The Challenges of Introducing the Blockchain Technology in Logistic Chains

Ainis STURMANIS
SJSC Latvijas dzelzcels, Gogola 3,
Riga, LV-1050, Latvia

Justina HUDENKO
JSC LatRailNet, Dzirnavu 16
Riga, LV-1016, Latvia

Maris Juruss
Faculty of Engineering Economics and Management, Riga Technical University
Riga, LV-1048, Latvia

ABSTRACT

Globalization trends call for changes in the paradigm of logistic chains, creating effective interrelation links among individual countries not only by physical infrastructure, but also connecting various economies, policies, cultures, technologies etc. in a smart way.

This study investigates the minimization of transaction costs by using modern software technologies. The article has two aims. The first is to identify and to quantify transaction, transition and misalignment costs (TTM). And the second is to discuss if and how these costs can be minimized by using software technologies e.g. blockchain technology (BC).

Given insufficiencies in data collection, we quantified costs mostly for Latvian case regarding its forthcoming participation in the rail freight corridors. This study analyses four alternatives: without introducing BC, introducing public BC, introducing limited access BC, introducing hybrid BC.

Keywords: transaction costs, blockchain, logistics chain

1. INTRODUCTION

One of the most valuable aspects of the competitiveness of a logistic chain is a trade cost from one point to another. It is a sum of the costs of each logistic chain member and the transaction costs among them. Many countries are introducing open access to infrastructure and reducing financial and administrative burdens, in order to increase competition among transport and logistic companies [2]. This helps to decrease the costs of each logistic chain member; however, another financial burden appears in logistic chains in the form of transition, transaction and misalignment costs. Moreover, given the processes of globalization, the liberalization only on internal markets is not enough. No state can afford **not** to be connected with international transport corridors. Therefore, the questions of states' procedural inefficiencies such as excessive time and the cost of completing border formalities are additional obstacles that must be solved if a logistic chain is international.

There are many quotes that BC may help to track the ownership changes in real-time and to reduce transaction costs both from a company to a company and from a company to a state to their minimum. On the other hand, it is more than clear that the transition to a modern technology has many barriers – technological, managerial, organizational and social – that must fall. But it not clear whether BC can help to solve the problem of misalignment within logistic chains and whether transaction costs that would appear in BC are smaller than the existing ones.

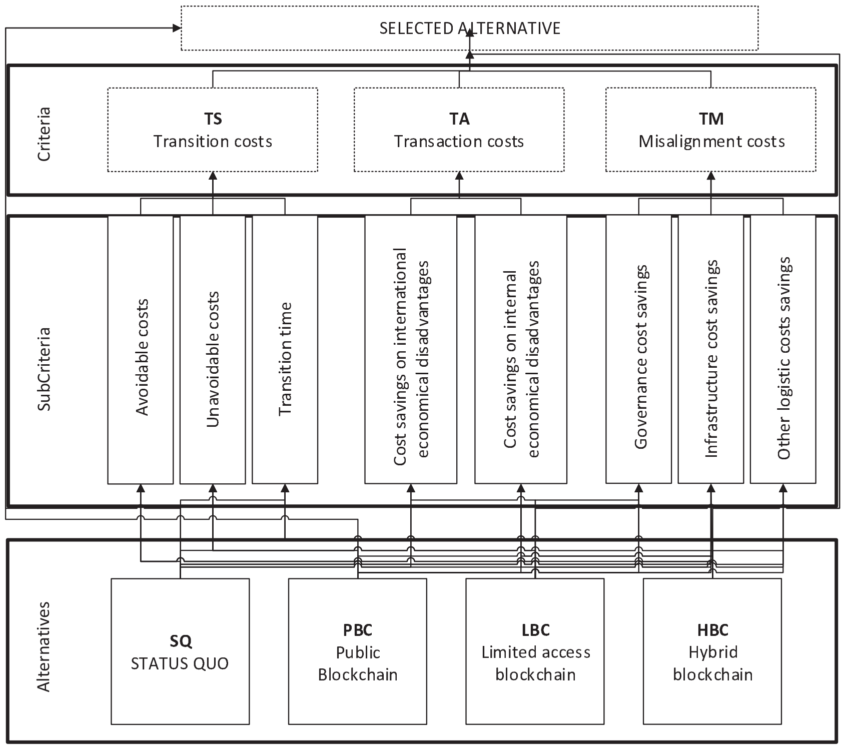
It is difficult to explore transaction costs because of their dual nature. It could be easy to observe and measure costs for writing contracts, costs for interrupted contracts and costs for organizing tenders as well as costs incurred by state to supervise the provision of a tendered service. It is also possible to collect data that occur due to a transition to a new regulation or technology, as well as to estimate misalignment costs as capacity losses. But all the data exists on each stakeholder's level and there is no existing statistics in such dimensions. Given that stakeholders have an incentive to optimize their own costs rather than the costs of the system [5] and there are still lots of market imperfections, especially in monopolized parts of logistic chains [32], it is a challenge to collect robust data. So, the first purpose of this study is to motivate practical activities to deal with the problem of transaction costs by proposing an agenda of identifying and quantifying TTM. For this reason, we reviewed the existing experience on the impact of TTM on logistic chain sustainability, and presented the generalized research questions based upon this review.

