IDENTIFICATION OF SOURCES OF KNOWLEDGE ABOUT DISRUPTIONS IN INTERMODAL TRANSPORT

Marzena KRAMARZ[1*], Edyta PRZYBYLSKA[2]

[1] Silesian University of Technology, Zabrze, mkramarz@polsl.pl, ORCID: 0000-0003-0619-5809
[2] Silesian University of Technology, Zabrze, eprzybylska@polsl.pl, ORCID: 0000-0002-9475-5927
* Correspondence author

Abstract: Intermodal transport networks, as examples of business networks created in supply chains, are differentiated not only due to types of key resources in the organization, but also due to such things as network structure, the nature of the organizations involved, the types of relations they have, and the roles of individual actors in the network. The business network is understood as a dynamic system whose configuration depends on the fulfilment of particular tasks and the competencies of the organizations which form them. Such networks are inherently temporary, because a new task can initiate the creation of completely new inter-organizational bonds or change the type of pre-existing relations between network nodes. The cooperation of enterprises in a freight transport network compels one to look at the problem of knowledge management in a wider context. The paper focuses on the first stage of knowledge management, which is knowledge acquisition in an organization and its environment. The paper presents the idea of gathering knowledge, and identification of the sources of disruptions in an intermodal network.

Keywords: intermodal transport, disruptions, logistic network.

1. Introduction

Contemporary European transport policy definitely stresses the necessity to develop inter-branch and balanced transport systems. These guidelines include intermodal transport, which involves transporting loads in one invariable loading unit on the entire transport route, using mainly those branches of transport which generate smaller external costs. However, achieving intermodal transport requires commitment from many entities and the creation of an interorganizational transport network. Such interrelations may consist of not only competition, but also collaboration between entities to determine the success and realization of planned activities and assumed aims. However, the considerable complexity of intermodal transport networks makes them susceptible to disruptions at different stages of material flows. These disruptions can vary in nature, impact and origin, and can be generated by every participant in the network. Due to the significant influence on the reliability of realized flows, it is essential to gain knowledge about disruptions in order to allow networks to establish a resilience to them. In connection with the above, this paper aims to design a model of managing knowledge about disruptions in intermodal transport networks. In order to achieve such a goal, three detailed exploratory questions were assumed:

- What disruptions are characteristic for intermodal transport networks?
- What are the sources of disruptions in intermodal transport networks?
- Which actors of the network should be included in a disruption monitoring system?

Obtaining answers to the above research questions and fulfilling the assumed objective will allow further research into the resilience of intermodal transport networks.

2. Interorganizational networks in intermodal transport

For decades management sciences have been leading investigations into the nature of interorganizational networks. They are defined as networks of enterprises, economic networks or business networks (Kawa, 2013, p. 77). The literature broadly described the reasons for, and potential advantages obtained from functioning within networks. However, a consensus emerged that an organization's results are no longer able to be based only on the internal resources and possibilities of an enterprise, but they have to be widely based on resource flows and relations to other entities in the market (Centenaro, Guedes Laimer, 2017, p. 66). Consequently, the network approach changes the field of exploration by shifting the source of the competitive advantage from the inside of an organization to the outside of it, and there it focuses on single network links, their relations, and adopted methods of cooperation or organization (Czakon, 2015, p. 11). Referring to the above statements, according to W. Czakon (2015, p. 11), the expression of attained superiority due to its functioning in the network could be called a network pension, and treated as a definite distinguishing characteristic trait of the network.

"Network" is a key notion in the network approach, and it means a number of units connected within a system of many different connections (Guzdek, 2016, p. 193); it is a set of actors connected by a set of bonds (Czakon, 2012, p. 15); it is a specific form of connections among entities, based on correlations, cooperation and confidence (Antonowicz, 2016, p. 76). According to the IMP Group (The Industrial Marketing and Purchasing Group), a network is a set of long-term formal and informal (direct and indirect) connections (relations) which appear between two or more entities (Kawa, 2013, p. 77). In another study, A. Kawa and B. Pierański (2015, pp. 24-25) stress that an interorganizational network is formed by at least three independent entities and the bonds appearing among them. However, A. Buttery and E. Buttery (1994, p. 17) indicate two or more organizations connected with relations which influence all participants of the network. Supply networks are a type of network where material flows play a key role. They are defined as: "a system built from nodes cooperating with one another in order to increase the geographical range of influence, market penetration, activity diversification, and an increase in the innovativeness of the offered products and services" (Kramarz, Kramarz, 2015, p. 61).

In connection with the fact that the functioning of interorganizational networks has become a characteristic trait of any contemporary economy, it must be stressed that network activity is performed by enterprises representing different kinds of business activity in the market. An example is a transport business represented by different branches, concerning both passenger and freight transport. In connection with the above, it is essential to define the notion of a "transport network". The literature most frequently presents this it through the prism of connections in the form of roads, railway lines, or air links within a punctual infrastructure (Kawa, 2013, p. 333). Also, D. Bernacki (2012, p. 674) identifies transport networks with sets of transport units and transport connections appearing among them in the form of transport routes. However, in the presented depiction, a transport network is not understood as compatible with the network approach known from management sciences.

