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Disruption as an element of decisions in the supply chain under uncertainty conditions: A theoretical approach

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Abstract
The aim of the article is to designate catalogues of typological disruption as an inherent element of supply chain management in the light of uncertainty conditions. By means of deduction, the typological characteristics of the disruption and the catalogue of management decisions were determined. In this way, the scope of theoretical knowledge based on the theory of risk and supply chain management was expanded by leading the discourse towards the location of the so-called required uncertainty in the canon of obligatory components of management strategies. The article presents an overview discourse leading to the conclusion that contemporary supply chain management requires at least an attempt to forecast the effects of uncertainty conditions, including the risk of disruption.

Introduction

Building a company's competitive advantage in the era of globalization and internationalization requires the cooperation of enterprises in demand networks in a way that achieves a common goal. For each link of the supply chain, realizing competitiveness based on a chain management strategy cannot be guided solely by the particular interests of a single enterprise. On one hand, the implementation of a competitive business model in the supply chain takes into account decisions at the tactical level of enterprise management, and on the other hand, it implements the supply chain management strategy.

The multifaceted nature of modern supply chain management, such as when transferring decisions from the level of operational logistics to the strategic level of supply chain management, creates an area of functioning of these chains in new, often unpredictable conditions. System stability (when the supply chain is understood as a system) depends on the effectiveness of managers' actions, as well as an ability to absorb knowledge (learning) and a level of resistance to disruptions and unforeseeable events.

The turbulent environment of the supply chain operation creates conditions of uncertainty in which the skillful management of unpredictable events becomes an important element. The question arises whether the phenomenon of disruptions is an inherent part of the risk management process (can we talk about the risk of disruptions in the situation of a wide range of other turbulent phenomena – what is the concept of disruption?). Or from the perspective of macro-environmental risks in the supply chain,

are disruptions the starting point for the formation of so-called conditions of uncertainty? Two seemingly contradictory questions (the differences between risk and uncertainty are known) do not have clear answers. Indeed, considering the problem of disruptions from the perspective of the supply chain's macro-environment may be common (part of homogeneous disruption factors) for the theory of risk and understanding of the conditions of uncertainty. Hence, a far-reaching preliminary conclusion to the ontological considerations in this article, points to the differences in the way of reacting (including eliminating the effects) to the risk of disruptions from the perspective of factors that create uncertainty conditions, and not in terms of the place of origin of endo and exogenous variable factors.

The aim of this article is to consider the substances of uncertainty conditions and the characteristics of a systemic approach to disruption management as elements of uncertainty, through the perspective of risk management in the supply chain and the decisions then made. The approach gives the discourse in the article an illustrative character and at the same time constitutes a voice in the ongoing discussion.

Disruption and uncertainty in light of the theory of risk – state of knowledge

Diversity within the concept of risk means that risk can be assigned properties and functions that perform the role of a given phenomenon, depending on the undertaken problem. Hence, there is a large diversification in defining the concept of risk and a high level of multiplication of typologies, classifications and conceptual structures. The literature considering risk is rich and valuable (Sienkiewicz, Marszałek & Górny, 2012, p. 21). In terms of uncertainty, the literature is less rich, but it should be noted that there are fewer aspects of defining uncertainty. An overview of some aspects of defining uncertainty is provided in Table 1.

Risking the claim that the etymology of the concept of uncertainty is dated earlier than the concept of risk (Knight, 2012, p. 233), it should be explained that risk began to be consciously identified as an activity constituting a choice in a situation where the probability of consequences could be determined (Kaczmarek, 2008, p. 52). In view of the awareness of the existence of risk factors and factors of an unknown origin, one should consider the relationship between the concept of risk and uncertainty in the manner presented by A.H. Willet (Willet, 1951, p. 6.), who argued that risk is an objectified uncertainty. That is, if it does not have a negative impact on the state of flows and processes and does not change their functioning structure (does not result in ailments), it is not uncertainty (or risk in conditions of uncertainty) (Willett, 1951, p. 27; Marzantowicz, 2017).