The next research problem is connected with quantifying the output from the improvement of a logistic chain. We didn't aim to examine the fiscal effects for the government but rather to investigate the total effects for the society, having in mind that higher logistic costs result in poorer economic efficiency: lower levels of foreign investment, a lower savings ratio, reduced exports of services, reduced access to technology and knowledge, and a decline in employment [3]. But each economy has its own priorities and, therefore, its own performance indicators on logistics development. Accordingly, we delimited our study to the evaluation on how the conversion of conventional business contracts into BC smart contracts eliminates TTM mostly for Latvian case of forthcoming participation in the rail freight corridors. But we trust that the presented model is general enough to be used for other modern ledger technologies developed to get logistic chain data securely to the right place, at the right time, in the right format.

To achieve the goal, we divided our study into three stages: (1) to highlight TTM in a logistic chain; (2) to understand how TTM can be minimized by BC; (3) to evaluate whether the introduction of BC is sustainable.

Figure 1

The design of selection of the alternative of using blockchain technology in a logistic chain



Source: Authors' composition

The evaluation was based on the theoretical part of the research and information available to authors about Latvian case of forthcoming participation in the rail freight corridors on non-disclosure basis. We used Saati Analytic network process method [36] to conduct comparative analysis of four possible alternatives:

- status quo (SQ);
- introducing public BC (PBC);
- introducing limited access BC (LBC);
- introducing hybrid BC (HBC).

We evaluated the criteria for the whole transition period. We put weight for each criterion guided by Latvia's usual political preferences, but the model allows to adjust state preferences (long- or short- term orientation, uncertainty avoidance etc.) for each case study in each country. The Fig. 1 presents the selection algorithm of the alternatives.

The structure of this paper derives from the structure of the study.

2. TRANSACTION, TRANSITION AND MISALIGNMENT COSTS IN LOGISTIC CHAINS

The transport infrastructure developed 30 and more years ago has become irrelevant because of changing transportation needs. Previously connected places have disappeared, and globalization trends ask for stretching routes to intercontinental lengths. The latter asks for speed acceleration and cross-border solutions (meaning both technological and data interoperability). The environment issues, that have become more and more disturbing, are shifting logistics to more environment friendly transport modes (e.g. rails and water transport) usually accompanied by less ecological but more flexible transport modes. Therefore, present logistic chains are huge complex "door to door" systems. Any rigid part in such a system may collapse the system in whole.

