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THE EFFICIENCY OF THE MARITIME CONTAINER SUPPLY CHAIN AT THE MARITIME CONTAINER TERMINAL WITH REFERENCE TO IDENTIFIED RISKS

ABSTRACT

Background: Containers has become one of the most common methods of goods' transportation. Passing through many links in the chain, containers influence the efficiency of the supply chain. At every point, time and cost needed for performing specific operations, determines the efficiency. While executing those operations it is important to being conscious of the risks, which can be met. Due to wide range of supply chain, importance of maritime transport, strategic role of maritime container terminals and homogeneity of operations' nature taken at terminal, the problem of efficiency of the maritime container supply chain has been narrowed to the issues concerning supply chain efficiency at the maritime container terminals with reference to identified risks. The objective of this paper is to develop maritime container supply chain efficiency indicators at the maritime container terminal with reference to the identified risks

Methods: Therefore some general research methods are proposed as critical literature review, logical reasoning and more research purpose oriented methods as methods of risk assessment like HAZOP and SWIFT.

Results: Efficiency indicators with respect to time and cost have been developed with reference to five main risk categories at the maritime container terminal.

Conclusions: Proposed set of indicators offers possibility to examine relation between occurred events and cost and time efficiency of whole maritime container supply chain. General form of the presented indicators gives an opportunity for being suitable and sufficient at general level of maritime container terminal.

Keywords: supply chains, efficiency indicators, maritime container terminal, risk identification, literature review

P. Cyplik et al. (eds.), *Contemporary challenges in supply chains, Vol. 2*,
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INTRODUCTION

Supply chain (SC) is geographically stretched, complex network [Pryke et al. 2009] of mutual connections between participants of this structure. Within this construction, there are many transhipment points, such as terminals or distribution centres, and transport links, like road transport or maritime transport. In the global supply chains main role is played by the maritime container shipping [Panayides 2006, Panayides and Song 2008, Hoffmann et al. 2018]. The maritime container terminal, which is one of the transhipment points, can be perceived as an essential node, which integrates other transport modes. This integration is expressed in two forms: as a set of management activities, such as planning and controlling, and as a set of executive activities, which includes handling, reloading, warehousing etc. The operations, taking place at the maritime container terminals, are crucial in terms of supply chain efficiency. While executing those operations it is important to being conscious of the risks, which can be met, which will influence on the overall link efficiency, as well as whole chain efficiency. Due to wide range of supply chain, importance of the maritime transport, strategic role of maritime container terminals and homogeneity of the nature of operations taken at terminal, the problem of efficiency of the maritime container supply chain has been narrowed to the issues concerning supply chain efficiency at the maritime container terminals with reference to the identified risks.

Although in the literature there is space devoted to the performance and efficiency of the supply chain (e.g. [Gunasekaran et al. 2004, Banaszewska et al. 2012, Mathivathanan et al. 2017] there has been lack of focus on issues of economic efficiency of the maritime container supply chains (MCSC) with a reference to risks.

The field of risk management in the supply chain is well examined (e.g.: [Yang 2011, Hahn and Kuhn 2012, Vilko and Hallikas 2012, Elleuch et al. 2016, Vilko et al. 2019], although in the literature there has been lack of focus on issues of risk in the maritime container terminals with reference to the supply chain efficiency.

The aim of this paper is to develop maritime container supply chain efficiency indicators at the maritime container terminal with reference to the identified risks. The above stated purpose is carried out through a research process, which covers such stages as the identification of the state of art in the field of supply chain efficiency, risk management and risk at the maritime container terminal, and based on findings, an original indicators of maritime container supply chain efficiency with reference to maritime container terminals risks are developed.

P. Cyplik et al. (eds.), *Contemporary challenges in supply chains, Vol. 2*,
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The paper is divided as follows:

- Section 1 provides literature review concerning efficiency of the maritime container supply chains;
- Section 2 contains literature review concerning risk management in the supply chains and risk assessment methods that have been used during conducting research;
- Section 3 shows results;
- Section 4 presents discussion;
- Section 5 includes final conclusions.

EFFICIENCY OF THE MARITIME CONTAINER SUPPLY CHAINS – LITERATURE REVIEW

Supply chain efficiency

Efficiency and performance are often conceptualized as the same [Ganga and Carpinetti 2011, Estampe et al. 2013, Shafiee et al. 2014]. On the other hand, there are researchers who perceive efficiency as one of the components of performance [Chopra and Meindl 2003, Charlampowicz 2017]. Due to the different characteristics and targets of MCSC economic efficiency should be divided into three categories: cost efficiency, time efficiency and spatial efficiency [Charlampowicz 2017].