For objective reasons, the risk itself does not have to be negative in a situation where, apart from damage, there is a possibility of benefits (e.g. economic benefits), and the conditions of uncertainty, understood as a set of factors limiting the possibility

Table 1. Selected definitions of uncertainty (own elaboration based on: Marzantowicz, 2017, after: Kosiński, 2000; Janasz, 2009; Arrow & Fisher, 2012; Knight, 2012; Domurat & Zieliński, 2013; Liu, 2014; Jedliński & Marzantowicz, 2017; Barczak et al., 2020)

Author	Definition
Kosiński, 2000	Uncertainty is defined as a set of factors dependent on the activity of the enterprise and its environment. There is a relationship between uncertainty and risk.
Janasz, 2009	Uncertainty is the inability to predict the effects of an action. There is a link with the classical economic approach to risk.
Domurat & Zieliński, 2013	Uncertainty as a result of ignorance. There is a relationship between uncertainty and risk. The concept of ambiguity is also used, which may have a similar basis to uncertainty.
Jedliński & Marzantowicz, 2017	Uncertainty is characterized by the inability to predict the effects and consequences of events. Even if there is certainty about an event, the set of consequences may be non-quantifiable.
Knight, 2012	Uncertainty is associated with risk. Classic approach to economics. However, uncertainty can create the desired effects.
Arrow & Fisher, 2012	An early and classic approach to uncertainty combined with risk. Indication of the efficiency of management in conditions of uncertainty.
Liu, 2014	A modern approach to the theory of the phenomenon of uncertainty in various areas. Uncertainty as an element of the set of events and effects necessary to predict the effects and predict the future.
Barczak et al., 2020	The sources of unpredictable variables determine the type of uncertainty. Uncertainty has a stochastic, strategic or deterministic dimension.

of full prediction of future events and significantly preventing the estimation of the effects, they largely contribute to the elimination of negative phenomena (as a negative set of effects and consequences). It can be assumed that "... apart from unpredictable factors (which usually constitute a larger part of the set), there must be factors that are quantifiable. Here, not only a set of factors is important, but also a set of effects (and effects), which may create many options that make up the portfolio of results ...", and that "... the effects of uncertainty create scenarios that may be partially subject to forecasting the future ..." (Marzantowicz, 2017, p. 64). It should be stated that the determinant of the effectiveness of the actions taken is precisely the risk – so it results from the uncertainty.

Disruption is one of the most frequently identified factors among the wide range of endogenous and exogenous factors that create conditions of uncertainty. In common understanding, the concept of disruption can be defined as a change causing turbulence for a given phenomenon – a temporary change in its functioning, process interruption, disorganization or disruption, etc. In management sciences, disruption is understood to a narrow extent as unplanned difficulties in the operational dimension. Where there is a susceptibility of the system to variable factors, the so-called interaction of the threat with this system occurs (Zawiła-Niedźwiecki, 2013). Disruption defined in this way determines the statement that the effects negatively affect the continuity of activities, processes and finally the system (depending on identification of the vulnerability point).

Excluding other factors (mostly external) from this part of the discussion, it should be stated that the disruption is a consequence of the risk. The effect of risk is a disruption. Hence, the concepts of disruption and risk of disruption are separated. Depending on the type (or place) of the disruption (the disruption typology is presented in the next subsection), the moment of making a decision about whether or not to take the risk of disruption is identified. Therefore, is the correlation of disruption risk management in the horizontal management system justified in the context of risk theory and in light of shaping the conditions of uncertainty? The answer should be yes, as there is a cause and effect relationship between uncertainty, risk and distortion. Uncertainty covers the widest range of variables – it is the broadest concept presented. The problem is not the identification of all variable factors, but the quantification of effects and consequences (including prediction), which in turn determines the management scenarios.