As a reaction to the modern challenges most open to trade countries are restructuring their transport markets in two directions. The first is a vertical separation of existing integrated companies into infrastructure companies (mostly controlled by a public entity) and undertakings (supposed to be private companies). The second is the regulation of the charging systems, where charges are limited to that proven and effective cost base or even to marginal cost level.

These initiatives may be considered successful, but they introduce transition costs, increase transaction costs and highlight existing misalignment costs.

Transition costs

Transition costs occur when political decisions on changes in the market structure result in the reallocation of one market stakeholder's (or market stakeholder group's or society's) surplus to another. Transition costs can be evaluated as very sufficient. For instance, the agreed budget of the Connecting Europe Facility instrument established by Regulation 1316/2013 allocated to transport is EUR 24.05 billion. Transitions costs may be avoidable and unavoidable:

– unavoidable ones appear with the change of production equipment and staff positions, studying and consulting costs to minimize uncertainty (e.g., environmental, behavioural, supplier-customer, competitive, strategic) [1], costs of errors (e.g. courts) that occur due to wrong interpretation of recasts;
– avoidable ones appear as efficiency losses due to the delayed (procrastinated) deregulation of a regulated monopoly or its partial deregulation.

Despite the strong position of the European Commission that promotes fast changes in infrastructure liberalisation, the avoidable transition costs exist on the European transport market because the states are usually the owners of the infrastructure, the policy-makers and the main market stakeholders at the same time. This situation creates internal contradictions in setting goals and dealing with challenges. Due to subordinate position of infrastructure managers, policy-makers based on a political document often address challenges but avoid having financial obligations for them. On the other hand, instead of perfect competition on the liberalised part of transport market, the oligopoly must be considered the usual market condition now. This happens because members of long logistic chains are not interested in competition due to the long terms of return of investment.

We observed avoidable transition costs in the Latvian seaport-rail logistic chain by means of the increasing trend of the total charge level where rail service charge level grown faster than in maritime service [32]. We concluded that the main reasons of the tendency were the wrong public infrastructure charging system and the lack of cooperation between the participants of the logistic chain. We also noted that in different EU states the effect of transition is different, but we did not find a reason of this. Hofstede's cultural dimensions theory [33] perfectly gives answers to: why a society quickly accepts what power is distributed; society's tolerance for ambiguity; society's reference for achievement; whether this achievement has long-term or short-term orientation, and; to what extent society preserves existing traditional systems. But the advanced research is needed to approve the efficiency of this theory.

Another transition problem appears on the global level. States open to trade are interested in the development of transport corridors throughout their countries. Such states are interested in the competitive advantages of their respective corridors and tend to enhance quality in several areas: providing passing capacities and harmonizing technical standards, transport law and carriage documents, simplifying the freight rate policy and norms of crossing state borders, as well as generating a reverse freight traffic flow. At the same time, such countries depend on the decisions made by other participating countries which may be less open. States build their transit policy with reference to the beneficiary from these services: if transport effects (export growth, provision with resources etc.) influence the country's economy, the state is interested in financing the infrastructure; if not, the provision of specific terms of transportation to a significant extent is motivated by the international agreements and economic relations between the states of the forwarder and the consignee with the transit country. This is extremely important for the modern transport corridors which length is measured in thousands of kilometres, while the number of states involved quite often exceeds ten.

The transition period must have its limits; so, the present value of transition costs can be estimated by using Eq.(1):

$$TS = UTS/(1+r)^{t1} + ATS/(1+r)^{t2}\,, \tag{1}$$

where:

TS - present value of transition costs;
UTS - losses in efficiency due to delayed transition of the system;
ATS - costs of breaking existing links and costs of developing new links of the system;
t1 - term of transition delay;
t2 - term of the novel link system development;
r - the return that could be earned per unit of time on an investment with similar risk

Transaction costs

Transaction costs are usually viewed as the costs to prepare, negotiate, carry out and supervise contracts, salaries and other cash payments to managerial and administrative staff, the costs for consultants and the costs for the regulatory bodies. [4] Although the role of the transaction costs remains difficult to assess, most studies examining international routing strategies consider them very sufficient [22-28]. Transaction costs are driven by market imperfections, opportunistic behaviour, information asymmetry and misalignment of transactions and governance structures [2].