Cost efficiency of the supply chain

[Pettersson and Segerstedt 2013] defined cost as all significant costs in the SC. The high level of cost efficiency in the SC is possible only when, the SC is fully integrated and has sufficient information flow. In the cost-oriented SC it is crucial to identify all relevant costs that appears at every stage of SC. When full information concerning place, frequency and amount of cost at every stage of SC is available, then it is possible to make selection of costs based on their importance in order to achieve higher level of cost efficiency. Although before implementing cost-cutting actions it is essential to recognize the influence of cost reduction at one stage to cost increase in the other area [Gunasekaran et al. 2004].

Time efficiency of the supply chain

Even though costs are playing important role in every management process, the cost-cutting actions are not always bring profitable final outcome. If the SC is passing through highly uncertain, volatile market, then the reliability of delivery and the delivery time are more

P. Cyplik et al. (eds.), *Contemporary challenges in supply chains, Vol. 2*,
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important factors in overall SC efficiency. The time efficiency is a feature of SC that assumes the ability to meet customer expectation in the context of lead-time reduction [Agarwal et al. 2006, 2007, Gligor et al. 2015, Charlampowicz 2017]. Time, as a measure of SC performance, which is one of the factors of efficiency, was also successfully used to identification the areas of non-added value activities in the processes [Whicker et al. 2009]. [Kolinski and Sliwczynski 2016] highlighted the problem of transposing strategic objectives to the operational level, some of the proposed calculating formulas are connected with time efficiency of the supply chain.

Spatial efficiency of the supply chain

Spatial efficiency of the SC is a feature which connects the time efficiency and cost efficiency and is expressed in the mutual relation between cost and time [Charlampowicz 2018c]. One of the factors influencing on the spatial efficiency and building up the competitive advantage is geographical locations of the partners in the network [Arnold et al. 2004]. During planning the network some factors should be taken under consideration, such as: transportation congestion, state and availability of infrastructure and local regulations [Weisbrod et al. 2016, Charlampowicz 2017].

Maritime container terminal efficiency

The global supply chains, as complex structures, have many links, which not necessarily would be homogeneous. The maritime container shipping plays main role in the global supply chains [Panayides 2006, Panayides and Song 2008]. Due to rising market concentration the role of container shipping will continue to increase [Charlampowicz 2018a, 2018b]. Within these chains the maritime container terminals (MCT) can be perceived as essential nodes, which integrates other transport modes. The main advantage of MCT, in the context of research, is the fact that the services and organization of it is similar on global level [Farrell 2012, Bergantino et al. 2013].

The research concerning MCT efficiency mostly focused on the technical efficiency understood as the ability to handle more containers [Almawsheki and Shah 2015, Kutin et al. 2017]. This type of efficiency is one of the factors of economic efficiency. The high level of technical efficiency allows to achieve more profit through ability to more efficient services. This efficiency of services can be expressed through lower cost of operations or shorter time.

P. Cyplik et al. (eds.), *Contemporary challenges in supply chains, Vol. 2*,
https://doi.org/10.17270/B.M.978-83-66017-89-4.9

The literature in the field of technical efficiency of the MCT is well examined (see e.g. [Cullinane et al. 2002, 2006, Cullinane and Wang 2006, Jiang and Li 2009, Almawsheki and Shah 2015, Pérez et al. 2016]). [Cullinane and Song 2006] confirmed the positive relation between port size and its technical efficiency. Research conducted by [Pérez et al. 2016] showed that the most efficient are ports with three or four terminals.

In the literature there is only few papers dedicated to other types of efficiency of the MCT. [Bichou 2013] conducted research, which confirmed that variation in operating conditions, such as e.g. terminals procedures, have direct impact on the terminals' efficiency. This research looked at the terminal efficiency also from other points of view, such as managerial one. Another paper, where technical efficiency was one among other parameters is research carried out by [Kaselimi et al. 2011], where the relation between technical, market-related and governance-related factors was analysed. This relation was important element in expansion strategy development.

The MCT is a link, where crucial operations are taking place, this link integrate other transport nodes and due to the characteristics, homogeneity and importance of this element in the volatile supply chain structure it is important to identify risks that can be met in MCT. After risk identification it is possible and crucial to develop efficiency indicators for MCSC in the context of risks, which can be met in the MCT.