In this paper, transport networks will be identified as groups of entities connected to one another by formal and informal relations. These can have vertical and horizontal connections. The former concern enterprises interrelated in the "supplier-recipient" relation. Flows occurring between them mainly concern objects and information, thus creating a supply chain. The latter concern entities which represent the same business activity, offer the same or similar products on the market, but participate in different supply chains (Kawa, 2013, p. 335). D. Ford and S. Mouzas (2013, p. 436) stress the significance of relations in established interorganizational networks. Firstly, they indicate that they cause a decrease in the separation of entities in the network. Moreover, they treat relations as primary assets, such as financial or physical ones, which are also valuable to the economic entity. Additional relations have a considerable influence on the activation and development of performed activities and possessed resources. J. Rześny-Cieplińska (2010, pp. 226-227) treat transport business enterprises building networks as a form of adopted strategy for creating competitiveness in the market. Moreover, in her opinion, networks within which transport enterprises perform activity should be classified according to several criteria, for instance: property, participation conditions, the scope of activity, and the type of activity. In the context of the last criterion attention should be paid to the significant number of different networks to be formed. They are, for example, networks built within a given transport branch or their combination. Consequently, there appears an idea of intermodal transport networks as part of contemporary transport policy, which stresses the necessity to build an integrated and balanced multi-branch transport system. Again, attention should be paid to defining an intermodal transport network not concurrent with the approach in management sciences. M. Janic (2007, pp. 33-34) defines an intermodal transport network as a set of nodes of intermodal character together with flows of consolidated loads appearing among them, such as containers, exchangeable semitrailers or bodywork, involving the utilization of at least two branches of transport. The main participants of such a network are supposed to be: senders and recipients of loads, operators of trans-shipping terminals, and transport enterprises which physically realize transport as part of different branches of transport. However, similarly to transport networks, this paper looks at intermodal transport networks of a different nature, taking into account the building of interorganizational networks based on horizontal relations between units. In such a depiction, an intermodal transport network will be defined as a set of entities representing a widely understood branch of intermodal transport together with the relations appearing among them. These entities will in practice be connected with different branches of transport used in freight traffic (road, railway, inland navigation, sea, air freight). In such a network the leading actors will be: forwarding agencies (in individual branches of transport), transport forwarders, including intermodal transport (within different transport relations, e.g. road-railway), logistics operators offering full service of loads, also taking into account transport tasks, operators of intermodal terminals (railway, sea, air and inland waterway terminals), and administrators of linear infrastructure or customs agencies.

The notions of networks, supply networks, transport networks, and intermodal transport networks introduced in this part of the paper, compatible with the network approach in management sciences and their relationships, are presented in Figure 1. Supply networks are the broadest context for analyzing relationships for material flows. Within them, various supply chain configurations can be identified (Fig. 1). In addition, it must be noted that transport networks are interorganizational relationships offering activity for various configurations of supply chains appearing in practice. This is connected with the complementary part of transport service visible in every branch and at each level of the load flow in supply chains. It is different with constructed networks of intermodal transport, which firstly do not have to fulfil their own role for each supply chain, and secondly do not complete their task at all levels of the flow. What is meant here are mainly deliveries to the final customer, identified as the consumer, which enter into the scope of functions and issues of so-called last mile freight. Intermodal transport is not used in it.

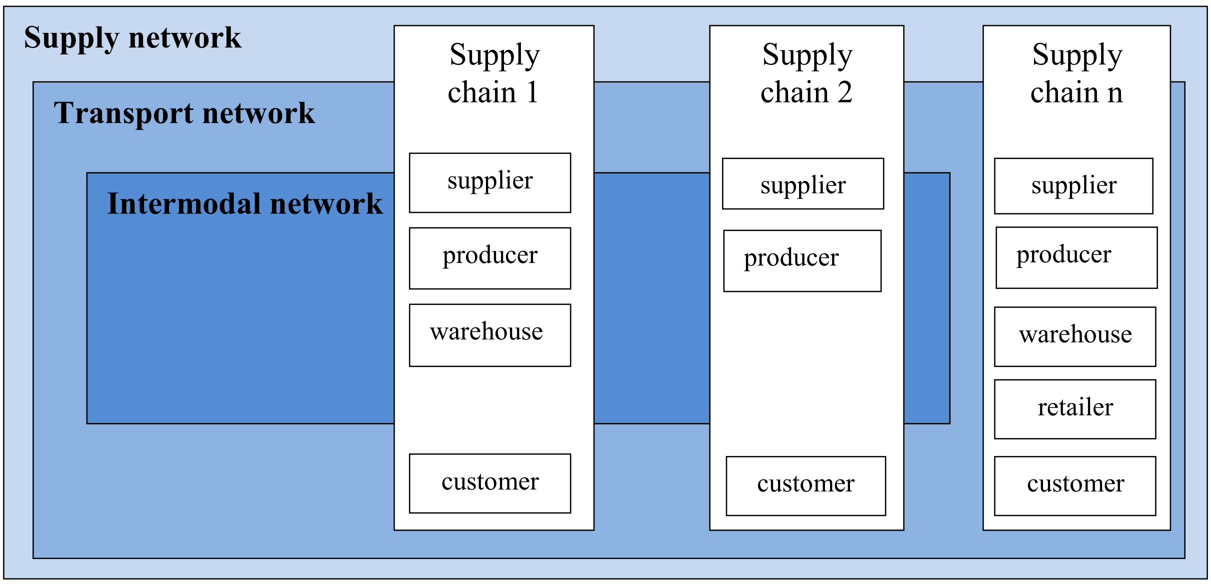

Figure 1. A transport network versus an intermodal transport network. Source: authors' study.

The activity of contemporary transport markets, including especially of the intermodal character, requires close co-operation and partnership among haulage operators, and with other entities participating in the process of transport and logistics service. The necessity to provide customers with complex services at high quality level involves building transport networks which consist of various entities. Their mutual collaboration allows full co-ordination and the improvement of material and informational flows (Antonowicz, 2011, p. 14). The contemporary transport market is global in nature, represented by enterprises with different capital whose range is international. It is a challenge for building collaborative networks due to the considerable complexity of managing such an international network. This is associated with cultural differences and business practices in individual countries where network participants come from (Guzdek, 2016, p. 196). Also, W. Downar (2010, p. 103) stresses the enormous complexity, multi-agent approach, organizational variety and strong external and internal connections in transport activity. Consequently, it requires interactions between organizations which are directly or indirectly connected with offering transport services. The complexity of the process of providing the customer with value demands a new approach to transport management. One of its guidelines is to build permanent, formal or informal relations based on collaboration and confidence. Especially small and average enterprises, representing the same segment, build collaborative networks in order to increase their own competitiveness in the market. This is associated with access to external partners' resources (Centenaro, Guedes Laimer, 2017, pp. 66, 69-70), and replacing or supplementing competitive relations with those based on collaboration.