The barriers in operation and management of multimodal transportation, that create transaction costs, are classified into five types:

– legal and institutional (a prior consultation system for entering a port on related business; a licensing system for getting licenses to enter a port on related business; other practices that contribute to unfair practices);
– financial and traditional (matters related to research, planning, collection, control and overview of customs duties, as well as overall tariffs);
– technological (management of the electronical systems);
– physical and institutional (traffic congestion and jams, environmental and energy concerns)
– discrimination/restrictions. [29]

Other regular transaction costs appear in logistic chains as higher operational costs because of the need for additional traffic management and data analysis. [30] The common trend nowadays is to put more and more legal restrictions and obligations to the monopolised part of the logistic chains that raises administrative costs and weakens the effectiveness of management. Therefore, transaction costs create more problems in markets with small number of stakeholders or when the public sector has a responsibility for the provision of services.

We see the relation of transaction costs in international logistic chains to the gravity model of international trade [34]. According to that, transaction costs depend on:

- the existing trade flow (the smaller it is, the greater transaction costs are needed);
- the distance (the greater distance, the greater amount of transaction costs is associated with overcoming formalities (borders, languages, legislation merging etc). and risks (piracy, transactions, commercials etc.) and;
- the economic policy efficiency, meaning, the extent the previous problem is solved.

So, the transaction costs can be evaluated by the Eq. (2):

$$TA = \sum_{i=1}^{n} MTA \frac{\beta_{1i}\beta_{2i}}{\beta_{3i}}\ , \tag{2}$$

where:

TA - transaction costs of in logistic chain with *n* involved states in the period;
MTA - marginal costs of creating contracts, salaries and other payments;
β_1 - factor that explains the economical preferences of *i* country and the extent of possibility to have alternatives;
β_2 - factor that shows legal and institutional, financial technological and other restriction burdens in the logistics costs of *i* country;
β_3 - factor that explains logistics demand from/to *i* country involved in logistic chain (i=1 for internal logistics).

Misalignment costs

Misalignment implies that the prevailing governance structure is not optimized in relation to the activities they are supposed to govern. The current market organization with its prominent level of fragmentation is an important reason for inefficiencies. [5]

In the rail-maritime logistic chains misalignment costs appear as additional maintenance and renewal costs caused by asymmetric information between the undertaking level and the system level. At the system level, the infrastructure managers are obliged to provide capacity in amount and quality they are not convinced in. Undertakings usually have no obligations for the quality of the provided information on ordered capacity. The traffic on the demonopolized infrastructures cannot be forecasted on historical data, as the demand is usually not predictable because of the market conjuncture and considerable cyclical, directional and seasonal fluctuations [30].

Our analysis of the Eurostat data on shares of commodities transported by rail in 2008 and in 2016 showed that while there is no dramatical change in the volume of traditional cargos, the volume of so-called «unidentifiable» goods is grew fast. The infrastructure managers have no idea about competitive advantages from this growing sector and cannot meet consumer needs (such as to run at a specific time; within a particular route; considering different technical and technological conditions) flexibly. This leads to the losses of the highest possible value added. [31]

The evaluation of misalignment costs in logistic chain can be executed as Eq.(3):

$$\text{TM} = \ln \sum_{i=1}^{n} (GC_i + IC_i + OC_i), \quad (3)$$

where:

TM - misalignment costs in the period;

GC - the difference between full costs of governance structures and marginal costs of governance in *i* state;

IC - the difference between full costs of infrastructure maintenance and marginal costs of infrastructure maintenance in *i* state;

OC - the difference between full costs of other logistic related costs and marginal costs of other logistic related costs in *i* state.