Disruption as a substance of uncertainty's conditions – typology of disruptions in supply chain management

Forecasting future events, management strategies and finally the chain's business models in the current turbulent environment requires the inclusion of an assessment of uncertainty effects in any strategy designed to stabilize flows in a supply chain. The set of stabilizers is defined (material, finance, infrastructure, services, etc.), however, the disruption portfolio may not be a closed set. Hence, it is difficult to quantify all the consequences of an unpredictable event, understood here as a disruption. The cause and effect mechanism as an inviolable structure that is the basis for determining a manager's effectiveness is exposed to a number of factors that disrupt flows in the supply chain. Thus, resulting in the interruption of the cause-and-effect chain of the management process in the supply chain. It can be

Table 2. Characteristics of a disruption in the supply chain according to selected authors (Zwicky, 1969; Kleindorfer & Saad, 2005; Handfield & McCormack, 2007; Teuteberg, 2009; Peng, Peng & Chen, 2014; Mohammadi et al., 2016, Barczak, Dembińska, Marzantowicz, 2019)

Author	Disruption characteristics
Kleindorfer & Saad, 2005	Random, natural, on purpose
Teuteberg, 2009	Planned, Unplanned, Standard, Custom
Zwicky, 1969	Dependent on: duration, level of severity, level of probability of occurrence, source, location, impact, etc.
Handfield & McCormack, 2007	Delays in procurement, production, distribution; depending on the scale of the network
Peng, Peng, & Chen, 2014	It results from the dynamics of supply chain management and change forecasting.
Mohammadi, Tavakkoli-Moghaddam, Siadat & Dantan, 2016	It results mainly from the macro-environment of the supply chain, creates conditions of uncertainty, it can be modelled.
Barczak, Dembińska, Marzantowicz, 2019	A disruption is an element of uncertainty, but when it has measurement potential, it becomes part of the risk.

assumed that a completely stable supply chain is hermetically resistant to the effects of predictable and unpredictable variables (Marzantowicz, 2018).

In the event of the occurrence of external and internal variables determining any change in the pace and directions of flows in the supply chain, affecting the dynamics of changes in logistic and operational activities, and even in the management strategy, one can speak of a disruption. In the literature, there are again a number of definitions of disruption itself, and there are also numerous theories regarding the categorization of disruption as well as its characteristics and attributes. Nevertheless, from the point of view of the conducted considerations, it is important to pay attention to the semantic typology of disruptions in the supply chain. A summary of common theories is presented in Table 2.

An analysis of the theory regarding the definition of a disruption and an assessment of its attributes shows the distinction between categorization according to the source of the variables, the time of their occurrence, and also the manner of their impact. On the basis of the list in Table 2, an attempt was made to determine a typological catalogue of disruptions in supply chain management, as shown in Table 3.

When identifying the sources of uncertainty and the sources of disruptions, the recognition plane for variable factors may be the same (or derivative). Taking into account the assumption that as a result of uncertainty there is a risk of disruption, it should be stated that the variable (but quantifiable) factor will belong to that part of the uncertainty conditions which partially allow the estimation of the effects of the uncertainty. The risk of a disruption may be a set of variables that are predictable in terms of their occurrence, but are characterized by a wide set of consequences, among which only those with the highest value (as a result of forecasting) are part of ex ante and ex post management. Therefore, they belong to the set of factors influencing the conditions of uncertainty in the functioning of the supply chain. Again, it should be pointed out that in the described context, the risk of disruptions creates threats (the aforementioned changes, e.g. in flows), but also opportunities – when an adequate, effective response can be undertaken by identifying the source of the variables.