M. Antonowicz (2016, p. 77) defines intermodal transport as a service system and characterized as the collaboration, cooperation and partnership of all entities participating in the service regardless of the number of chain links involved. These entities have a various character. They are inter-related by long-term relations, add values to the transport as part of their activity, and often take the role of suppliers and recipients in relation to one another. The network approach towards intermodal transport assumes that the organizational results are no longer based only on the internal resources and possibilities of an enterprise, but largely on the relations and flows of resources which the enterprise has with other entities in the market. C. Theys, W. Dullaert and T. Notteboom (2008, pp. 1-37) indicate that the success of the development and realization of intermodal transport is strictly connected to the ability to combine loads and coordinate different activities, branches and entities within the intermodal chain. They stress that a multi-branch and multi-agent approach of intermodal transport calls for building collaborative networks of the involved parties. Simultaneously, in their opinion, it is essential to motivate entities to start collaboration within their networks. They refer to costs, which require that the participation of individual entities in collaboration will not cost more than their individual work. They propose using the potential of cooperative game theory for collaborative network analysis within intermodal transport with regard to fair cost sharing among the involved parties. The necessity to collaborate instead of compete in intermodal transport is also stressed by A. Febrarro (2016, pp. 84-85), who indicates the possibility to exchange real-time information with the use of intelligent transport systems as an advantage of collaborative networks, and notes that the possible supplementary cost resulting from the collaboration of entities can be compensated for by the reduction of storage and waiting time for loading/unloading, or the loading/unloading operation itself.

Also, the literature indicates building intermodal transport networks as a way to reduce external transport costs referring to the negative impact on the natural environment. It is hoped that an efficiently built network will be a chance for the fulfilment of the idea of balanced cities, regions or countries (Yamada, et al., 2009, p. 129). A. Centenaro and C. Guedes Laimer (2017, pp. 66, 69-70) ascribe a special advantage functioning in a network to the possibility of increasing their own competitiveness in the market, which mainly concerns small and average enterprises. Apart from the environmental aspects, they include, for instance: the possibility to reduce transport costs, to improve the quality of transport, an increase in market share, or reduction of the risk connected with performed activities (Serrano-Hernández, at al., 2017, p. 398).

The key role in an intermodal transport network is played by enterprises representing nodes in the form of intermodal terminals; their location, served branches of transport and connections appearing among them are indicated (Munima, Haralambides, p. 89). A similar opinion in relation to the significance of operators of terminals in networks was introduced by R. Šakalys and N. Batarlienė (2017, p. 282). They especially focused on the necessity to synchronize the activities of terminals with respect to place and time. Moreover, they stress the necessity of close coordination of operations among all the involved entities, especially including of the linear and point infrastructure and transport operators. M. Antonowicz (2011, p. 14) also focuses on the part of the infrastructure (mainly including terminals, logistic centres, ports) which is an instrument for creating conditions for concentrating entities interested in offering transport services and providing patency and efficiency of realized flows in the network.

Bearing in mind the indicated conditions of intermodal transport networks, this paper focuses on the issue of disruptions appearing in material flows in such a network.

3. Disruptions and managing knowledge about disruptions in supply chain and transport networks

Disruptions in supply chains are defined as unexpected events which slow down or stop material flows between organizations participating in manufacturing and delivering goods and services (Schmitt, Singh, 2012, pp. 22-32). Y. Sheffi (2005) notes that every type of disruption requires other activities, so, depending on key risk factors, prevention can vary. Sheffi (2005), while investigating ways in which enterprises can respond to strong disruptions and conduct activities reducing threats connected with disruptions, claimed that:

- Reduction of bottlenecks connected with disruptions occurs through monitoring, early-warning systems (an increase in the sensitivity of a supply chain), and quick reaction to the change of needs, collaboration and redundance;
- operating flexibility is increased through standardization of parts, facilitating their replaceability (product modularity, product designing from the logistics perspective), the postponed production strategy or mass customization of products (multi-variant approach) in response to changes of needs which are difficult to forecast, management of relations with customers and suppliers.

These approaches are an answer to identified disruptions, including their type, frequency and effects, and aim to increase the resilience of the entire system. The effects of disruptions in intermodal transport is a deterioration of the reliability indicators, i.e. certainty, completeness and punctuality of fulfilled transport processes. Gaining and gathering information about disruptions and then processing this information into knowledge which is distributed among the network participants is becoming an essential element of managing the entire intermodal transport network. Gaining, gathering, processing and making knowledge available are elements of knowledge management systems (Chung-Jeng, Jing-Veins, 2007, pp. 104-118).

Regardless of the scope of the knowledge gathered in the network, it is essential to make a distinction between data, information, and knowledge. The idea of imperfect knowledge takes into account inaccuracies, ambiguities, incompleteness, contradictions and untruths from each of the elements of the knowledge pyramid (Krause, Clark, 1993, pp. 3-9; Ackoff, 1989, pp. 3-9). As stressed by Bukowski (2016), data consisting of signs and symbols, recorded, processed and sent, have themselves neither particular meaning nor utility. Only their interpretation decides their value. The information which is a set of sorted, processed, well-ordered data, presented in a form which can be useful for the recipient, has a subjective character because it depends not only on data, but also on the process of their interpretation (Bukowski, 2016; Skyttner, 2008). Knowledge comes into being by integrating new information with the existing knowledge concerning a given area of interest, and requires an ability to assess the available information and understand the reality in light of the available information (Janiszewski, Labroo, Rucker, 2016, pp. 200-208). The skill of effective utilization of the possessed knowledge and experience is defined as wisdom. In this understanding, Table 1 presents an interpretation of individual elements of the knowledge pyramid for disruptions in material flows.