3. BLOCKCHAINS AND OTHER SOFTWARE LEDGERS IN LOGISTIC CHAINS

Future perspectives in terms of data collection focus on smart devices (cloud computing, smart identification technologies, sensors); smart robotic collectors (designed for capturing data in extremely special conditions); intelligent adaptive devices (machine learning and artificial intelligence technologies). The transmission of data develops as wireless communication based on advanced encryption methods. The synchronization of central and distributed network architecture performs on a human neural principle basis. Future magnetic data storage is supposed to be replaced by biological media that can keep the data by dynamic, episodic, and semantic modes and to simulate the ability of human to learn facts and relationships. The future of the processing collected data is generally assumed to be concentrated on smart cloud-based infrastructure where decision making will be implemented in self-learning and smart (inviting other models) manner. The key factors of smart decision-making are to (1) pick up precise data as a parameter; (2) figure out resolutions quickly; and (3) evaluate the results sufficiently. The data interpretation is expected in easy visualization, drag-and-drop mode with the ability of self-learning [20].

The opportunity to introduce BC as the basis of financial and commercial applications instead of existing old fashion paper procedures is investigated in many studies [9, 10, 11, 12, 13]. The adoption of foundational technologies typically happens in four phases, where each phase is defined by the novelty of the applications and the complexity of the coordination efforts needed to make them workable. These phases are the innovation trigger, the peak of inflated expectations, the trough of disillusionment, the slope of enlightenment. BC is coming to the third stage [17] when it has earned a big portion of criticism on:

- operability within existing technological systems: they have low computational power and storage capabilities, use diverse protocols and technologies that create complex and sometimes conflicting configurations [18];
- authentication and security standards - the liability from a customer data breach, property damage, data damage, loss of income due to outages and failure, website defacement etc. [15].
- understanding how BC really works - supply chain managers should begin to view the quality of the data products they depend upon for decisions in much the same way they view the quality of the products their supply chain delivers [19].
- legal and compliance issues - the behaviours of the institution are difficult to change [21].
- energy demanding [6];

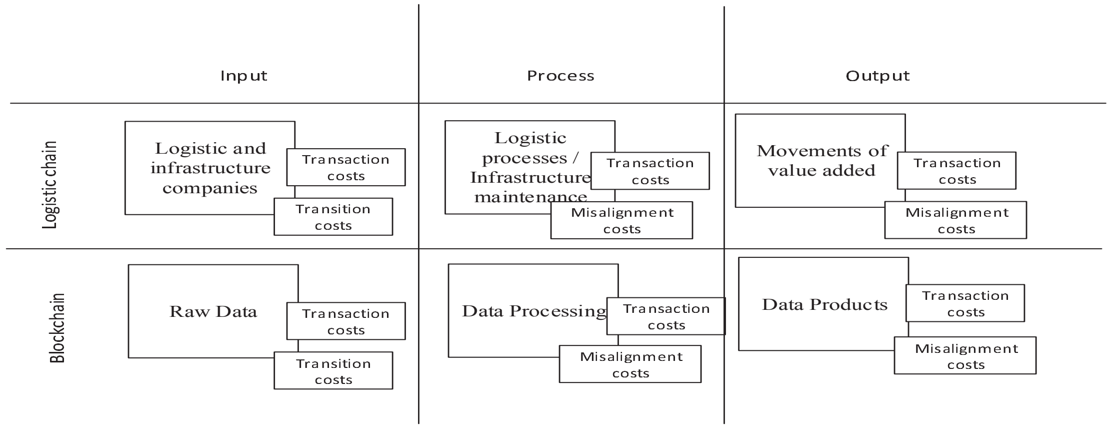
From this it could be concluded that the introduction of BC in logistics is also linked to TTM. Moreover, considering the essential importance of transport infrastructure [16] (and therefore the imperative data protection) the significance of TTM can be evaluated as influential.