In the literature there is a gap of knowledge concerning the MCSC efficiency with reference to risk at the MCT.

RISK MANAGEMENT IN THE MCT

Risk management in the supply chain

Risk pervades every dimension of life, both professional and personal. Risk is immanent feature of any business activity. Risk can be perceived as a chance of danger, damage, loss, injury or other undesired consequences [Harland et al. 2003]. In the management studies researchers connects risks with the likelihood of occurrence of an uncertain event or set of circumstances that would have negative impact on performance or possibility of achieving targets. Risk refers to the variance in corporate outcomes or performance, which cannot be forecasted ex ante [Miller 1992]. Basically risk can be defined as a possibility of loss [Chiles and McMackin 1996].

P. Cyplik et al. (eds.), *Contemporary challenges in supply chains, Vol. 2*,
https://doi.org/10.17270/B.M.978-83-66017-89-4.9

SC, as a complex network having various mutual relations between participants, operating mostly under volatile market conditions, is vulnerable for numerous unpredictable, undesired events. Ability to cope with risks is very fertile area in the field of SC management and many researchers are interested in this area (e.g.: [Hahn and Kuhn 2012, Holweg and Helo 2014, Kamalahmadi and Parast 2016].

Supply chain risk management (SCRM) is a set of actions containing identification and evaluation of risk and consequent losses in the global supply chain, implementation of suitable supply chain management (SCM) strategy among SC members that lead to close matching of actual costs and profitability with those desired [Manuj and Mentzer 2008]. SCM strategy, that would be suitable for unpredictable, volatile market, is a strategy that has features connected with the ability to prevent risk or operating normally despite of the disruptions. The resilient methodology in the SC fits the bill as it emphasizes dynamic, unforeseen and even unknown types of threats, disruptions, complex interactions and uncertainty [Jain et al. 2018] and refers to the ability of the SC to return to the at least original state after experiencing disruptions [Carvalho et al. 2012]. It can be stated that during implementing the resilient SCM it is very important to develop specialized tools for forecasting future risk and to simulate the impact of the responses on the organization and on the whole supply chain [Carden et al. 2018, Ribeiro and Barbosa-Povoa 2018].

Risk identification is the first step in developing risk management process [Manuj and Mentzer 2008, Blome and Schoenherr 2011]. The sources of risk, in the GSC, can be divided into supply risks, operational risks, demand risks, security risks, macroeconomic risks, competitive risks, and resource risks. The first four risks are associated specifically to the supply chain. Moreover most of these 8 categories of risks are overlapping and do not exist in isolation [Manuj and Mentzer 2008].

Another classification perceived emerging of business and organizational risks from external and internal factors such as: organizational factors, environmental factors, industry factors, problem-specific factors and decision-makers factors [Rao and Goldsby 2009]. These factors are not independent of each other.

The literature of SCRM is extensive (see e.g.: [Manuj and Mentzer 2008, Soni et al. 2014, Elleuch et al. 2016, Mishra et al. 2016, Vilko et al. 2019], however not many studies has been undertaken to address MCSC, which is an area of growing importance [Lam 2011]. In the MCSC the MCT is crucial node in the SC due to, compared to other transportation modes,

P. Cyplik et al. (eds.), *Contemporary challenges in supply chains, Vol. 2*,
https://doi.org/10.17270/B.M.978-83-66017-89-4.9

having more interfaces with other stages and members of SC, which represents the potential of weak points. The identification of risks in the MCT is the first step to managing uncertainty in the MCSC.

Identification of risks in the maritime container terminals

In the literature there has been little space devoted to the seaport risks and its influence on the MCSC. There are two types of maritime risk: one is connected with maritime transportation, and the other is connected with the seaport operations. Both have few aspects is common, however they are also unique enough to distinct from each other [Cho et al. 2018].

One of the research dedicated to the maritime transportation risk presented a case study carried out to determine the most common causes of unintentional damages on cargo ships at coasts and open seas of Turkey, shows that the most common type of error was human error [Mentes et al. 2015]. Growing traffic level in ports is one of the main indicators for improvements in efficiency and service of ports and there is a need of continuation of deploying better traffic control systems to match the increasing volume of vessels and cargo movements [Yip 2008].

The most immediate impact from port disruptions is the adverse effects on terminal operators [Lam 2016]. The research carried out by [Cho et al. 2018] focused on the seaport operations risks and identified infrastructure and operational efficiency in the seaports as an important factor, respectively, to decrease maritime risk and increase traffic volume. The leading categories of container security initiative risk factors are operational risk, physical risk and financial risk [Yang 2011].

