

THE CHALLENGES OF CONCEPT MULTI-ECHELON INVENTORY MANAGEMENT

Liliana Czwajda* and Monika Kosacka**

Faculty of Engineering Management, Poznan University of Technology, Strzelecka 11,
Poznan, 60-965, Poland

* E-mail: liliana.czwajda@gmail.com

** E-mail: monika.kosacka@put.poznan.pl

Abstract. The increasing complexity of supply chains and the dynamic development of information technology result in the increased interest of the Multi-Echelon – Inventory – Management concept. Although the concept is well – known in the last decade worldwide, in Poland the concept is still not enough explored. This paper presents the supply chain from the perspective of Multi-Echelon – Inventory – Management concept realization. The basis for the concept is to optimize the inventory level in the entire supply chain, what is considerably more difficult than managing it in a single-echelon. The main contribution of this paper is to introduce main challenges of multilevel systems and determine the classification of risks and sources of uncertainty in the entire supply chain.

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1. INTRODUCTION

Globalization, shorter product life cycle, rapidly changing demand and increase in the expectations and demands of customers, confirm that world is changing dynamically, what affects increasing requirements for supply chains. According to the requirements, supply chain has to deliver the right product in the right amount and in the right time to the final customer. Today, the customer buying the final product, justifies the existence of all channel partners instead of one company. Taking into account all costs generated by supply chain participants, they will be included in the final price of the product bought by customer (Kot, Statostyka-Patyk & Krzywda, 2009). The meaningful of the supply chains was indicated by Christopher (1992), who stated that in the future companies will not compete, supply chains will compete.

There are two types of definitions of supply chain. The first approach is based on supply chain partners, e.g. definition of the supply chain established by Witkowski, who defined it as “group of companies carrying out together all actions required to meet the demand for certain products in the whole chain (network) flow of goods – from the delivery of source materials to the delivery to the end user” (Witkowski, 2003, p. 95). In the second approach the emphasis is placed on involved activities, for instance supply chain includes management of products, information and resources flow between various supply chain stages (Choi, Li & Yan, 2008, p. 356). It has been recognized that the success of each organization is dependent on the performance and reliability of their suppliers, and customers (Wilding, 1998). Therefore, there should be taken global perspective of supply chains optimization, what ensures multistage network concept – multi-echelon, which are synonymous of the supply chain networks.

The concept of the multi-echelon inventory management has gained importance over the last decade mainly because of increasing complexity of supply chain and dynamic development of information technology, what enables integrated control of supply chains consisting of several processing and distribution stages (Gumus & Guneri, 2009, p. 5565). The terms “multi-echelon” or “multi-level” production/distribution networks are synonymous with networks/supply chains, where an item moves through more than one stage before reaching the final customer (Ganesan, 1999, p. 341). The number of levels in these structures are created by subsequently occurring intermediaries. In the single level structure, between suppliers and customers intermediaries are only at the one level, without any relationships with other intermediaries. However, in the multilevel (multi-stage) structure, agents are present at every level of distribution, entering into relationship with a higher-level intermediaries. The number of agents in particular distribution level is determined mainly by the nature of customer demand (Ambroziak & Jachimowski, 2011, p. 18). The structure of the distribution system is mainly influenced by placement of the

demand and supply of the products. As a result there are distinguished single-level as well as multi-level stage structures, presented in the Figure 1.

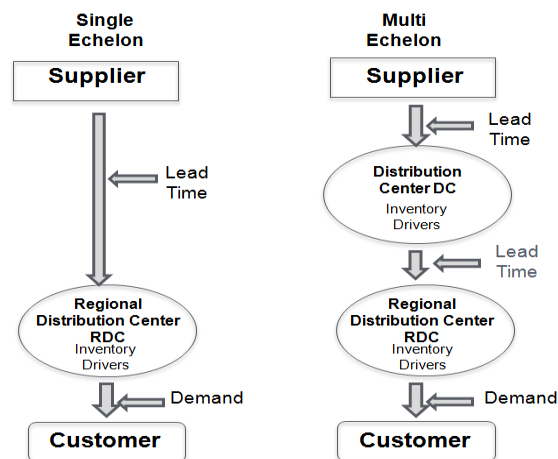


Fig. 1. Single-level and multi-level distribution systems (Lee, 2003, p. 5)