Main expectations from the introduction of BC are related to the decrease or even elimination of misalignment costs by total transparency of operations when using open platform for logistic contracts. In an ideal scenario, all validating nodes would vote on the order of transactions for the next block, and logistics chains would go with what the majority decided. This expectation is also fraught with risks. Firstly, it is a possibility to get control of the network by joining with multiple identities. [18]. Secondly, the costs of using public BC are inadequate due to performance, scalability, and consistency requirements, and also due to language expressiveness that are hard to solve. Therefore, public BC should be used only in cases where decentralization and transparency are essential. In all other cases, the hybrid solutions must be used [7, 8] in combination with global technological concepts of digitalization, such as Internet of things, Big Data, Machine-to-Machine communication [16] or combining parts of the system with private or consortium BC [14].

The Fig.2, created on the basis of the analysed information shows, that existing developments in BC are far from an ideal world. The BC demonstrates TTM in all parts of logistic chains: the collection of the raw data asks for transaction costs for data mining and transition costs for creating a smart contract; data processing creats misalignment associated with the maintenance of hardware as well as transactions for authentication of recipients; the received data asks for transaction costs for its transformation to the state accepted format and misalignment with configuration and protection of the receiving hardware. Using this analogy, we concluded that TTM must be quantified for BC in a way described in the part 2 of the paper and comparative analysis of possible alternatives is needed.

Figure 2

Comparison of transaction, transition and misalignment costs in logistic chains and blockchains



Source: Authors' composition based on Wang 's et al (1995) analogy between product and data manufacturing processes [35]

Based on the comparative analysis conducted in a way described in the introduction part it was concluded that there is a need to change a status quo. In a weighted model, where the need to decrease misalignment and transaction costs was weighted stronger than the need to decrease transition costs, the hybrid BC and public BC were co-awarded as the best alternatives, the second-best result was shown by limited access BC.

Tab.1. provides the summary of the comparative analysis. The results show that the priority of the hybrid BC and public BC is not definitive, as all alternatives demonstrated weaknesses in one or two criteria. In order to improve results of the introduction of hybrid BC the simplification of implementation and operability of contracts must be invented. Main challenges of the public BC are related to decreasing risks and costs of operations.

4. CONCLUSIONS AND PROPOSALS FOR ACTIVITIES

As a result of the study, the transaction, transition and misalignment costs of logistic chains are identified and equation for their quantification is developed. We concluded that the application of BC in logistic chains results in comparable transaction, transition and misalignment costs (TTM) too.

We introduced the instrument of decision making on improving logistic chain performances and made a trial for Latvian case of forthcoming participation in the rail freight corridors. The case study showed that keeping the status quo is not more feasible. The established decision-making instrument could be easily adapted according to new developments in IT technologies or existing administrative technologies, as well as to changes in transport policy priorities in countries where a logistic chain works.

Table 1

The results of the comparative analysis of using blockchain un Latvian rail freight logistic chain

Alternatives	**Transition costs**	**Transaction costs**	**Misalignment costs**	**Weighted value**
Weight of criteria	0.1	0.5	0.4	
Status Quo	0,27	0,14	0,24	0,19
Public BC	0,20	0,25	0,34	0,28
Limited access BC	0,27	0,37	0,09	0,25
Hybrid BC	0,26	0,24	0,33	0,28

6. REFERENCES

[1] Cho, H., (2014), **Determinants and Effects of Logistics Costs in Container Ports: The Transaction Cost Economics Perspective**, The Asian Journal of Shipping and Logistics, Vol. 30(2), pp.193-215.

[2] Andersson, M., Hulten,S. (2016), **Transaction and transition costs during the deregulation of the Swedish Railway market**, Research in Transportation Economics, Vol. 59, pp 349-357.