Table 1.
An interpretation of elements of the knowledge pyramid in management of knowledge about disruption

Elements of the pyramid knowledge	Interpretation for disruptions in material flows
Data	Disrupting factors, deviations in material flows
Information	Who is accountable for disruptions? Where do disruptions arise and where are their effects? How often do individual disruptions appear? Which factors strengthen disruptions?
Knowledge	Cause and effect relations between particular disruptions (their force and frequency) and effects (including organizational and financial ones). How were disruptions counteracted? What were the reactions to the effects of disruptions? Which disruptions pose a threat to the reliability of the realized logistic processes? Which activities should be taken to limit the effects of individual types of disruptions? With which force do factors strengthening disruptions affect the effects of disruptions?
Wisdom	What are the effects of using a particular strategy of strengthening the resilience in a given supply chain? What decides about its strong and weak aspects? What is a chance and what a threat?

Source: authors' study.

According to the above-mentioned elements of the knowledge pyramid, knowledge acquisition in intermodal transport networks should combine that found in individual chain links and the existing data, which are then merged to supply a base of knowledge about potential disruptions in intermodal transport networks (Kyriakou, Nickerson, Sabnis, 2017, pp. 315-324). Such knowledge is the basis for risk management in transport networks. The paper defines a transport risk as the probability of an occurrence of an undesirable event which can bring about loss or harm in the object of translocation (risk in the understanding of flow safety), or unpunctual or incomplete fulfilment of an order (in the understanding of network resilience).

This problem is even wider when we look at the system from the perspective of a supply network in which different supply chains work simultaneously, aided by the same transport network. Then the system for managing knowledge about disruptions should be supplied with knowledge about disruptions generated at the level of individual participants of supply chains. These include suppliers, manufacturers, chain links, distribution channels and even final customers. This variant was not taken into account in the conception presented in this paper.

Resistant transport systems are networks which allow reliable fulfilment of transport processes with the utilization of alternative routes in situations when disruptions appear. W. Burgholzer, G. Bauer, M. Poset, and W. Jammernegg (2013, pp. 1580-1586) noted that when planning a transport network, it is essential to identify bottlenecks and design mechanisms for compensating for disruptions. According to them, knowledge about the effects of potential disruptions is precious for decision-making support for the developers of transport projects in order to make them less susceptible and more attractive to all of their users.

Measurement of disruptions and maximization of resilience in intermodal transport networks were also the subject of research by E. Miller-Hooks, X. Zhang and R. Faturechi (2012, pp. 1633-1643), who, when building their model of optimum resilience, identified the resilience determinants of transport networks. While building a stochastic model, they took into account the location of container terminals. A similar direction of research into intermodal transport networks was chosen by M. Francesco, M. Lai, and P. Zuddas, (2013, pp. 827-837) when also designing a stochastic model. However, they focused their attention on other nodes of the intermodal transport network: ports. Based on the designed model, they created scenarios of material flows in intermodal transport networks.

In the above-mentioned publications researchers identify sources of interference, or sources of risk, in intermodal transport networks. Their analysis allows for a separation of potential disruptions in intermodal transport networks. Therefore, risk in transport processes can be associated with:

- wrong decisions caused by false, unreliable, insufficient and irregular information;
- negligence, ignorance or non-observance of regulations and appointed procedures connected with required documents, binding duties of a haulage operator, the human factor;
- technical factors;
- random factors.

Freight transport is particularly connected with the possibility of threat to goods, damage or loss, which in practice causes a decrease in the safety of material flows. This threat frequently results from the incompetence of the transport enterprise, and more precisely an incompetent, irresponsible worker who allows such threats during the transportation of a commodity. Threats affecting a decrease in safety during the transportation of an entrusted commodity arise through endogenous factors and the influence of the external environment on the transported commodity. Particularly, attention must be paid to such elements as (Romanov, Stajniak, Konecka, 2017, pp. 620-624):

- the technical state of a vehicle;
- the suitable protection of shipment;
- the technical state of roads;
- the driver's skills.

Increasing the security level in transport is influenced by legal regulations. They especially concern the maximum period a vehicle can be driven non-stop, and the frequency and length of pauses in driving. Safety is also directly influenced by: observance of traffic rules, a high culture of driving, maintaining a good physical condition, i.e. eating properly and regularly, valuable rest during pauses in driving.

Potential sources of disruptions, identified in this part of the paper, were described in detail in pilot research, which concerned two subnets of intermodal transport in Poland. The notion of a "subnet” was adopted here in consideration of their fragmentary character in relation to the entire intermodal transport network of working in Poland.

4. Disruptions in intermodal transport based on the example of the Polish intermodal network

Intermodal transport in Poland still has only a slight participation in the structure of freight traffic, yet systematically it is gaining importance. Striving for further development of this idea of transport requires a focus on disruptions which appear in the Polish intermodal transport network. Intermodal transport operations are highly complex and involve a great number of transport service entities. This requires a considerable level of collaboration of the involved enterprises and a high level of operational co-ordination.