According to Lee (2003), there are inventory drivers in single-echelon approach as well as multi-echelon approach (Fig. 1). They are under company's control. Consequently, the frequency of stock replenishment, strategies of inventory ordering and customer service levels are control variables, while the decision-maker may affect the amount of stored and transported inventories and the level of service provided to the end customer. System consists of two nodes: Distribution Center (DC) and Regional Distribution Center (RDC) (Lee, 2003, p. 5). The primary objective of the multi-echelon approach is to minimize the total inventory level in all spheres of the RDC and DC while satisfying service commitments to end customers. What is more, the concept takes also into account the impact of the costs of transport and warehouse operations because their cost factors are part of the optimization. However, the concept of multi-echelon could bring benefits, there should be implemented according to the following principles (Lee, 2003, pp. 8–9):

1. avoided multiple independent forecast updates in each echelon,
2. measure the distortion of demand and determine of the causes in order to establish the possible corrective actions, monitor and manage the bullwhip effect,
3. enable visibility up and down the demand chain, what will results in visibility into the other echelon's inventory positions,
4. synchronize order strategies, e.g. synchronizing the ordering cycles at the DCs with RDC operations will reduce lead times and lead time variation between the RDC and the DCs,
5. offer differentiated service levels. It is a result of the multi-echelon approach because the company controls how and when a product enters and leaves the RDC.

2. CHALLENGES FOR MULTI-ECHELON CONCEPT

Optimization of the inventory level at all levels of the supply chain involves countless number of challenges including: the extension of cooperation to other partners, eliminating disruptions along the entire material and information flow as well as integration of those flows in the supply chain. Regarding flows, they are set between multiple dependent manufacturers and distributors, which often are included in the various supply chains (Świerczek, 2007, p. 76), which is a source of additional challenges.

2.1. Material and information flow

Management of the all activities related to the movement and storage of raw materials require an efficient information flow, which is the asset of each company. It is particularly important for logistics companies, due to the fact that it occurs in each logistics process (Mindur, 2008).

In order to implement the concept of multi-level inventory management to ensure current access to data at multiple levels of the supply chain at the same time, there is a need for an efficient, complete and transparent information flow throughout the supply chain. It is related mainly to the following data including: demand, inventories, lead times as well as the factors causing an unexpected increase in stocks. Moreover, as it was indicated in research conducted by Liang and Huang, the lack of information exchange on the type and state of the system of the inventory between the partners in supply chain makes the control of the inventory impossible. It results in difficulties in forecasting (Liang & Huang 2006, p. 390). Lack of the information exchange as well as inadequate quality of information are closely associated with the , “bullwhip effect” phenomenon and inventory control process, which have been widely discussed below.

The bullwhip effect refers to increasing swings in inventory in supply chain in response to ineffective information flow, what results in excessive accumulation of stocks in particular supply chain partners. It is also called “misalignment between the demand and order signal” (Costantino, Gravio & Tronci, 2015, p. 127). Inadequate information flow or lack of them between the partners in the supply chain, leads to distortion of information moving along the supply chain. It results in the intensification of demand variability and the bullwhip effect.

This effect may occur even with a gradual increase in information distortions, in terms of small changes in demand. This phenomenon creates serious problems for partners in the supply chain, causing errors in demand forecasts, low capacity utilization, excess inventory and poor customer service. Consequently, there are observed: increase in safety stock, the use of additional production capacity, increase in storage space and additional investment costs and fluctuations in capacity utilization (Costantino, Gravio & Tronci, 2015, p. 128).

The exchange of information has been recognized as one of the main possibility for the bullwhip effect taming (Lee & Tang, 2000, p. 626). In contrast, one of the main reason of the bullwhip effect is the forecast error, which can be minimized by sharing sales data.