[3] Sanchez, R.J., Hoffmann, J., Micco, A., Pizzzolitto, G.V., Sgut, M., and Wilmsmeier, G.,(2003), **Port efficiency and international trade: Port efficiency as a determinant of**

maritime transport costs, Maritime Economics & Logistics, Vol.5, pp.199-218.
[4] Merkert, R., (2010), **Changes in transaction costs over time – The case of franchised train operating firms in Britain**, Research in Transportation Economics, Vol.29., pp. 52-59.
[5] Nash, C.A., Smith, A.S.J., van de Velde, D., Mizutani, F., Uranishi, S., (2014), **Structural reforms in the railways: Incentive misalignment and cost implications,** Research in Transportation Economics, Vol.48, pp. 16-23.
[6] Vranken, H., (2017), **Sustainability of bitcoin and blockchains,** Current Opinion in Environmental Sustainability, Vol. 28, pp.1–9.
[7] Molina-Jimenez, C., Ng, I., Solaiman, E., Crowcroft, J., (2018), **On and off-Blockchain enforcement of smart contracts**, Retrieved from: https://arxiv.org/abs/1805.00626 10.05.2018
[8] Vukolic, M., (2015), **The quest for scalable blockchain fabric: Proof-of-work vs. BFT replication**, Proceedings International Workshop on Open Problems in Network Security, LNCS Vol. 9591, pp. 112–125.
[9] Underwood., S, (2016), **Blockchain beyond bitcoin,** Communications of the ACM, Vol. 59, No. 11, pp.15-17.
[10] Umeh, J., (2016), **Blockchain double bubble or double trouble?** ITNOW, Vol.58(1), pp. 58–61.
[11] Fanning, K., Centers, D.P., (2016), **Blockchain and its coming impact on financial services,** Journal of Corporate Accounting, Vol.27, pp.53-57.
[12] Yli-Huumo, J., Ko, D., Choi, S., Park, S., Smolander, K., (2016) **Where is current research on blockchain technology? A systematic review,** Public Library of Science, Retrieved from: http://dx.doi.org/10.1371/journal.pone.0163477, 01.05.2018.
[13] Bit Fury Group, Garzik, J. (2015) **Public Versus Private Blockchains — Part 1: Permissioned Blockchains**. White Paper. Retrieved from: http://bitfury. com/content/5-white-papers-research/public-vs-private-pt1-1. pdf., 01.05.2018
[14] Zheng, Z., Xie, S., Dai, H., Chen, X., Wang, H., (2017) **An overview of blockchain technology: architecture, consensus, and future trends**. Proceedings of 6th IEEE International Congress on Big Data. Retrieved from: https://ieeexplore.ieee.org/document/8029379/, 01.05.2018
[15] Ezell, B.C., Robinson, R.M., Foytik, P., Jordan, C., Flanagan, D., (2013), **Cyber risk to transportation, industrial control systems, and traffic signal controllers.** Environment Systems and Decisions, Vol. 33, pp. 508-516.
[16] Tokody, D., Tor, M., Szucs, E., Flammini, F., Barna, L., (2018), **On the development of intelligent railway information and safety systems: an overview of current research**, Interdisciplinary Description of Complex Systems, Vol.16(1), pp.176-185.
[17] Panetta, K., Top Trends in the Gartner Hype Cycle for Emerging Technologies, Retrieved from: http://www.gartner.com/smarterwithgartner/top-trends-in-the-gartner-hype-cycle-for-emerging-technologies-2017, on 15.08.2017.
[18] Christidis, K., Devetsikiotis, M., (2016) **Blockchains and Smart Contracts for the Internet of Things**, Retrieved from: https://ieeexplore.ieee.org/document/7467408/ on 01.05.2018.
[19] Hazen, B.T., Boone, Ch.A., Ezell, J.D., Jones-Farmer, L.A., (2014), **Data quality for data science, predictive analytics, and big data in supply chain management: An introduction to the problem and suggestions for research and applications**, International Journal of Production Economics, Elsevier, Vol.154(C), pp. 72-80.