Disruptions presented in the paper were identified on the basis of the pilot research for two main subnets functioning within train transport (trans-shipment of containers) and road and sea transport (ferry crossings). Disruptions are separately described in Tables 2 and 3. The former presents disruptions connected with the segment of intermodal transport networks involving strict cooperation between Polish and international operators of train transport together with operators of trans-shipping terminals which form a supranational intermodal network. This network additionally involves numerous road haulage operators, other operators of trans-shipping terminals, and operators and shipowners connected with maritime transport. The entity responsible for organization and management in this type of transport is the network logistic operator, which is a leading intermodal operator which does not realize transport tasks independently.

Table 2.
Disruptions in the Polish intermodal transport network using railway transport

No.	Name	Explanation	Responsible entity
1.	Lack of capacity of the railway line	Connected with poor condition of the railway infrastructure; with lack of a sufficient number of additional tracks at stations to allow passage on one-track lines; emergency locks on some sections of railway lines, especially during night hours; maladjustment of access tracks to European parameters; infrastructure repairs	Administrator of the railway infrastructure
2.	Low priority of container depots in prepared time-tables	Necessity to let all kinds of passenger trailers go first; possible additional decrease in priority in emergency situations	Administrator of the railway infrastructure
3.	Insufficient space on destination railway stations	Small number of additional tracks for stops of train sets awaiting further delivery – necessity to stop train sets on previous railway stations	Administrator of the railway infrastructure
4.	Failure of railway traffic management devices	Infrastructure managers do not comply with the rules regarding the ongoing maintenance and control of relay traffic control devices. The problem appears both at railway stations and on railway lines, which results in a lack of transport safety, and delays.	Administrator of the railway infrastructure
5.	Waiting for taking over train sets between haulage operators of the train transport	Problems with planning, connected with lack of required resources (e.g. engines), cause long waiting time despite earlier train set notification	Railway transport operators

Cont. table 2.

6.	Extended time of shunting works connected with changing engines	Waiting for another engine causes prolonged stoppages at the change station, and the priority falls on the entire train set at further sections of the route	Railway transport operators
7.	Lack of engines at the transfer station	Results from errors in planning and delays	Railway transport operators
8.	Delayed train set from abroad	Caused by many reasons, e.g. lack of engines, lack of staff, loading delays, etc.	Railway transport operators
9.	Waiting for cars	Waiting for groups of cars coming from other terminals to be coupled to the main set	Railway transport operators
10.	Staff problems	Lack of traction team (e.g. no engine driver); lack of authorization on a particular type of engine; lack of knowledge about the route	Railway transport operators
11.	Failures of cars	Regular inspection for incorrectness in the used means of transport	Railway transport operators
12.	Failures of engines	Regular inspection for incorrectness in the used means of transport	Railway transport operators
13.	Lack of an auditor	Lack of a person responsible for technical inspection, inspection of the train set to check its conformity with documentation	Railway transport operators
14.	Lack of the planned train in the SEPE system	The train will not start because it is not visible to the traffic controller and other staff members	Railway transport operators
15.	Damage to containers	The terminal can refuse to accept the train set for trans-shipment and further transport in connection with defects	Operator of trans-shipping terminal/ road haulage operators/railway transport operators
16.	Long and delayed train loading	Despite notification the haulage operator must wait for completion of loading/unloading	Operator of trans-shipping terminal
17	Delays in preparing documentation	Necessity to wait for the delivery of required documentation	Operator of trans-shipping terminal
18.	Weather conditions	Climatic influence is unpredictable, independent from network participants	None

Source: authors' study.

The disruptions indicated in the table do not exhaust the list of all possible disruptions. However, they are key events which appear in the analysed segment of the intermodal transport network. Additionally, disruptions appearing at other levels of the network should also be indicated, e.g. collaboration of road transport entities with operators of trans-shipping terminals and with operators of train transport and with maritime transport operators, etc. Nevertheless, this is not the subject of analysis in this study.

Another example of an intermodal transport subnet analysed from the perspective of disruptions is the collaboration of entities in road and ferry deliveries. This type of activity involves the transportation of loads via road transport to the seaport, followed by trans-shipment of the road conveyance by ferry and, at the last stage, road transport to the recipient. This network consists of: road transport enterprises (forwarding and transport), logistics operators, customs agencies, operators of seaports, and maritime transport shipowners. The identified disruptions are presented in Table 3.

Table 3.

Disruptions in a Polish intermodal transport network with the utilization of road-and-ferry transport

No.	Name	Explanation	Responsible entity
1.	Congestion	The problem of road congestion is still growing, and is additionally a phenomenon which is difficult to predict regarding place and time	Lack
2	Incompatibilities of commodity at loading	Connected with loading too small/too big loads, or loading the wrong commodity. It results in, e.g. delays due to changing of loaded products	Road forwarding/ logistics operator or operators of embarkation points
3.	Incorrectly planned shipment time	Caused by planning the shipment time without regard to the appearance of possible random events	Road forwarding
4.	Lengthened time of waiting for loading	Delays generated in embarkation points despite earlier notification	Operators of embarkation points/ logistics operators
5.	Failures of transport equipment	Regular inspections for faultiness in the used means of transport;	Road haulage operators
6.	Legal problems regarding the driver's working time (e.g. necessity to realize a weekend pause)	Regulations connected with the driver's working time strongly affect the time and punctuality of transport. Transport tasks are planned regarding the working period. However, problems occur, e.g. congestion, which cannot be foreseen, and yet they affect the time of individual activities and consequently lengthen the time of the transport process. Consequently, they affect the available drivers, and the possible working period to be used	Road haulage operators/ road forwarding
7.	Low frequency of ferry crossings on a given line	It results in a decrease in transport flexibility. Moreover, a possible delay for the ferry check-in causes considerable unpunctuality and prolongs the delivery time	Maritime transport operators
8	Driver's working time – lack of possibility to turn the driver's daily pause during ferry crossing	The driver's working time is limited, so it is difficult to synchronize it with the ferry crossing time. There is an alternative solution thanks to which the driver can take the driver's daily pause during the ferry crossing provided it is started while waiting for the crossing in the port. This option is used primarily when the crossing lasts less than 12 hours and when the diel pause should start before the starting time of the crossing beginning	Road forwarding
9.	Duration of ferry crossing	Time is differentiated and depends on the line. Due to the nature of maritime transport, the transport time is relatively long compared to other branches of transport	Largely, disruption of this type results from the nature of maritime transport; however, the directly responsible entities are sea-operators
10.	Cancellation of the ferry crossing	Results mainly from the appearance of inadequate weather conditions	Maritime transport operators
11.	Border check – transport documents	Long waiting time for customs agencies to accept transport documents	Customs agencies
12.	Border check – low availability	Limited opening hours of customs agencies causes a frequent necessity to postpone the border check to the next day	Customs agencies

