



Agnieszka Szmelter

Department of Logistics
Faculty of Economics
University of Gdańsk, Sopot, Poland
a.szmelter@ug.edu.pl

**The impact of complexity on shaping logistics strategies
in global supply chains**

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Abstract

Aim/purpose – The paper aims to summarize approaches to complexity management by implementing particular logistics concepts within logistics strategies in global supply chains and to highlight a research gap in this regard. Additionally, complexity management concepts are presented.

Design/methodology/approach – To achieve the research objective, a systematic literature review was used. 11 research paper were analyzed with use of review protocol.

Findings – Approaches to mentioned research problem are heterogeneous in current literature and there is a research gap in complexity studies in logistics, precluding further research, for example, on complexity measurement systems.

Research implications/limitations – Identified research gap will require further studies. Studied area requires more empirical research, especially in the field of complexity measurement and management techniques in particular global supply chains.

Originality/value/contribution – The paper summarizes current knowledge about logistics concepts helping to manage complexity in global supply chains and defines research gaps. There are no available literature summary of that kind. The article contains a full review of logistics complexity management concepts presented in scientific literature until the end of 2016.

Keywords: complexity, logistics, supply chain, management, automotive.

JEL Classification: F23, L62, L92, R41.

1. Introduction

In the last few decades, there has been a lot of changes in the approach to the organization management due to, among others, volatility of markets, consumer expectations and demand. There have been many changes in organizational structures of global companies and their offers, especially their product portfolios. The need to adapt to many global and regional market trends, called by some researchers and practitioners mega- and metatrends, resulted in the emergence of new business models, namely learning, fractal and intelligent organizations. There have also been changes in international supply chains. Many of them have become global due to the concentration of capital and oligopolization of branches, for example in the automotive industry (also on this market new business models emerge, for example, Basic Mobility Provider, Mobility Service Provider, etc.). What is more, growing importance of information and intellectual capital in shaping competitive advantage has an impact on the formation of large network structures. All these factors combined with industry-specific aspects of business activity led to increased interest in complexity phenomenon in the economy – on a micro-, meta- and macroscale.

The problem mentioned in the paper is a lack of universal approach to complexity management as a part of logistics strategies in global supply chains. There is also no available summary of approaches to complexity management as a part of logistics strategies in global supply chains. The aim of the study is to summarize available approaches and analyze if they are homogeneous or not. Complexity is one of the most important elements of shaping logistics strategies [Szmelter & Woźniak 2015] and will be in the future, especially because of volatile demand. What is more, global supply chains are complex systems and their operations are based on many variables. Globalization of businesses results also in increasing level of complexity. Still, there is a knowledge gap in the area of efficient logistics concepts helping to manage complexity.

The structure of the paper is organized as follows. The first section gives a review of the literature on logistics, especially supply chains complexity. The second part of paper presents methodology of research: methods and research procedure. The third section contains results of research. The main part of this section is comparative analysis of approaches to complexity management in logistics presented by different researchers. The last one part concludes the paper, presents its limitations and specifies areas for future research.

2. Literature review

Complexity is the problem discussed for decades in cybernetics and systems theory. The first mention of this topic can be found in research papers published in the late 1940s [Weaver 1948]. In management science, complexity and the theory of complex systems emerged in the 1970s [Beer 1970; Gościński 1971; Stabryła 1974; Ansoff 1975; Gasparski 1978; Koźmiński 1979]. Increasing complexity of systems in the context of logistics was first mentioned by Gouesbet and Weill [1984], Gattorna, Chorn and Day [1991], Lawler et al. [1993], and in Poland by Długosz [2000]. In most cases papers published in the 1990s focused on complexity in the context of operational management in production facilities.

The most popular sentence about complexity in logistics said Christopher [1998], who observed that “[...] the complexity of the logistics task appears to be increasing exponentially”. There are two ideas, wrongly described as the same matters, related to management of logistics systems – complicated and complex systems. First one were identified for a long time with complex systems, now it has been changing. A complicated system is a sum of complicatedness levels of its parts. Its behavior is easy to predict. In a complicated system, individual elements, components, and relationships between them can be identified, extracted, also defining and predicting their actions is possible. It is easy to understand how such system behaves by observing its components behavior and analyzing it by using, for example, linear or non-linear regression. There is no such possibility in the case of complex systems [Mesjasz 2014]. They are chaotic, characterized by non-linear dynamics of interactions between their parts, impossible to be described by use of statistical analysis. Predicting their behavior cannot rely on the behavior of their parts [Pathak et al. 2007].