Table 3. Typology of disruptions in supply chain management

Domain	Type	Classification
Demand	Macro environment	Repetitive and unique associated with a sudden change in demand Economic and non-economic related to changes in the economy Changing decisions/Modifying strategic decisions Natural (e.g. accident, catastrophe)
	Internal	Stimulating management decisions
Flows	Macro environment	Stimulating management decisions
	Internal	Resource and quality (e.g. in terms of returns)
Links	Macro environment	Legal, social, environmental (ecological)
	Meso environment	Limiting the flow of information Changing relationships between links – change of contracts Excluding or including the links in the management process
	Micro environment	Forcing or inhibiting the reconfiguration and restructuring process In terms of qualifications and competences Decreasing the level of effectiveness
Purchasing	Macro environment	Changing relationships with suppliers Extending the cash to cash cycle Changing the structure of purchases
	Internal	Changing the structure of purchasing costs Making inventory management difficult Changing the type of purchases Forming an iceberg effect Deregulating the purchasing cycle
Warehouse and distribution	Macro environment	Delaying delivery Dissimulating network efficiency
	Internal	Deregulating the inventory cycle Delaying delivery
Competition	External	Reducing the level of competitive advantage Restrictive development

System approach to reacting to disruptions in the light of supply chain management in conditions of uncertainty – discussion

The supply chain as a system is managed holistically, and it should be recognized that the supply chain management is systemic in nature. Therefore, it takes into account all flows and links as a creation of a nature that implements logistic processes and activities in a manner directed at a defined goal. Considering uncertainty as an obligatory element of management and strategy today (we can talk about the so-called required uncertainty as an inherent part of management scenarios), management scenarios should be created that take into account the possibility of disruption, and thus the risk of disruption. Conditions of uncertainty (because this is how external and internal changes influencing the management process should be understood) are the source of disruptions, and these in turn generate turbulences that define reactions and level the effects of disruption and uncertainty (including unforeseeable factors).

Supply chain management scenarios taking into account the conditions of uncertainty and how to respond to disruptions are part of the strategy, therefore they are determined by the way of making decisions, but also by the efficiency and effectiveness of their implementation. This means that uncertainty can be managed – it is possible to effectively manage the supply chain under conditions of uncertainty (Marzantowicz & Dembińska, 2019a, 2019b). It is worth noting that not only does the risk of disruption determine the type, pace and method of making decisions, but also shapes the value stream operating under conditions of uncertainty. In light of this, it is possible to designate the types of decisions and, consequently, ways of responding to disruptions in supply chain management in conditions of uncertainty as follows:

1. Active decisions.
   - Decisions in the scope of forecasting the effects of disruptions and uncertainty conditions, both in the probabilistic aspect – when using mathematical probability and other prediction tools, i.e. analysis of repeated series. Taking preventive actions, reacting in real time and variant management of the catalogue of effects.
   - Deterministic decisions where the effect of the risk of disruption and uncertainty can be partially estimated. Management of quantifiable effects and ongoing responses to unpredictable events. Possibility of partial measurement (mainly in terms of effects and aftermath). Reacting ex post following an assessment of the effects and their impact on the action taken, assuming that the manner and effectiveness of the decisions are determined by the highest value of the impact assessment.
2. Reactive decisions.
   - Absorption decisions involving the inclusion of existing disruptions in the management process. A characteristic feature of decisions is the learning process, i.e. building a catalogue of reactions based on the experience of the effects caused by the disruption.
   - Encapsulating decisions, consisting of conducting the management process in a way that prevents the impact of disruption on the managed process, operation or flow. Endogenous character defined as building the management process in a hermetic and rather constant manner, not taking into account internal changes and devoid of so-called bottlenecks.
3. Passive decisions.
   - Decisions that are ineffective from the point of view of the management process. Consisting of the cessation of the management process as a result of a disruption or generating a re-attempt of the management process. A characteristic feature is the extension of reaction time and the inability to build solutions related to the occurrence of uncertainty conditions, including disruptions.

The type of strategic decisions made under conditions of uncertainty, including the risk of disruption, depends on the supply chain industry. However, it should be noted that decisions at the strategic level concern activities with a longer time perspective. Hence, they should be applied comprehensively to supply chain management, which justifies a systemic approach to managing the risk of supply chain disruption in light of the conditions of uncertainty (despite the practical view that the disruption primarily affects the operational level). A systematic system of decisions related to the occurrence of a disruption in supply chain management is shown in Figure 1.

