Augustyn Lorenc (alorenc@pk.edu.pl)
    Logistics Systems Division, Cracow University of Technology

Małgorzata Kuźnar
    Reliability and Technical Exploitation Division, Cracow University of Technology

The Cost of risk evaluation in intermodal transport – variant analysis

Analiza kosztów i ryzyka w transporcie intermdalnym – analiza wariantowa

Abstract

In the article, the impact of monitoring systems on the possibility of lowering costs and improving the flow of information in the transport chain has been analysed. For the analysed transport chain, tree variants have been taken into consideration: variant I – without using systems for monitoring location, variant II – container transportation with using systems for monitoring location, variant III – container transportation with using location monitoring and cargo parameters. The conducted tests made it possible to confirm the benefits of implementing this type of system, especially for high-value goods. In the article, a simulation for 50,000 cases of container transportation was done. The simulation and cost analysis has shown that it is possible to reduce the cost of risk significantly.

Keywords: intermodal transport; containers; positioning systems; localization monitoring; cargo parameters monitoring; risk and costs performance analysis

Streszczenie

W niniejszym artykule przebadano wpływ systemów monitorowania ładunków na możliwość zmniejszenia kosztów i poprawy przepływu informacji w łańcuchu transportowym. Dla analizowanego łańcucha transportowego rozważono trzy warianty: wariant I – bez systemu lokalizacji, wariant II – z systemem do monitorowania lokalizacji, wariant III – z systemem do monitorowania lokalizacji i parametrów ładunku. Wykonane badania pozwoliły stwierdzić korzyści wynikające z zastosowania tego typu systemów, zwłaszcza dla produktów o wysokiej wartości. W artykule wykorzystano dane dla 50 000 przypadków przewozu ładunków. Przeprowadzone symulacje i analiza kosztów pozwoliły potwierdzić, że możliwe jest w dużym stopniu zmniejszenie kosztów ryzyka.

Słowa kluczowe: transport intermodalny; kontenery; systemy monitoringu, lokalizacja, monitorowanie parametrów ładunku, analiza ryzyka i kosztów

1. Introduction

Multimodal transport involves the carriage of goods using at least two different modes of transport.Intermodal transport is the transport of goods in one and the same transport unit using successively several modes of transport without reloading the goods themselves when changing the mode of transport. An intermodal transport unit may be, for example, a container or a swap body. Intermodal transport is therefore a particular type of multimodal transport.

The risk analysis for each element of the supply chain in an intermodal transport, including the identification of the occurring risks, is extremely important for the functioning of the supply chain [1]. The implementation of effective risk management in related chain links has a significant impact on the security of the entire flow process. Both in the transportation and in other links of the chain it is necessary to identify susceptible to fault places and recognise current and potential risks [2, 3]. The appropriate level of reliability of the supply chain is exposed to various types of risk due to the presence of many types of risks associated with changes in the internal and external environment [4]. Figure 1 presents the global cargo theft risk in 2014.
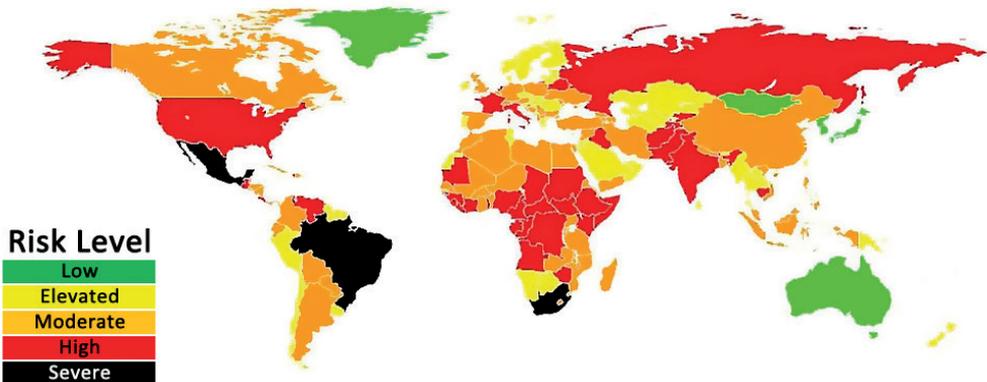