Bullwhip effect cannot be completely eliminated, but by choosing the appropriate ordering policy and selection of appropriate parameters of improved forecasting methods, the inventory level may be reduced by 55% of the total value (Costantino, Gravio & Tronci, 2015). Designing the replenishment policy is a key activity in supply chain management, taking into account the specific parameters of this policy. Accuracy of information from retailers can increase the accuracy of forecasting and thereby reduce the level of safety stock. Moreover, the forecasting technique affects reducing the bullwhip effect (Kelepouris, Miliotis & Pramataris, 2008).

Inventory management in the supply chain (SCIM) includes planning and inventory control throughout the supply chain (SC) from suppliers to markets. This subject is very important in all types of organizations in the current highly competitive business environment (Chen & Paulraj, 2004, p. 131).

Visibility of the inventories, supply and demand in the supply chain is at the top of the most relevant initiatives in recent times. In order to support them, there have been used information technologies. Distortion and information errors may cause lack of visibility and problems with the control of ordered stocks. It results in hiding the true state of information and lack of possibility of taking corrective actions for unpredictable events in the consequence. Lack of coordination and visibility among partners significantly influence the efficiency of the supply chain and the increase of the management costs. Consequently, uncertainty in the supply chain is increasing. Many researchers in their work have paid their attention to inventory control at various levels. In order to increase the stability of inventories, there have been proposed initiatives directed to increase the efficiency of the inventory level control process achieved by: activities which increase the coordination, expand access to local and global information and improve the forecasting process.

2.2. Risk and uncertainty in the supply chain

Davis (1993) pointed out that, the key issue affecting the efficiency of the supply chain is uncertainty. In contrast, Christopher (1992) explains that, uncertainty is one of the main reasons of maintaining safety stock in the company. Globalization, technological change and increasingly demanding customers, lead to increased requirements for the supply chain. It may result in a higher level of uncertainty for the organization and thus a higher level of incurred risk. It may be uncertainty over future demand or uncertainty of supplier's skills in fulfillment the promise of providing goods or materials of appropriate quality. The uncertainty in the supply chain may also occur if a decision is taken in the terms of lack of information about changes in the environment, in the supply chain, or inability to use required data. It

may be a result of scarcity of capacity for information processing as well as the choice of one option during decision making without knowledge about the effect of the decision on the efficiency of the supply chain. Consequently, it impedes achieving their objectives (Pluta-Zaremba, 2008, p. 2).

However uncertainty is inevitably associated with the risk management, the risk management is measurable since the estimations of parameters can be made with a certain probability of results (Khan & Burnes, 2007, pp. 197–216).

In the literature, there is accepted the relationship, where the risk is the linear function of the uncertainty, where with greater uncertainty, the risk is increasing, on the other hand uncertainty reduction is related with the risk reduction (Arrow 1979, p. 27). Due to the concept of multi-echelon, there should be adopted the holistic approach to the uncertainty and risk in the supply chain. Unfortunately, in the literature such approach is not available. It has become a direct premise for preparation the risk classification for the entire supply chain.

In the literature, risk and uncertainty are separately classified. The main criterion of risk categorization is risk placement with the respect to the enterprise, resulting in two categories of risk: internal and external. The internal risk is related primarily to the internal activities of the company, where there are various limitations as well as adverse events in its operational activity. On the other hand, external risks come from the environment of the supply chain, including: the nature, the political system, competition and the market. In general, similar risk division includes the micro and macro risks, which are often named as catastrophic and operational (Sodhi, Son & Tang, 2012, pp. 1–13).

Macro-risks are related to adverse and relatively rare external events or situations that may have a negative impact on the company, such as the environment (earthquakes and weather-related disasters) and manmade (e.g. The war and terrorism and political instability). However, negative impact is much greater in relation to the micro risk, which refers to a relatively frequently occurring events and comes directly from the internal activities of companies and/or their relationships with other partners in the supply chain (Ho, Zheng & Talluri, 2015). Some authors extend the categorization of internal and external risks, considering risks associated with network or supply chain (e.g. the supply/demand risk).