There is a lot of complexity theory in management, the number of complexity research increases exponentially [Szmelter & Wozniak 2015]. The main areas of researchers’ interests are: establishment and functioning of organizational structures, information systems analysis, knowledge management, strategic management, operation of organizations networks [Mesjasz 2014], but most of all operations management [Szmelter & Wozniak 2015]. However, there are few studies presenting complexity as a factor shaping logistics strategies of companies and supply chains or describing complexity management as a part of logistics strategy. In addition, the literature does not provide a homogeneous, uniform approach to these issues. Over ten years ago, Perona and Miragliotta [2004] argued that it is not known how to define and measure properly complexity of the production system and the logistic system which is supporting it, and finally – how it affects the company’s performance. Nilsson [2006] and Yang and Yang [2010] pointed

out that complexity management is too rarely described in the case of supply chain management and is an unexplored area of logistics decisions. Since then, much has changed and researchers and managers started to pay much attention to the influence of complexity on the results of companies operations. This was especially often during and after the last global economic crisis of 2007-2008.

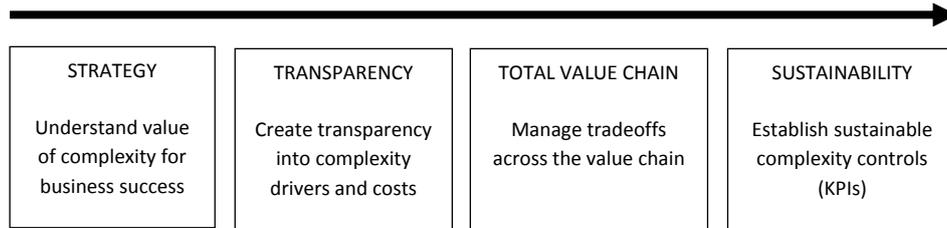
Logistics complexity has been identified by both researchers and practitioners as the new variable in management that changes relationships between strategies, structures and performance of single companies and whole supply chains [Szmelter & Wozniak 2015]. Development of knowledge about complexity in logistics has resulted in the concept of CALS (Complex Adaptive Logistics Systems), a derivative of the idea of International Supply Networks (ISN) presented, among others, by Hicks and Gullett [1975]. ISN are characterized by their ability to adapt to constantly changing the environment in a way to successful avoidance of negative effects of these changes. Modern supply chains should become CALS to master the complexity they cannot avoid and use the potential that is in this complexity. They should be flexible, self-organized, co-evolutionary and emergent. They should be built of innovative actors, who can form dynamic interplay network between institutions, products, technologies and markets [Hülsmann, Colmorn & Bakhrutdzinava 2009]. It raises many problems in the field of business analytics, for example in the area of reading weak signals of market changes, quick decision-making and implementing decisions, as well as constant control of its results.

In most cases complexity is presented as a threat to the stability of supply chains, but it can be also a source of their success, especially in the field of innovation management and organizational learning [Stacey 1993; McMaster 1996]. Complexity, in fact, may contribute to both the creation or destruction of value [Szmelter & Wozniak 2015]. A change in one actor in the supply chain can cause huge changes in the others, which is why it is so important to reasonable manage the complexity, control it, manipulate it and be able to anticipate the consequences of these actions. Effects of logistics systems complexity are for example diversity of product variants and operations, which mainly generate additional costs. Causes of complexity cannot be completely eliminated, so organizations and supply chains have to learn how to manage this complexity, control it and avoid it [Bauernhansl 2012].

Therefore, complexity management should be one of the strategic elements of management in enterprises and supply chains [Perona & Miragliotta 2004], including logistics management. In order to bring the desired effect, it should be systematic (see Figure 1) and conducted at every stage of the product innovation and life cycle. It is crucial to understand the complexity, to identify its determi-

nants, sources, costs, impact on value chain and then to establish key performance indicators to control it and adjust management rules to its character. A good practice is also determining the optimal level of complexity (for example by use of product variant analysis and optimization, process analysis and optimization, continuous improvement, etc.).

Figure 1. Stages of systematic complexity management



Source: Sheel, Hubbert [2014].

Taking into account the above considerations, the following research questions were put forward in this study:

RQ1: Are considered approaches of complexity in logistics strategies homogeneous or not? If not, what are the differences between them?

RQ2: Is there a research gap in complexity studies in the area of logistics strategies in global supply chains?

