertainty. It is impossible to build a closed catalog of decisions in the field of logistic management in conditions of uncertainty. Regardless of the factors of uncertainty, the most likely decision concerns the acceleration of the pace of the logistic process, while at the same time introducing a reduction of resource consumption. When there are variable factors of unknown origin and their source is not identifiable, the greatest dependence power is demonstrated in relation to the decision related to the slower pace of the logistic process. This allows one to notice the impact of all variable factors during the process. Consequently, there is a likelihood of increasing resource consumption.

In the case of variables of internal origin, whose source is unidentifiable, the highest dependency is observed in the case of the decision regarding the increase of the pace of the logistic process. When variable factors originating from the inside appear and their source is unidentifiable, it is difficult to notice their impact in real time. The acceleration of the process allows quicker access to and the response to possible (especially negative) effects. Consequently, the use of resources that can be subjected to unpredictable factors should be reduced. The highest correlation strength in the case of external factors, the occurrence of which is partly predictable despite unknown sources of origin, has been shown in relation to the decision to slow down the pace of the process and increase resources. This allows the conclusion of an additional application saying that external factors are crucial for deciding to slow down the pace of the logistics process.

Internal factors of unknown origin, the occurrence of which can be partly predicted, show the highest correlations in relation to the decision related to the increase of the pace of the logistic process and the probability of the need to reduce resource consumption. This allows the additional conclusion to be made that internal origin factors usually require the acceleration of the process temperature in order to assess more quickly the effects of the uncertainty conditions.

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