Source: authors' study.

Similar to the case of Table 2, the list of disruptions indicated in Table 3 is not complete. Further analyses and enlargement of research will allow the supplementation of the list of disruptions both for the presented intermodal transport subnets and other networks not taken into account in the paper.

5. The model of managing knowledge about disruptions in intermodal transport

Consequence plays a very crucial role in the identification of disruptions. It allows for the categorization of all the essential disruptions and threats, and for defining the classes of risks resulting from them. Therefore, it is advised to use different methods which supplement and verify one another. Compelling organizations in a collaborative transport network to share their knowledge is definitely the most difficult obstacle to building a system for managing disruptions in intermodal networks. It requires formalized methods to gain knowledge from commercial and logistic partners, as well as qualitative methods activating the acquisition of secret knowledge. The organization coordinating material flows must possess tools adequate for methods of gaining both open and secret knowledge. Moreover, it is essential to design a methodology of acquiring data, and then converted it into knowledge about disruptions in individual nodes of the supply chain. Organizations usually accumulate data exclusively about deviations in material flows which result from disruptions. Only a certain number of organizations convert those data into information about where and why deviations occur. Both this information and the unprocessed data should be accumulated in one network node.

Disruption studies that take into account disruption management problems, resilience and recovery of freight transport networks, focus on long-term strategic assessments that concern responsiveness to bombs, terrorist attacks, floods, earthquakes and terminal attacks (Serrano-Hernández, Juan, Faulin, Perez-Bernabeu, 2017; Sheffi, 2005). Only a limited number of studies consider the operational level, such as (Skyttner, 2008) who provides a disruption management method while considering road disruptions and their estimated duration (Ambra, Caris, Macharis, 2019, p. 3). Identification of disruptions should occur in real time, so it is necessary to supplement the measurement performed by a computer science system with diary research. The data obtained as a result of the diary research in the chain link where they were recorded should be converted into information on disruptions available for other network nodes. As shown by investigations, computer science systems sometimes tend to record deviations in material flows, ineffectively classifying them to particular sources of disruptions. However, such a connection is necessary in the knowledge base. Disruptions should be recorded in all cooperating links. However, the information transferred to the material decoupling point should be information exclusively about those events whose effects failed to be levelled in the chain link in which they occur. Those disruptions which resulted in deviations from fulfilled processes, which were levelled in the base enterprise by available methods such as supply chain surplus, subcontracting, extraordinary transport or flexible resources (Kramarz, 2013), should be accumulated in knowledge systems in each organization and made available to the coordinator as open knowledge of this link. Simultaneously, the entire system is influenced by factors strengthening disruptions. They are factors whose source is independent from the system itself. However, the effects of those events strengthen disruptions appearing in the system. This means that endogenous disruptions, whose sources are identified in the intermodal transport system, that is on the level of network actors, cause effects whose consequences will be greater in interaction with exogenous factors (strengthening endogenous disruptions). Exogenous factors especially include natural disasters, atmospheric factors, strikes, blockades, congestion, and changes of legal regulations. Participants of the intermodal transport network do not have any influence on those factors. They must monitor them and accumulate them in a system for managing knowledge about disruptions.