The dynamic model capable of dealing with changing operational conditions in ports has been proposed by [Alyami et al. 2019], although researchers focused mostly on the human factors related risks.

[Pallis 2017] has presented the Port Risk Management methodology, which is a decision support framework that can be used to asses whole port's and terminal's overall risk level in order to implement improving strategies. In this paper risks in the MCT has been divided into five categories: human, mechanic, environment, security and natural. Every category has several risk sub-categories.

P. Cyplik et al. (eds.), *Contemporary challenges in supply chains, Vol. 2*,
https://doi.org/10.17270/B.M.978-83-66017-89-4.9

Risk assessment methods

The literature in the field of risk assessment methods is extensive (e.g. [Valis and Koucky 2009, Andersen and Aamnes 2019]. The risk identification is first and in many ways the most important action in the risk assessment [Pallis 2017]. Risk identification includes disruption that can be met in the MCT and the functions of MCT that need to be protected. The risk assessment should consist the qualification of most important terminal's risks. The risk factors presented in this paper have been identified based on literature review [Rao and Goldsby 2009, Pallis 2017], logical reasoning and methods of risk assessment, namely HAZOP and SWIFT.

2.3.1 HAZOP

HAZOP is an acronym for Hazard and Operability Analysis [Andersen and Aamnes 2019]. It is a structured process of risk assessment, and this method is a qualitative technique based on using guide words that question the possibility of not achieving plans targets at each stage of the system [Valis and Koucky 2009].

2.3.2 SWIFT

SWIFT is an acronym for Structured What-If Technique [Andersen and Aamnes 2019]. This method has been designed as a simpler alternative to HAZOP, and is used through using standard "what if" phrases to investigate how system, or any stage of the system, would be affected by disruptions [Valis and Koucky 2009].

RESULTS

Due to the importance of the MCT it is crucial to develop the SC efficiency indicators based on the identified risk factors. The efficiency indicators should be developed with respect to cost efficiency and time efficiency. During the risk identification process some general research methods has been used, such as literature review and logical reasoning, and more research purpose oriented methods of risk assessment, which is a mixture of HAZOP and SWIFT methodology. The results of the research are presented in the table 1.

Table 1. MCSC efficiency indicators in MCT with reference to identified risks

Risk category	Cost efficiency indicator	Time efficiency indicator
Human factors	Direct cost of delays in the SC	Time of re-introduction cargo to the SC
	Cost of cargo loss	Time needed for rescuing the vessel

P. Cyplik et al. (eds.), *Contemporary challenges in supply chains, Vol. 2*,
https://doi.org/10.17270/B.M.978-83-66017-89-4.9

	Cost of compensation	Time of extending the loading/unloading
	Cost of maintenance and repairs	Time of extending the delivery
		Time of maintenance and repairs
		Time needed for re-introduction cargo to the system
Mechanical factors	Direct and indirect cost of delivery to next stage	Time of maintenance and repairs
	Cost of environmental threat	
	Cost of compensation	Time of repeated delivery
	Cost of cargo loss	Time of extending the delivery
	Reposition cost	Time of proper displacement of the cargo
	Cost of maintenance and repairs	
	Cost of delay in delivery to the next stage	
Environmental factors	Direct and indirect cost of delivery delay to next stage	Time of re-introduction cargo to the SC
	Cost of compensation	Time of extending the delivery
	Cost of cargo loss	Time of quarantine
Security factors	Cost of new fees	Time of customs
	Detention cost	Time of detention of the cargo
	Cost of repeated transport	Time of repeated transport
Natural factors	Cost of cargo loss	Time of extending the delivery
	Direct and indirect cost of delivery delay to next stage	Time of repeated transport
	Cost of repeated transport	

Source: own elaboration

The above presented five risk factors have numerous risk sub-categories to which the efficiency indicators with respect to cost and time has been developed. The risk factors, similarly to sub-categories, has been identified based on literature review [Rao and Goldsby 2009, Pallis 2017]. In the human factor it can be identified following sub-categories: vessel collision, grounding, sinking, navigation error, pilotage error, poor maintenance, falling of the crane, falling the cargo, error in introducing cargo to the system. Mechanical factors consist of poor maintenance (of vessel or terminals infra- and suprastructure), STS/RTG failure, system failure, fire/explosion, error in cargo handling, failure during reposition. Among environmental factors such sub-categories are identified: oil spills, chemical contaminants, ballast water