It has been noted, that there are other classification which are results of the adopted perspective, e.g. marketing, production (Małyszczek, 2015). In particular, the marketing perspective causes the risk division in accordance to the main sources of risk such as: company image, responsibility, health and safety, cost reduction, compliance, social relations, customer relations and product development. In the light of the production perspective, there are such risk categories as: delays, inventory, manufacturing process failures, resources, information and transport system (Tummala & Schoenherr, 2011, pp. 474–483).

Furthermore, there is available categorization resulting from the phase of the logistics flow, placed in the context of other threats where there is included demand, operational and supply risk. The risk of supply is related to adverse events in the

purchasing phase, which have a negative impact on the company's ability to meet customers expectations. Operational risk refers to adverse events in the production/services phase. The risk of demand applies to adverse events in the distribution phase, e.g. making orders by customers and/or fluctuations in the size of those orders. Additionally, these three risk categories interact together and they can be mutually reinforcing.

In the supply chain there is also the risk of linkage between companies. It refers mainly to the risks associated with the integration, cooperation and coordination. Moreover, risk may be categorized in accordance to the time horizon of the management, resulting in strategic, tactical and operational risk, however the last one is well studied. In addition, there is available risk division according to the degree of negative impact on the company (Ho, Zheng & Talluri, 2015) as well as because of the value chains: suppliers, business, distribution channels, buyers (Nowacki, 2014).

In the literature, there can be found also a separate categorization of the uncertainty in the supply chain, what primary covers with the identification of sources of risk. The sources of uncertainty can be divided into three groups: (Simangunsongy, Hendry & Stevenson, 2012, p. 4498):

1. uncertainties from the focal company, e.g. internal organization uncertainty (product characteristics, manufacturing process, control/chaos, decision complexity, organization/behavioral issues and IT/IS complexity),
2. internal uncertainty of the supply-chain arising within the realm of control of the focal company or its supply chain partners (end-customer demand, demand amplification, supplier, parallel interaction, order forecast horizon and chain configuration, infrastructure and facilities),
3. external uncertainties associated with factors outside the supply chain, which are outside a company's direct areas of control (environment, government regulation, competitor behavior and macroeconomic issues, and disasters).

The uncertainty in the supply chain is determined mainly by the uncertainty of demand, supply and production. These three types of uncertainty are correlated, which means that the increase of one of them influences the other (Pluta-Zaremba, 2008).

In order to ensure the proper supply chain performance, there are required information and transport technologies and efficient financial system. Any disruption in indicated systems can lead to serious problems in the supply chain. In order to ensure proper operation of mentioned technologies, the adequate logistic/production or information infrastructure is essential. It is relevant to be aware of that, it can be a subject of interferences and failures, too. Therefore, authors claims, that the risk of the infrastructure will have a high importance level (Ho et al., 2015). The other sources of uncertainty include: the uncertainty of supply, process control, parallel interaction, the complexity of decision, IT/information systems, organization, processes and policies, people and external events, information flow. As a consequence, it was stated in the paper, that uncertainty division is based on the genesis. It was confirmed in the division presented by Ivanov and Sokolov (Konecka, 2015, p. 88).

Authors perceived, that sometimes the classification of the risk and uncertainty are the similar or the same. Taking that into consideration, there was prepared the common classification for risk and uncertainty, presented in the Figure 2.