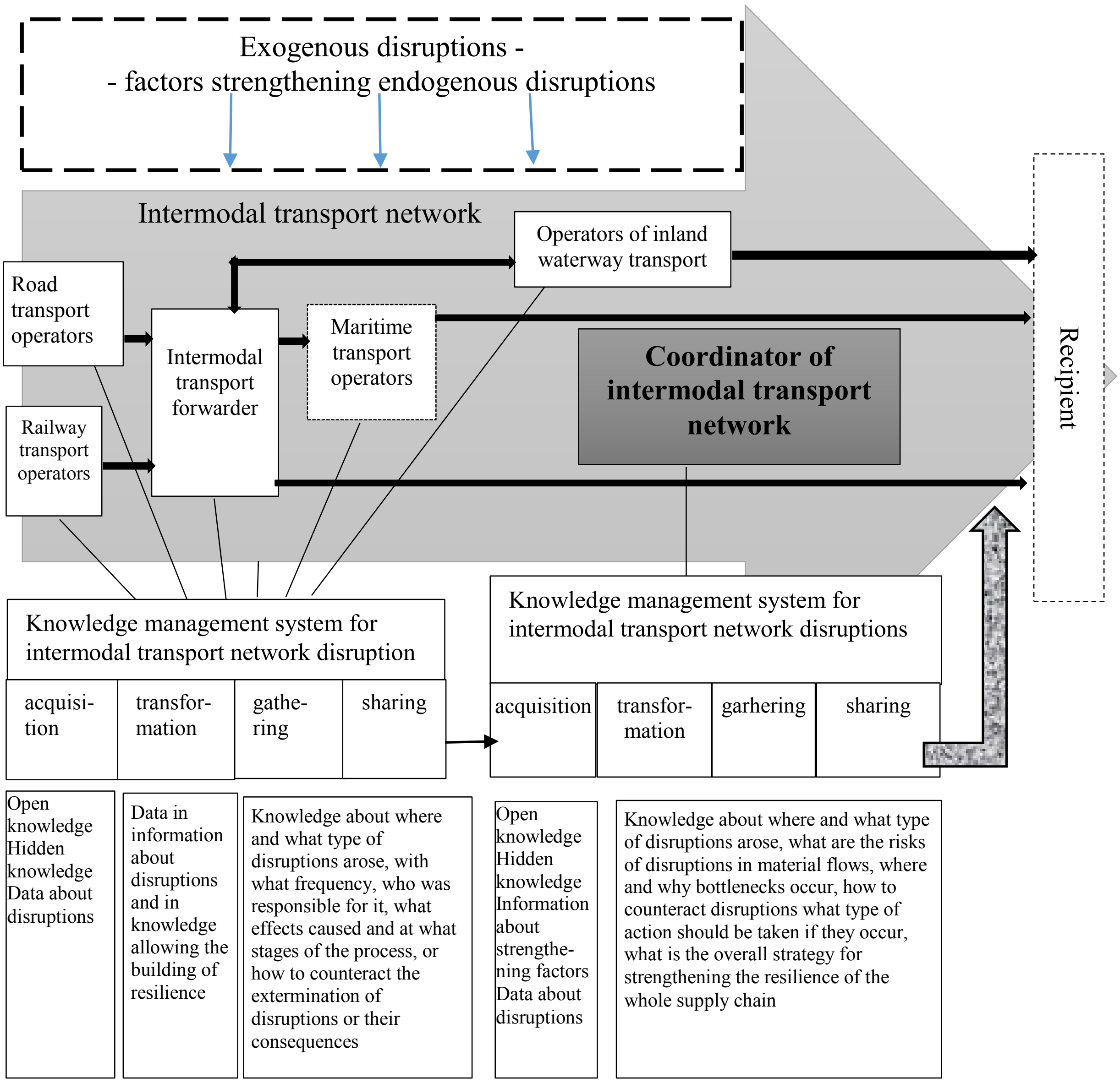

Figure 2. Idea for a system for managing knowledge about disruptions. Source: authors' study.

The presented idea of a system for managing knowledge about disruptions assumes that the knowledge base should be located in the node which has a central position in the network, i.e. one which is a bond of the network. Figure 2 assumed the hypothesis that the coordinator of such a network was the operator of an intermodal transport network. However, the indicating attributes of the coordinator of an intermodal transport network is an object of parallel research into intermodal transport networks, and consequently verification of this hypothesis will be continued in further stages of the research. The introduced idea of a system for managing knowledge about disruptions in intermodal transport networks requires commitment from all partners and knowledge sharing, as well as the unification of measurement of the disruptions in all network nodes.

6. Conclusions

Intermodal transport networks, similar to supply chains and other systems, including single organizations or distribution channels, and due to the key meaning of material flows, they must analyse the susceptibility of the system to disruptions and also build resilience. Building resilience requires on one hand access to data and information on disruptions in all chain links of the system, and on the other hand, possession of knowledge about ways to cope with particular disruptions in order to consequently limit their effects and realize orders efficiently. It is also essential to possess knowledge about intensifiers of disruptions in the network. They are exogenous factors whose sources lie in natural disasters, congestion, weather conditions, blockades, strikes, etc. This paper aimed to design a model for managing knowledge about disruptions which, based on the literature research and pilot studies in two intermodal transport subnets in Poland, is presented in Figure 2. The study indicated the key actors of this network and characterized the stages of gaining, processing, accumulating and making available knowledge separately for individual actors of the network and for the coordinator of the network.

Pilot studies allowed for arranging participants of the intermodal transport network and indicating those entities where it is necessary to monitor disruptions. Simultaneously, they provide more detail for the set of potential disruptions developed at the stage of the literature research. As was noted, it is not a closed set. However, it includes the most common disruptions as well as disruptions causing the most serious effects. The designed system for managing knowledge about disruptions assumes compensating for disruptions in subsequent individual chain links of the intermodal transport network. And those events supply the knowledge base on ways to solve particular problems in material flows. The main information which is combined in the base with knowledge about disruptions are those events, together with their frequency and effects, which spread to other nodes in the intermodal transport network.

The presented results provide a basis for proper research aiming to develop a computer science tool to aid managing knowledge about disruptions in intermodal transport networks. The research led as part of the structure of the system for managing knowledge about disruptions in intermodal transport networks is accompanied by investigations regarding the potential attributes of the coordinator of such a network.