3. Research methodology

Research process consisted two main steps. The first one was an initial literature research to check the popularity of chosen topic in the research literature. It was also related to other research areas examined within one big research project about complexity, divided into preparation detailed research in separate papers. An initial study was conducted to explore, how popular research subject is complexity in logistics strategies. To prepare such summary, EBSCOhost search engine was used (search criteria were ‘complexity’ in the title and ‘logistics strategy’ in the text). Summary of publications on the complexity in logistics (cf. Table 1) shows that this topic is discussed more and more often in scientific literature, which undoubtedly reflects growing needs of the research about complexity in logistics systems. Area of complexity in logistics strategies is becoming increasingly popular in the world’s scientific literature and is developing at an accelerating pace. Nevertheless, this initial literature review exposed a literature gap in the field of complexity management in logistics strategies. It turned out that despite growing number of published papers about complexity in logis-

tics strategies there are only few which contribute to concepts of complexity management in global supply chains. There is also no holistic approach to this manner, selected research treated this research study in a selective way.

Table 1. Popularity of research about complexity in logistics strategies in world's scientific literature

Years	Number of items (articles and other research materials)
1980-1989	1
1990-1999	3
2000-2005	4
2006-2010	13
2011-2016	38

Note: Elaboration with a use of EBSCOhost search engine (4.01.2017).

To analyze state of the art about complexity in logistics strategies, a systematic literature review method was used. This method allows reporting what is and what is not known in the specified knowledge area. It was expected to provide solid evidence for existence a knowledge gap in the mentioned topic. In the other hand, the research was primarily aimed to show the usefulness of incorporation of complexity management into logistics strategies to build the competitive advantage of supply chains.

This research was a qualitative study according to rules created by Denyer and Tranfield [2009]. Because of qualitative character of analyzed studies, the results are summarized in a descriptive report (Table 4 in research findings section). According to Denyer and Tranfield [2009] literature review in management studies should be replicable, exclusive, aggregative and heuristic. Its rules are transparent. The research was planned to minimize the bias and maximize internal and external validity.

The research procedure is presented in Table 2. The process of literature database creation for research is described in Table 3. The selection process was made with the use of three biggest research search engines: Ebscohost, Web of Science and Google Scholar to enhance possible results in the range of different types of information. The Boolean Logic was included, but the selection process was made in stages (see Table 3). The keywords were used to address research questions. Only studies that meet the inclusion and exclusion criteria are included in the review. Selected research papers were analyzed taking into account abstracts (in the early phase of selection) and the content (in the later phase). That is why in this paper a review protocol was made to record approaches to complexity management in logistics strategies. The analysis rules in the last step of literature selection were (in addition to keywords):

1. Language of paper – only in English,
2. Research method – no restrictions,
3. Key findings related to complexity or complexity management in logistics strategies, linked to logistics management concepts.

Table 2. Research procedure

Phase	Stage
I	Determining the study purpose
II	Determining basic literature
	Selection of publications
	Preparing publications database
III	Bibliometric analysis
	Content (text) analysis
IV	Preparing a report/paper

Table 3. Process of literature database creation

Literature selection criteria	Publication search engine		
	Ebscohost	Web of Science	Google Scholar
'Complexity' in title	318 565	90 609	approx. 195 000
'Logistics' in keywords and 'strategy' in text	108	284	58
Areas: economics, management, business	36	39	55
After abstracts verification	15	15	27
Full texts available	10	6	14
All (after removing duplicates)	22		
After text analysis	11		

The efforts were made to prepare a report to represent high-quality evidence for existing research gap in logistics studies regarding complexity in the field of complexity management as a part of logistics strategies. Because of a low amount of selected papers a statistical analysis was not a good method to be included in the research procedure. Still, the research was aimed to identify if results of studies are homogeneous or heterogeneous.

According to Denyer and Tranfield [2009], the systematic review method in management is heuristic, so the output of using this method are in many cases rules, suggestions, guides useful in solve problems, but are not the solutions. They are helpful for managers to design solutions and possible scenarios in their field. The outputs of systematic literature review in this research can be used for both practical activity and further scientific research.

Reviews in management are more explanatory and interpretive than aggregative [Denyer & Tranfield 2009] and this is true for the research presented in this paper. The research questions were stated to involve a broad range of stakeholders, mostly practitioners and researchers interested both in complexity stud-

ies and in logistics. Despite many articles on the complexity in logistics, only 11 was fitted to the subject of this paper. Most found articles and other publications focused on operational management and production management.

4. Research findings/results

Literature sources analyzed in this research mostly contained only a partial description of the issue of complexity in logistics management of companies and supply chains. It turned out that researchers present different approaches to complexity management in the area of logistics, although in their studies some similarities can be observed. The study results are shown in Table 4.