[20] Zhong, R.Y., Newmanb, S.T., Huang G.Q., Lan, Sh., (2016), **Big Data for supply chain management in the service and manufacturing sectors: Challenges, opportunities, and future perspectives.** Computers & Industrial Engineering, Vol. 101, pp.572–591.
[21] DiMaggio, P. J., Powell, W. W. (1983). **The iron cage revisited: Institutional isomorphism and collective rationality in organizational fields**. American Sociological Review, Vol.48(2), pp.147–160.
[22] Mourao, M.C., Pato, M.V., Paixao, A.C., (2002). **Ship assignment with hub and spoke constraints,** Maritime Policy and Management, Vol.29 (2), pp. 135–150.
[23] Zeng, Z.B., Yang, Z., (2002), **Dynamic programming of port position and scale in the hierarchised container ports network**. Maritime Policy and Management, Vol.29 (2), pp.163–177.
[24] Luo, M., Grigalunas, T., (2003), **A spatial-economic multimodal transportation simulation model for US coastal container ports**. Maritime Economics and Logistics, Vol. 5, pp.158–178.
[25] Trujillo, L., Tovar, B., (2007), **The European port industry: an analysis of its economic efficiency**, Maritime Economics and Logistics, Vol.9(2), pp.148–171.
[26] Anderson, C.M., Park, Y.A., Chang, Y.T., Yang, C.H., Lee, T.W., Luo, M., (2008), **A game theoretic analysis of competition among container port hubs: the case of Busan and Shanghai**. Maritime Policy and Management. Vol. 35 (1), pp.5–26.
[27] De Langen, P.W., (2002), **Clustering and performance. The case of maritime clustering in The Netherlands**, Maritime Policy and Management, Vol.29, pp.209–221
[28] Lam, J.S.L., (2011), **Patterns of maritime supply chains: slot capacity analysis,** Journal of Transport Geography, Vol. 19(2), pp.366–374.
[29] Lovea, P.E.D., Zhou, J., Matthews, J., Lavender, M., (2018), **Managing rail infrastructure for a digital future: Future-proofing of asset information**, Transportation Research Part A, Vol.110, pp.161–176.
[30] Hudenko, J., Ribakova, N., Počs, R., (2016), **Cost that is Directly Incurred as a Result of Operating the Train Service on the 1520 mm Rail with Primarily Freight Transportation.** Transportation Research Procedia, 2016, Vol.14, 1914.-1922.lpp.
[31] Andiņš, M., Hudenko, J., (2017), **The Distinction of Market Segments on the European 1520 mm Rail with Primarily Freight Transportation**. No: The 21st World Multi-Conference on Systemics, Cybernetics and Informatics (WMSCI 2017): Proceedings. Vol.2, 1.-6.lpp.
[32] Hudenko, J., Počs, R., (2015), **The Discrepancy between the Service Export Incomes of Rail and Sea Transport among Baltic States Transit Corridors**. No: The 19th World Multi-Conference on Systemics, Cybernetics and Informatics (WMSCI 2015): Proceedings. Vol.1, 63.-68.lpp.
[33] Hofstede, G., (2001), **Culture's Consequences: comparing values, behaviors, institutions, and organizations across nations** (2nd ed.). Thousand Oaks, CA: SAGE Publications.
[34] Isard, W., (1954), **Location Theory and Trade Theory: Short-Run Analysis,** Quarterly Journal of Economics. Vol.68 (2), pp. 305–322.
[35] Wang, R.Y., Storey, V.C., Firth, C.P., (1995). **A framework for analysis of data quality research.** IEEE Transactions on Knowledge and Data Engineering, Vol. 7(4), pp. 623 - 640.
[36] Saaty, T., (2005), **Theory and Applications of the Analytic Network Process**. Pittsburgh: RWS Publications.