References

1. Ackoff, R. (1989). From Data to Wisdom. *Journal of Applies Systems Analysis*, *16.*
2. Ambra, T., Caris, A., Macharis, C. (2019). Should I stay or should I go? Assessing intermodal and synchromodal resilience from a decentralized perspective. *Sustainability*, *11.*
3. Antonowicz, M. (2016). Usługa intermodalna w ujęciu systemowym. *Studia Ekonomiczne. Zeszyty Naukowe UE w Katowicach, 261*.
4. Antonowicz, M. (2011). Praktyka partnerstwa ogniw intermodalnego łańcucha transportowego kolej-port na przykładzie Holandii. *International Journal of Management and Economics, 31*.
5. Bernacki, D. (2012). Sieciowe aspekty działalności transportowej. *Logistyka, 6.*
6. Bukowski, L. (2016). *Zapewnienie ciągłości dostaw w zmiennym i niepewnym otoczeniu*. Dąbrowa Górnicza: Wyższa Szkoła Biznesu.
7. Buttery, A., Buttery, E. (1994). *Business Networks. Reaching new markets with low cost strategies*. Melbourne: Longman Business & Professional.
8. Burgholzer, W., Bauer, G., Poset, M., Jammernegg, W. (2013). Analysing the impact of disruptions in intermodal transport networks: A micro simulation – based model. *Decision Support Systems*, *54(4)*.
9. Centenaro, A., Guedes Laimer, C. (2017). Cooperative relationships and competitiveness in supermarket sector. *Review of Business Management, 63*.
10. Chung-Jeng, C., Jing-Wen, H. (2007). How organizational climate and structure affect knowledge management – The social interaction perspective. *International Journal of Information Management, 27*.
11. Czakon, W. (2015). Sieci międzyorganizacyjne w naukach o zarządzaniu – w kierunku sieciowych modeli biznesu. *Studia Ekonomiczne. Zeszyty Naukowe UE w Katowicach, 217*.
12. Czakon, W. (2012). *Sieci w zarządzaniu strategicznym*. Warszawa: Oficyna Wolters Kluwer Business.
13. Di Febbraro, A., Sacco, N., Saeednia, M. (2016). An agent-based framework for cooperative planning of intermodal freight transport chains. *Transportation Research, Part C*, *64*.

14. Downar, W. (2010). Budowanie sieci relacji a innowacyjność transportu. In E. Załoga, B. Liberadzki (Eds.), *Innowacje w transporcie. Korzyści dla użytkownika.* Szczecin: Uniwersytet Szczeciński.
15. Ford, D., Mouzasa, S., Ford, D., Mouzasa, S. (2013). The theory and practice of business networking. *Industrial Marketing Management*, *42*.
16. Francesco, M., Lai, M., Zuddas, P. (2013). Maritime repositioning of empty containers under uncertain port disruption. *Computers & Industrial Engineering, 64*.
17. Guzdek, S. (2016). Kooperacja jako główna forma współpracy przedsiębiorstw w międzynarodowych sieciach biznesowych. *Prace Naukowe UE we Wrocławiu*, *450*.
18. Janic, M. (2017). Modelling the full costs of an intermodal and road freight transport network. *Transportation Research, Part D*, *12*.
19. Janiszewski, C., Labroo, A., Rucker, D. (2016). A tutorial in consumer research: knowledge creation and knowledge appreciation in deductive – conceptual consumer research. *Journal of Consumer Research, 43*.
20. Kawa, A. (2013). Analiza sieci przedsiębiorstw z wykorzystaniem metody SNA. In Ł. Sułkowski (Eds.), *Przedsiębiorczość i Zarządzanie*, XIV/13/1, Łódź: Społeczna Akademia Nauk.
21. Kawa, A. (2013). Sieci pionowe i poziome w gospodarce. *Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu, 277*.
22. Kawa, A., Pierański, B. (2015). Współpraca sieciowa przedsiębiorstw w Polsce – wyniki badań. *Zeszyty Naukowe WSB w Poznaniu, 64/7*.
23. Kramarz, M., Kramarz, W. (2015). Gathering knowledge about disruptions in material flows in network supply chains. *Logforum, 11(1).*
24. Kramarz, M., Kramarz ,W. (2015). Configuration of a supply chain of metallurgical products in the context of the cooperation climate. *International Journal of Contemporary Management, 14, 3*.
25. Krause, P., Clark, D. (1989). *Representing Uncertain Knowledge: An Al Approach Intellect*, Oxford.
26. Kyriakou, H., Nickerson, J., Sabnis, G. (2017). Knowledge reuse for customization: metamodels in an open design community for 3D printing. *MIS Quarterly. Special Issue: IT and Innovation, 41(1).*
27. Miller-Hooks, E., Zhang, X., Faturechi, R. (2012). Measuring and maximizing resilience of freight transportation networks. *Computers & Operations Research*, *39(7).*
28. Munim, Z.H., Haralambides, H. (2018). Competition and cooperation for intermodal container transhipment: A network optimization approach. *Research in Transportation Business & Management, 26*.
29. Romanov, P., Stajniak, M., Konecka, S. (2017). Wybrane aspekty zagrożeń i ryzyka w transporcie. *Autobusy, 12*.

30. Rześny-Cieplińska, J. (2010). Klastry sieciowe w transporcie jako strategia budowania konkurencyjności przewoźników drogowych. In P. Niedzielski, and R. Tomanek (Eds.), *Innowacje w transporcie. Organizacja i zarządzanie*. Szczecin: Uniwersytet Szczeciński.
31. Šakalys, R., Batarlienė, N. (2017). Research on Intermodal Terminal Interaction in International Transport Corridors. *Procedia Engineering*, *187*.
32. Schmit, A., Singh, M. (2012). A quantitative analysis of disruption risk in a multi – echelon supply chain. *International Journal of Production Economics*,139.
33. Serrano-Hernández, A., Juan, A.A., Faulin, J., Perez-Bernabeu, E. (2017). Horizontal collaboration in freight transport concepts, benefits and environmental challenges. *SORT – Statistics and Operations Research Transactions*, *41(2).*
34. Sheffi, Y. (2005). *Resilient Enterprise Overcoming Vulnerability for Competitive Adventage*. Massachusetts: MIT Press.
35. Skyttner, L. (2008). *General Systems Theory: Problems, Perspectives, Practice*. Singapore: Words Scientific.
36. Theys, C., Dullaert, W., Notteboom, T. (2008). Analyzing cooperative networks in intermodal transportation: a game-theoretic approach. *Nectar Logistics and Freight Cluster Meeting.* Delft.
37. Yamada, T.B., Russ, B.F., Castro, J., Taniguchi, E. (2009). Designing multimodal freight Transport Networks: A heuristic approach and applications. *Transportation Science*, *43(2).*