Fig. 1. Global cargo theft risk in 2014 [5]

In the context of the security risk of the transported cargo, we can distinguish the following threats and adverse events [6]:

- ▶ loss of cargo,
- ▶ reduce the quality of the cargo,
- ▶ absorption of water by the load,
- ▶ contamination of the load,
- ▶ changes in weather conditions,
- ▶ fluctuations in temperature,
- ▶ accident or incident during the transportation,
- ▶ maritime piracy,
- ▶ failure to comply with procedures for cargo handling,
- ▶ environment pollution,
- ▶ fire, explosion.

Among the container cargo damage, can be distinguish physical and temperature related harms. Bad stowage is one of the contributory causes of cargo damage. Among the most common container cargo claims in the maritime transport 25% applies to physical damage, 14% of the claims are temperature related, 11% concern containers overboard lost, 9% theft and 8% shortage of the load [7]. Figure 2 shows percentage share of large cargo Claims broken down by types of damage.

The causes of container cargo damage can be different. For example, we can mention lack of export packaging, inadequate ventilation, wrong choice of container, poor condition of container, lack of clear carriage instructions, ineffective internal cleaning, contaminated floors (taint), wrong temperature settings, condensation, overloading, poor distribution of cargo weight, wrong air flow settings, organised crime, fragile cargoes stored in areas of high motion, damaged securing equipment, poor monitoring of temperatures, wrong use of temperature controls [8].
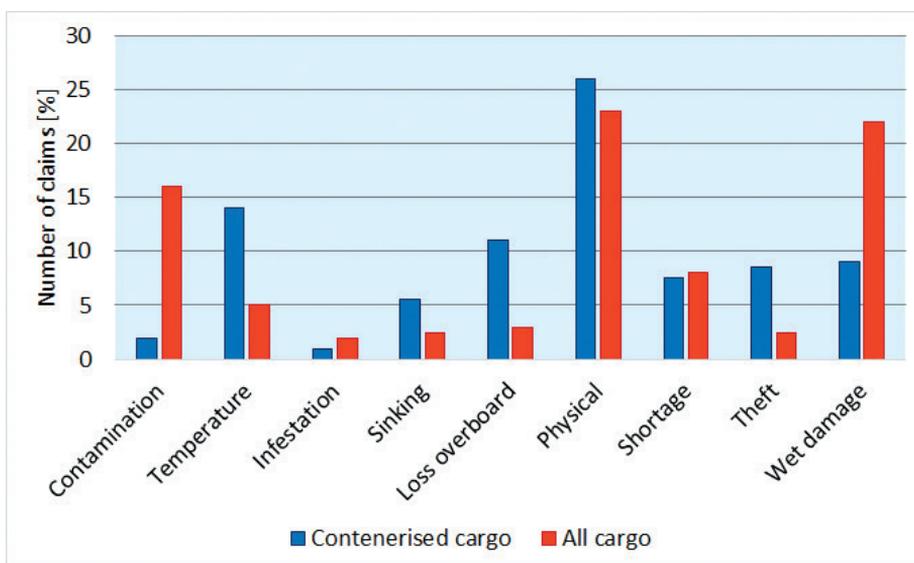

Fig. 2. Large cargo claims – type of damage

2. Location Systems - solutions overview

Intermodal Freight Transport is carriage of cargo using more than one type of transport using only one unit of load on the whole route of transport, without reloading the goods themselves when changing the mode of transport. Such kind of transport is often characterised by a high value of transported goods, mass character and large transport distances, moreover, often require a change in the carrier and even the mode of transportation. Therefore, the owners of intermodal freight and rail operators want to have information not only about its exact location but also the conditions of transport [9]. Most of the technological solutions such as GPS modules are universal and adapted to the requirements of the customer, regardless of whether it comes to industrial tools, dangerous chemicals, expensive drugs, exotic or high-

quality food products. Most commercially available units can monitor whether the specified temperature range is respected, measure the strength of shock or register moisture inside the load unit, record exposure to solar and electromagnetic radiation.