P. Cyplik et al. (eds.), *Contemporary challenges in supply chains, Vol. 2*,
https://doi.org/10.17270/B.M.978-83-66017-89-4.9

contaminants, air toxics, noise pollution, alien species and salvation of the vessel/cargo. In the security factors there are following sub-categories: political instability, terrorism, theft, smuggling/illegal trade. The last risk factor, natural factors contain following sub-categories: natural disasters, heavy wind/swell/sea. Some of the above presented factors have the same cost and/or time efficiency indicators (e.g. sub-categories of mechanical factors like STS/RTG failure, system failure and failure during reposition has the same outcome as a time and cost efficiency indicators, which is the cost of delay in delivery to the next stage and time of extending the delivery), so in order to avoid the constant repeats of the indicators, the sub-categories of risk were omitted.

DISCUSSION

The main advantage of above presented efficiency indicators of cost efficiency and time efficiency with reference to risks identified in the MCT is that they are having general characteristics. This gives an opportunity for being sufficient and suitable for any kind of MCT. On the other hand, during examination of the influence of the particular events on the cost efficiency (or time efficiency), there is a need of having full information concerning data from the whole SC. This means that the prerequisite of utilizing these indicators, in presented form, is operating in the fully integrated SC. This paper is the first that made an attempt to develop efficiency indicators of MCSC in the MCT with reference to identified risks. However it is crucial to remember that there is a need of further developing the presented indicators in terms of particular terminal business characteristics, which will influence on the possibility of risk factor occurrence.

CONCLUSIONS

The MCT is a crucial element of global SC, in which MCSC plays an important role [Panayides 2006, Song and Panayides 2008]. The MCT is a point of integration and interaction between different transportation modes. This gives a possibility of weak points occurrence. Disruptions met in the MCT have adverse effects for next stage of SC and, consequently, whole network. Based on the literature review there has been identified a gap in the knowledge concerning the MCSC efficiency at the MCT with reference to the identified risks. Most of the papers focused on risk management in the MCSC (e.g.: [Vilko and Hallikas 2012, Lam and Bai 2016, Vilko et al. 2019], some concerning risk at the MCT [Pallis 2017, Alyami et al. 2019],

P. Cyplik et al. (eds.), *Contemporary challenges in supply chains, Vol. 2*,
https://doi.org/10.17270/B.M.978-83-66017-89-4.9

and the MCT technical efficiency (e.g.: [Cullinane et al. 2006, Pérez et al. 2016] but there are no research combining risk issues at the MCT with the efficiency of the MCSC. This paper made an attempt to fill this gap by developing MCSC efficiency indicators at the MCT with reference to the identified risks, which was the main purpose of the article.

The further research directions are as follows: first, the above presented, set of indicators should be confronted with the real economic reality expressed in the form of implementation of these indicators to the existing MCT as a part of the MCSC. The results of this action would be very useful in terms of managerial, as well as, scientific point of view. This action would also be very useful in terms of defining the suitability of these indicators with respect to business environment. Another further research direction of a great importance is the further development of these indicators in terms of capturing full impact of disruptions from undesired events at MCT for whole MCSC. This operation is possible only in the fully integrated SC, where it is possible to define and evaluate influence of MCT disruption on whole SC. Additional further research direction is connected with the ability of developing similar indicators in other transhipment points in the SC, although due to differences in operational characteristics among other links in the SC it could be difficult to develop homogenise indicators for whole network. Although when full data, concerning particular SC, would be possible to acquire then it would be possible to develop such indicators, even though the results would be rather useful and implementable only for examined SC. Another further research direction of great importance is the need of analysis of the impact of the incorrect information flow on risk in the MCSC and the efficiency of the MCSC.

Lack of possibility to acquire data from MCSC to implement presented indicators, greatly limits the ability to utilize more extended research.

The main conclusions of this paper are as follows:

- Proposed set of indicators offers possibility to examine relation between occurred events and cost and time efficiency of whole MCSC;
- General form of the presented indicators gives an opportunity for being suitable and sufficient at general level of MCT;
- There is a need of empirical verification of presented metrics with economic reality;
- After empirical verification there is a need for further developing indicators for being more suitable for examined MCT and MCSC.

P. Cyplik et al. (eds.), *Contemporary challenges in supply chains, Vol. 2*,
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