Table 4. Elements of logistics strategies referring to complexity management

Activities area	Source/research	Concepts and solutions in logistics strategies
<i>1</i>	<i>2</i>	<i>3</i>
reducing complexity	Wilding [1998]	JIT (Just-in-Time)
		VMI (Vendor Managed Inventory)
		vendor integration
		TBM (Time-Based Management)
		short and middle-term planning
		non-linear dynamic analysis
		BPR (Business Process Reengineering)
		SPC (Statistical Process Control)
	PBC (Period Batch Control)	
	Bozarth et al. [2009]	lean management (especially lean production)
	Pathak et al. [2007]	
	Isik [2010]	
	Gang et al. [2010]	agent-based technologies
		new organizational structures
		product differentiation strategy
		producing new products with higher level of technological complexity
		postponement strategies
		long-term collaboration within the chain
		minimizing the number of suppliers
		minimizing of geographical dispersion
	Yang & Yang [2010]	postponement
		supply chain risk management (general)
		JIT
commonality		
Wong, Lai & Bernroider [2015]	modularity	
	supply chain information integration	
		advanced IT solutions

Table 4 cont.

1		2	3	
reducing and managing complexity	reducing structure (static) complexity	Serdarasan [2013]	reducing the number of products	
	managing dynamic complexity		reducing the product variants	
			reducing the number of outsourced partners	
			reducing the number of distribution centres	
			supply chain integration	
			partnership with suppliers, customers and service providers	
			supply chain visibility	
			standardization of operations	
			process automation	
			synchronization of data	
			information sharing	
	logistics outsourcing			
	managing decision making complexity		daily planning	
	reduction (impact on physical area) or management (on system's performance)		Perona & Miragliotta [2004]	process improvement
				process reengineering
centralized decision making				
automation of decision making				
lean production				
JIT manufacturing				
variety reduction program				
modularization				
group technology and cellular manufacturing				
product platform design				
mass customization				
value analysis				
partnership with suppliers				
information systems for planning				
integrated information systems with suppliers and customers				
outsourcing of warehousing and deliveries				
modularization				
automated internal handling				
outsourced production				
automated production resources				
mastering complexity	Abbasi [2008]	agent-based modelling, agent-based systems (also multi-agent systems)		
		visibility management		
		value chain management		
		flexibility management (of products and processes)		
		collaboration management (with customers and suppliers)		
		technology management (PDM, PLM, CRM, APS)		
		JIT		
		VMI		
		modularization		
standardization				

Table 4 cont.

1	2	3
		BPR supply chain reconfiguration postponement genetic algorithms information systems advanced forecasting market segmentation e-procurement e-commerce portals
reducing, mastering and avoiding complexity	Szmelter & Woźniak [2015]	determining the optimal number of product variants (one that will satisfy the needs of customers and at the same time will not cause low profitability of business) establishing the principle of the 'cleansing' product portfolio in order to avoid product cannibalism preparing a reliable analysis of costs (valuation of variants), overcoming the lack of information, resulting from incomplete and improper determination of the optimal amount of product variants

The complexity of system (mainly reported as supply chain) was usually described by them in two (static, dynamic) or three dimensions (static, dynamic, mixed – decision-making). In the static approach (at a given point in time), it included a variety and number of variants of system components (mainly products, business partners, functions, processes, etc.). The dynamic approach was related to the volatility, variability of system elements and relationships between them, especially in the context of a multi-dimensional uncertainty (e.g. access to raw materials, level of prices, structure and volume of demand). The level of supply chain complexity depends on the complexity of particular participants, their quantity, complexity of their networks, various relationships between them and many other characteristics. Complexity of each chain element causes complexity of the whole chain is growing exponentially, what brings many problems and constraints in supply chain management.

Most researchers focus on reducing complexity that is generally connected with structural (static) complexity. Serdarasan [2013] and Perona and Miragliotta [2004] mention also managing complexity as a separate area than its reduction, usually according to dynamic part of it (relations in supply chains, processes, decision making), then both static and dynamic complexity can be managed. Abbasi [2008] points the complexity mastering as the right direction of reducing its negative impact on the supply chain performance. On the other hand,

Szmelter and Woźniak [2015] propose the widest approach of three dimensions of complexity management in chronological perspective: firstly its reduction, then its mastering and in the end – avoiding complexity.

Researchers' approach to complexity management is quite similar, as are the logistic concepts and tools that facilitate this process, although a large variety of strategies, approaches, methods and tools can be observed in analyzed studies. The most popular are Just-in-Time, lean management, Vendor Managed Inventory, commonality and modularity of production and Business Process Reengineering. In analyzed literature, there is no difference between logistics strategies that are designed to reduce complexity, and those that focus on the mastering and avoidance of complexity. The same concepts and strategies are indicated in different areas of complexity management. There is no homogeneous classification and holistic approach to complexity management, what can cause problems in the future empirical research. However, analysis of the complexity, of its nature and causes, is present in the sphere of logistics and there are a number of solutions that help to reduce its impact on supply chain performance.