More advanced modules for monitoring parameters of containers also allow the cargo protection i.e., if the container doors are open, check if inside of the container there was no movement, lights or other deviating from standard events. In short, they can monitor everything that can have an impact on transported cargo. Available modules allow for current [10, 11]:

- ▶ monitoring the cargo location,
- ▶ recording of transport conditions,
- ▶ guarding the permitted range of conditions,
- ▶ temperature, humidity and shock measurement,
- ▶ container movement reporting,
- ▶ cargo protection by detecting unwanted actions of third parties,
- ▶ history of the cargo movement.

The units used in intermodal transport are designed specifically for monitoring containers. They are usually mounted on the outer wall of the container, have sensors on the door or the inside of the container and are sensitive to atmospheric conditions.

The installed device receives location data from the GPS satellites. The information is then sent via data transmission by mobile network to the server, which is then elaborated. When a vehicle is located out of range of a mobile network, e.g. in the middle of the ocean during a storm or other reasons, history of the position does not lose. If the GPS module cannot send position data, save it in its internal position and send it when possible.

The modules used in the monitoring of cargo transportation are highly prevalent on the market and are usually in the form of independent modules. According to destination and monitoring capabilities can be distinguished following systems:

- ▶ **Dedicated systems for port and container terminals**

    This is usually an online application dedicated to seaports and their clients, offering a wide range of functionality (TOS type systems - Terminal Operating System). Position location of containers in the harbour is one of the basic system options. It is not required to mount a GPS module to container because the application is based on a virtual model, i.e. every container which is inserted on storage square has assigned a specific location. Linking the container number to a specific place of storage allows the system to visualise the stored units in the terminal. This solution provides high accuracy, but in the case of reading errors make it difficult to locate the container. Apart from indicating the location on the square storage system allows you to show the status of the container, for example placing on the ship, unloading, storage, loading wagon/trailer, etc [12].

- ▶ **Systems to monitor the approximate position**

    Such systems are based on information exchange between users. Do not use the GPS modules or GPRS data transmission. Therefore, they do not allow the precise position of the load, but also did not require the installation of additional equipment for intermodal unit [13].

▸ **Systems to monitor only the locations of units**

The location device with a GPS receiver installed in the vehicle collects data on its current position. Then, using GSM/GPRS network, data is sent to the monitoring server, for which the user receives access. The application allows electronic tracking of cargo by monitoring its location and safety. By using SaaS solution - Software as a Service and capability to support almost every tagging technology (GPS, GPRS, RFID and others), it is possible to track and monitor cargo units almost all over the world [14].

▸ **Systems to monitor the specific parameters of the load**

Such a system makes it possible not only to identify the exact location of the cargo unit but also allows you to specify the specific parameters of the load. With the ability to define custom POIs - Points of Interests, and assign to them the maximum time within which the cargo should leave the defined area, it is possible to automatically generate notifications. This solution makes it possible to supervise costs resulting from too long waiting time for transhipment in a terminal or warehouse. The system offers automatic notification of temperature changes in relation to the established range. The system also includes the measurement of various parameters of the load, for example, temperature, pressure, leaks and other safety-related parameters [11].

▸ **Systems to monitor the location and parameters of the mode of transportation**

The system helps supervise individual units by using GPS locators. It is also possible to apply additional sensors that increase the number of monitored parameters. Data handling from the locators and using a special set of statistical tools may be held from a web browser. Sometimes, such a system does not provide direct possibilities for monitoring the position of the intermodal unit. Thanks to the information concerning the means of transportation and cargoes situated on it, it is possible to link the means of transportation location to the location of the container. Additional services and functionality of the system may permit inter alia: the registration of constant parameters (registration number of the vehicle, driver and vehicle data), registering exploitation parameters (vehicle mileage, pressure, digital signals), information about the faults and device status information, recording service information for the diagnosis [15].

3. Transport chain – considered variants

To be able fully to assess the benefits resulting from the application of location and cargos parameters monitoring systems, the transport chain has been established. As primary elements of that transport chain could be counted: road transport, sea transport, transhipment and storage in container terminals in ports. For each transportation process risk, which could appear in a process, has been identified. Transport chain with potential risk is shown in Fig. 3.