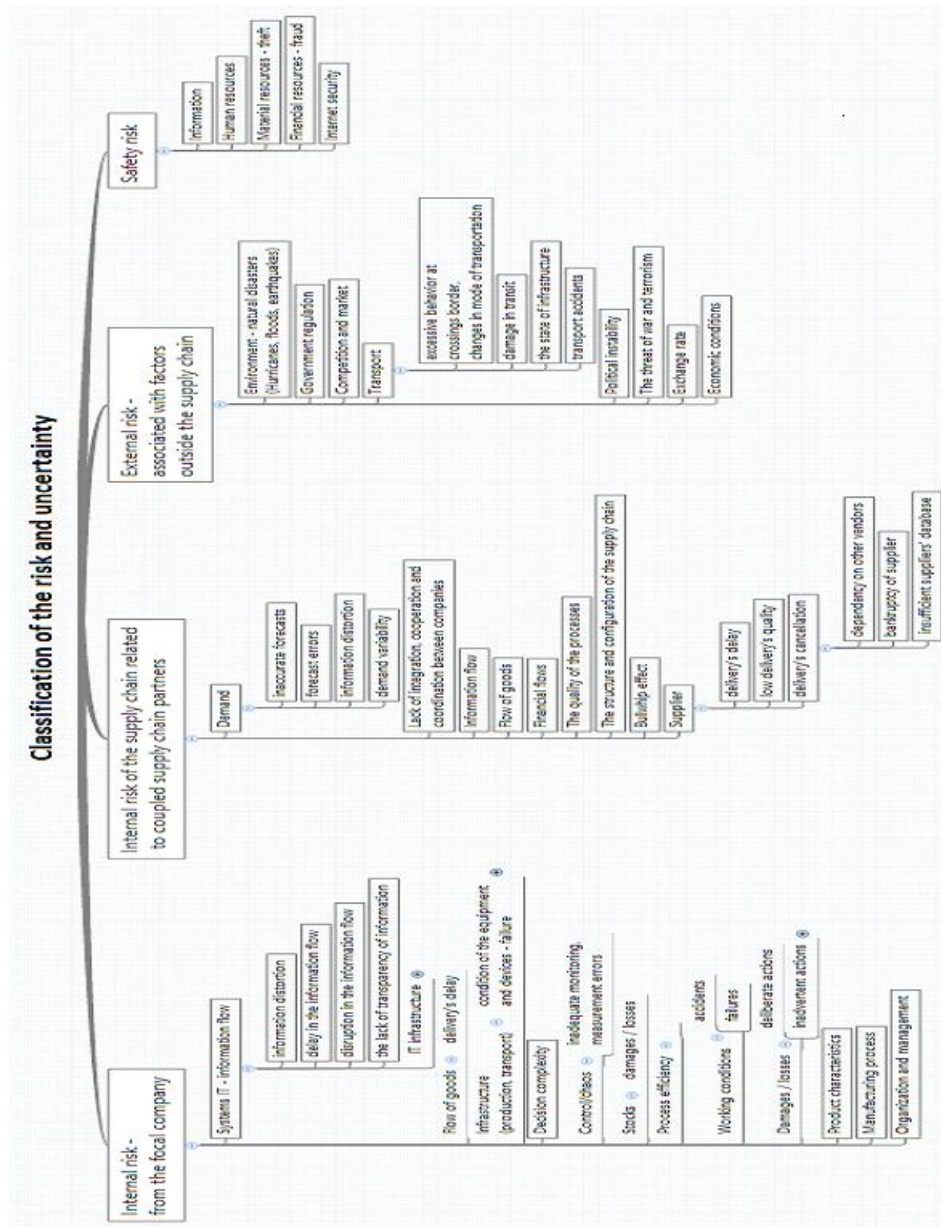


Fig. 2. Classification of the risk and uncertainty occurred in supply chain (own elaboration)

In the presented Figure 2 authors have attempted to create the classification for both risk and uncertainty in the supply chain, taking into consideration the distribution of risks and uncertainties provided by Simangunsongy and others (2012). Moreover the safety risk was included because of the large impact of such risks on the enterprise and supply chain. That type of risk is not under the control of the partners in the supply chain, although it can affect negative realized process according to the safety of the information, resources and activities integrality.

Presented classification provides a general breakdown: covering the entire supply chain. It should be treated as a model for preparing the risk classification for particular supply chain. It is relevant to prepare risk classification dedicated to the specific supply chain.

2.3. Possibilities of dealing with challenges of multi-level supply chains

The literature is a source of many various divisions of the possibilities of dealing with the uncertainty and risk. In the case of the risk, there is risk management and carrying out activities which aim to reduce the risk impact level on the organization and to secure the operational efficiency of the company.

Another aspect is the increasing integration of the supply chain, which has the effect on reducing risk and uncertainty. Consequently, the indicated reduction has a positive effect on the actions integration (Małyszczek, 2015). Uncertainty and risk are recognized in the literature as the best and simplest measure of the integration level of the supply chain (Towill & Childerhouse, 2003, pp. 17–27).