The discussion on classifying or creating a catalogue of management decisions related to disruption responses and uncertainty conditions in supply chain management is still open. For obvious reasons, the indicated catalogue should not be understood as a closed set of characteristic features. While within the theory of decision-making their type, method of implementation, and effectiveness depends on the manager's skills and tools available to him, in the

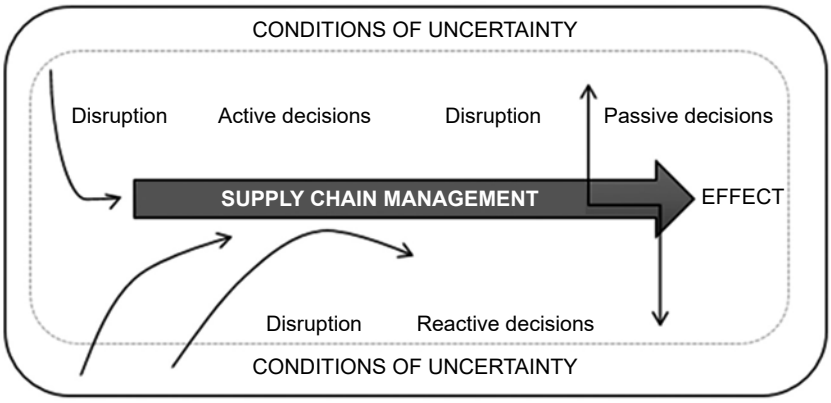

Figure 1. Illustrated systematics of decisions in supply chain management under conditions of uncertainty

context of supply chain management, the effectiveness of decisions and their level also depend on the ability to forecast and analyze the future effects of the occurrence of the variability factor and the decision itself.

Digital technologies as a tool for supporting decisions and responding to disruptions in supply chain management in conditions of uncertainty

The role of access to information is a permanent element accompanying the development of the concept of supply chains management (Nowicka, 2019). Information-sharing can be broadly defined as "inter-organisational sharing of data, information and/or knowledge in supply chains" (Kembro & Näslund, 2014, p. 181) and is mostly based on information technology (IT) capabilities impacting on flexibility (Jin et al., 2014). Flexibility is one of the most important abilities to adapt to changing operating conditions (Simchi-Levi, Kaminsky & Simchi-Levi, 2003; Szymczak, 2015) and therefore replying to uncertainty challenges.

Today companies have access to the broad spectrum of digital technologies that might serve at different levels and for different purposes in supporting supply chain management. These include: Internet of Things, mobile technologies (including wearables), cloud computing, computing fog, Big Data analytics, predictive analytics, blockchain, software agents, bots, additive technologies (3D printing and 4D printing, virtual reality), enriched reality, digital twins, collaborative robots (cobot), autonomous robots (including Automated Guide Vehicles and Unmanned Aerial Vehicles), artificial intelligence (AI) and machine learning, or digital platforms (based on digital technologies ecosystems) (Nowicka & Szymczak, 2020).

The choice of the type of technology that best suits a given supply chain process strongly depends on the specific circumstances and should be the subject of in-depth analyses, especially in conditions of uncertainty in the economic environment. However, taking into account the analyzed types of decisions (active, reactive and passive), it is possible to distinguish selected technologies that have reasons for special support in the indicated decision-making situations.

For example, one digital technology that might be appropriate for supporting active decisions could be a digital twins solution. Digital twins allow you to create a digital ecosystem for business processes, which is the equivalent of the real world – equally dynamic and changing over time. Digital twins enable adjustments to be made to the functioning of machines and devices that access the network, and through it to the digital ecosystem of digital twins, which is the bridge between the Internet of Things and digital modelling. Digital twin technology will have a huge impact on digital transformation as one of those innovations that blur the lines between the real world and the digital world. Digital twins support transport, but this is not their only application in the field of logistics and supply chains. In general, the concept of digital twins allows for direct scheduling, queuing and prioritization of tasks in the network of process and economic relationships – much cheaper than traditional planning and increasingly complex in modern supply chains. Such planning – supported by analysis of the potential effects that may occur as a consequence of specific action and event scenarios – allows for early preparation of actions (contingency plans) to eliminate the risks of downtime or the emergence of bottlenecks. Therefore the use of digital twins improves the strengths of the supply chain in the area of its resistance and improves resilience to various types of events that are not directly