5. Discussion

The analysis of available literature sources and state of the art allowed for answering stated research questions. It has turned out that the currently available studies, despite some existing convergence in the description of complexity management in logistics, are significantly different from perceiving complexity problems in global supply chains. Firstly, there is no universal approach to managing complexity in the context of logistics. Despite the latter perception of complexity in its static and dynamic dimensions, the approach to managing complexity is different. Most researchers only point to the reduction of complexity as an appropriate solution to the problem of its occurrence, forgetting to prevent this complexity. There are problems with the unified naming of logistics management activities – some of the same logistical operations and concepts deal only with complexity reduction, others – with management, others – with mastering or preventing complexity. Almost all sources indicate a complexity reduction as the main area, which concerns logistics strategies (usually structural, static parts of complexity). The available research results show that companies, which are dominated by the static complexity, usually tend to its reduction. In turn, organizations dominated by dynamic complexity are trying to master it and adapt its level to their processes, what enhances and intensifies reduction of static complexity by mastering and modelling complexity [Serdarasan 2013].

Secondly, there are also inconsistencies in individual publications where complexity management is one part of complexity management. Is it confusing and gives rise to problems for further research dealing with the problem. These research will be more and more because as can be seen in Table 1, the number of papers on complexity in logistics is growing rapidly.

Thirdly, the lack of a uniform approach to complexity management in logistics raises further problems, including developing complexity measurement system, which is used for planning and implementing subsequent management actions, also included in logistic strategies. This causes closing the vicious circle, resulting in wrong management decisions in the global supply chains. As a result, inadequate decisions result in a decrease in the effectiveness of the supply chain and lower competitive advantage.

The most important thing is to learn how to measure complexity, analyze it, show its real level and its characteristics in companies and supply chains. Universal measures for that can be created, both general and industry-specific. Complexity management should be planned in the whole supply chain to optimize its performance. Supply chain complexity management should be implemented in particular actors' companies and in the chain as a whole (for example by Lead Logistics Provider, chain orchestrator).

A universal approach to these problems is a gap in current knowledge to be fulfilled, so this fact observed by Perona and Miragliotta [2004] over ten years ago is still true. Also Nilsson [2006] and Yang and Yang [2010] pointed out that complexity management is an unexplored area of logistics decisions. Every of the cited authors presented own approach to complexity problems, applying them in the theory of logistics. This is a very young area of research because the complexity in logistics is of recent interest to researchers and practitioners, so there are few articles on this subject but their number has been constantly growing.

6. Conclusions

The article showed that logistics strategies of global supply chains should be shaped with taking into account complexity, including the complexity of the product, and consequently – increase in value creation network complexity and supply chain complexity. Complexity analysis results are required to make strategic decisions [Lechner, Klingebiel & Wagenitz 2011]. Therefore, complexity should be considered as one of the main factors influencing logistics strategies of today's supply chains, and complexity management – as a part of these strategies and decision-making process. What is more, Wanke, Correa and Hijjar's [2010] statement, that the level of logistics complexity is a driver for choices of supply chain objectives and decisions, has been indirectly confirmed.

This research paper is the first summary in the literature of existing approaches to complexity management as a part of logistics strategies in global supply chains. It extends current literature by summarizing available research results from different research methods, research procedures, research samples and geographical areas. It showed a research gap in this area, especially because of heterogeneous research results and conclusions of previous projects. Because of no universal approach to mentioned research problem, there will be also problems with shaping strategies in global supply chains, also logistics strategies. It can be used by both researchers and practitioners. The researchers can address identified research gap in their future work. The practitioners can revise complexity management approaches and logistics strategies in their global supply chains through the prism of multi-path complexity management, not only limited to its reduction, but also to prevention.

There are few limitations of this article. Research methodology concerns only papers with particular search criteria, but there are also many other works dealing with complexity management in logistics. This is only literature review made without any quantitative data about results of complexity studies and without empirical research. Despite many research papers based on companies' data (mostly on the operational level), there is still a lack of one holistic view in the area of complexity identification, measurement and management. There are no key performance indicator sets to evaluate complexity. Case study-based research papers have some limitations disqualifying them for implementation of principles of management complexity throughout the supply chain. Currently, there is hardly any analysis about whole supply chains, and this is a crucial research gap in complexity studies. Future research should focus on complexity management in whole supply chains, especially global operating ones because of their high complexity level. These and many other issues in complexity area should be addressed in future research.

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