Moreover, in the risk management process, there are used techniques and tools of the Total Quality Management (TQM) concept, which are utilized in order to mitigate the effects of bullwhip effect. Costantino, Gravio and Tronci proposed the solution with the use of the control cards with SPC, in order to smooth the inventory replenishment rules (2015, p. 1665).

Other possibilities of reducing risk in the supply chain, include: mitigating the supply risk by implementing behavioral techniques of inventory management, building and managing strategic relationships with suppliers, reducing the complexity of the supply bases, a natural protection of fluctuations in currency and commodity prices, confidence building and the introduction of knowledge management to the supply chain, as well as the introduction of the identification and assessment of the gaps in the supply chain, identification of “bottlenecks” (Ho, Zheng & Talluri, 2015, pp. 5031–5069).

Considering uncertainty, there are different possibilities of dealing with them, including the following strategies: postponement (product development, purchasing, production), the process flexibility supply chain flexibility as well as the flexibility of the client, suppliers, strategic commodities, support for the information and communication technology, ICT, management of the leading time (delivery of

products), financial risk management (Simangunsongy, Hendry & Stevenson, 2012, pp. 4493–4523).

Cooperation begins by sharing the information, and it is one of possible solution in mitigating the bullwhip effect and reducing its effect on the supply chain (Cho & Lee, 2013, p. 97). Cooperation is also mentioned as a strategy for reducing uncertainty among due to the exchange of information between the manufacturer and its partners down in the chain, and between retailers.

The next possibility is to provide strategic buffer stocks (Forslund & Jonsson, 2007, pp. 90–107) and use various management strategies of uncertainty management in the supply chain. The set of appropriate strategies includes those, which aim to reduce the uncertainty at its source in the management area, as well as the opposite ones. Another way is to mitigate the effects of uncertainty relating to activities reducing the adverse effects of activities in the supply chain (Simangunsongy, Hendry & Stevenson, 2012, pp. 4493–4523).

3. CONCLUSION

The concept of multi-echelon inventory management, provides possibilities for optimization throughout the supply chain, but it needs the holistic perspective. There should not be considered only single company, but the all partners in the supply chain. With more complex supply chains and the higher uncertainty and risk levels in the environment, there are enormous number of challenges for the supply chain. The most valuable issue is requirement of better quality of the information flow between partners in supply chain, what needs: close relationships, activities coordination and reliable and accurate information (e.g. on demand, inventories, lead times, what has the effect on reducing the bullwhip effect).

In the case of uncertainty and risk, the first claimed in the paper difficulty was lack of the one, clear risk classification referring to the whole supply chain, from the holistic point of view. In the literature there are available various classifications, however they are presentation of the opinion on that issue of the particular author, who analyzed particular part of the supply chain (company, phase of the material flow, etc.).

What is more, there is a problem with the nomenclature. Authors discovered that there are available different names for the same type of risk, depending on the author (e.g. the macro risk is also called an external risk).

The uncertainty has an impact on the risk that you can identify, analyze, control and regulate and manage therefore it is important to assign the sources of uncertainty to the relevant types of risk. In the presented distribution of uncertainty in the risk classification presents mainly a source of risk.

With the risk issue, there is inseparable related uncertainty issue. The uncertainty has an impact on the risk, which may be identified, analyzed, controlled and

regulated and finally it may be managed. Therefore it is important to assign the sources of uncertainty to the relevant types of risk. In the paper, the uncertainty is included in the risk classification, pointing out sources of risks.

The main purpose of the paper was to prepare the classification of risks in the supply chain, from the holistic perspective, what was achieved. Prepared classification is a model, which should match specification of the particular supply chain.

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BIOGRAPHICAL NOTES

Liliana Czwajda finished doctoral studies at Poznan University of Technology (PUT). Her research interests are in area of: production optimization and supply chain, quality, materials and information flow management.

Monika Kosacka is an student of doctoral studies at Poznan University of Technology (PUT). She received her master degree in Industrial Engineering from PUT in 2012. Her research interests are in area of: materials flow management, reverse logistics, sustainability and supply chains.