influenced by any of the chain entities (Nowicka & Szymczak, 2020). In addition, predictive analytics and Big Data might be an interesting support for active decisions. Predictive analytics is the branch of advanced analytics that uses data to make predictions about unknown future events. It utilizes many techniques, including data mining, statistics, modelling, machine learning, and AI to analyze current data to make predictions about the future. Other descriptors that are used when referring to predictive analytics include Big Data, business intelligence, data analytics, and business analytics that impact on decision processes within supply chain management (Schlegel & Trent, 2021).

For reactive decisions, an AI could be an interesting solution. AI, also referred to as machine intelligence or machine learning, is intelligence demonstrated by machines, which is in contrast to the natural intelligence demonstrated by humans. With improvements in storage, processing speeds, and analytic techniques, AI algorithms are becoming increasingly capable of sophisticated decision making and probably the true contribution of this technology will be its ability to make faster and better decisions than humanly possible (Schlegel & Trent, 2021). The ability of AI systems to learn and adapt as they compile information and make decisions is called adaptability. AI systems must adjust as circumstances or conditions shift. Examples include alterations in road conditions or environmental considerations. It must integrate these changes in its algorithms and make decisions on how to adapt to new possibilities. Autonomous vehicles, for example, can use machine-to-machine communications to alert other vehicles on the road about upcoming congestion, potholes, highway construction, or other traffic impediments. AI might support supply chain (reactive) decisions helping to reduce supply chain risk in various areas, including streamlined processes, near perfect planning, market shaping, faster and more accrue transportation, monitoring of corporate social responsibility issues or better integration of financial performance with supply chain optimization (Schlegel & Trent, 2021).

Other types of decisions (including passive ones) can be undertaken with the support of a range of digital technologies integrated in the "tailor-made" digital technologies ecosystem (Nowicka, 2019). One of the most promising forms of information-sharing on an almost real time-basis is the cloud computing platform (being a kind of control tower for supply chain management), the other – for improving supply chain flows' transparency – is blockchain or the Internet of Things. All of these support decision processes according to the situation or environmental circumstances. However it should be also noted that the level and quality of the information is a base for decisions itself. Therefore regardless of the type of decision, digital technologies should be revised in terms of how they can support decision makers before the disruption takes place within supply chain flows.

Conclusions

The theoretical and illustrative discourse presented in the article shows that in terms of uncertainty, recognition, management and measurement of uncertainty conditions in supply chain management, the canvas of science is wide open. Disruption and the risk of disruption as inherent components of uncertainty conditions characterized by a cause-and-effect trace constitute only one of a wide set of factors that will be manageable. At the same time, the considerations allow for conclusions of a general nature to be drawn:

- conditions of uncertainty (required uncertainty) are now an inseparable element of the management strategy in the supply chain;
- a component factor of uncertainty conditions, partially quantifiable, is disruption;
- the risk of disruption is the result of uncertainty conditions;
- the risk of disruptions has a specific impact on the management of the supply chain, because it depends on the degree of identification of its sources;
- the typology of disruption in supply chain management depends on the supply chain and at the same time on the management processes taking place in it (domain), therefore it is not the same as the typology of disruption in the supply chain;
- management decisions should be focused on the conditions of uncertainty and the risk of disruptions, taken and implemented at the strategic level;
- the classification catalogue of management decisions related to the risk of disruptions in supply chain management cannot be closed, because there is a dependence between time, place, industry and the type of the chain itself;
- there are several types of digital technologies that can support decision makers in different environmental circumstances, helping to predict or mitigate the effects of emerging disruptions.

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