For presented transport chain, tree variants have been taken into consideration:
▸ Variant I, container transportation without using systems for monitoring location,
▸ Variant II, container transportation with using systems for monitoring location,

▶ Variant III, container transportation with using systems for location monitoring and cargo parameters, like temperature, humidity, shock, opening the door, the light inside.

What is more, the costs for each transportation processes and the cost of undesirable incidents were established with a currency conversion at the rate of 4.407 for Euro/PLN 1.118 and USD/Euro (the state from 2017-03-04).
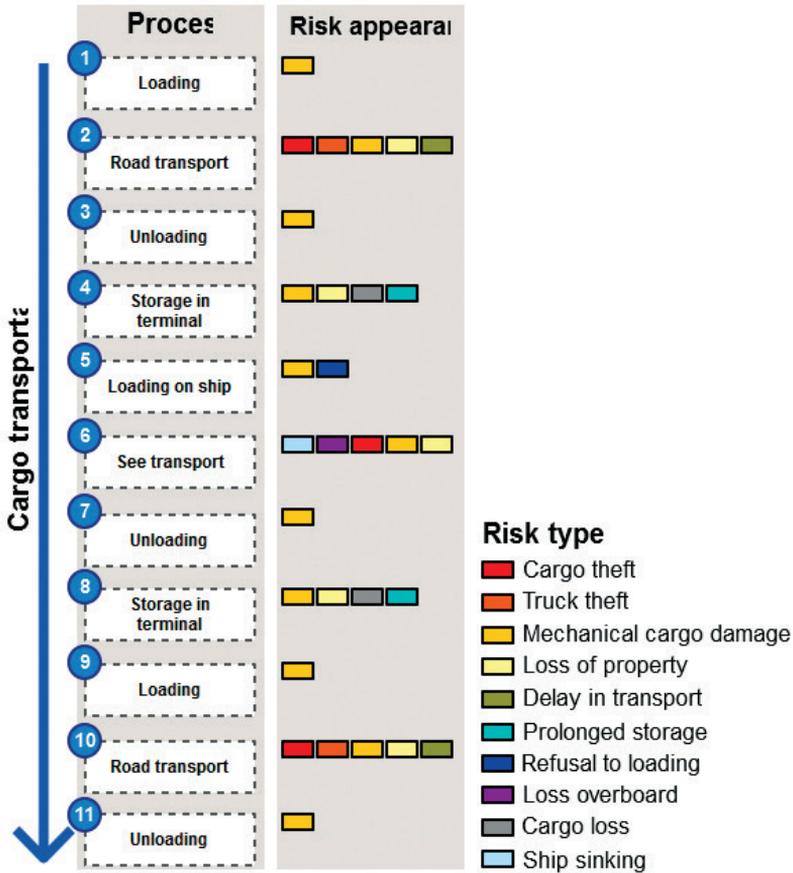

Fig. 3. Risk appearance in transport chain

Both the costs and the responsibility of loading during loading in the shipped company are on side of the shipper. Because of that, the cost of cargo damage was not taken into consideration in that analysis. If, at that stage, cargo damage would be stated, the manufacturer shall replace it. But in case of cargo damage in such a way that it is not possible to notice it during loading, the damaged cargo will be supplied to the customer. Those products will be replaced by new one in the future, so it will generate extra costs.

For cargo transportation by the road, the cost equal to 1.10 Euro/km was established. That rate base on standard transport costs in Europe.

Transhipment costs for container terminal were established by average costs in that type of services. So, it is 42.50 Euro by loading/unloading [22]. Cost of storage in the terminal is 4 Euro per day, and it complies with polish rail company PKP CARGO CONNECT [23].

Cost related to sea transport was established by calculation for transport from Shanghai (China) to Gdańsk (Poland) [22].

The probability of risk appearance was estimated by real statistical data. In 2014, there were 2 007 926 see transportation processes and 1 069 202 full load road transportation processes in Europe [22]. Base on statistic information of transportation and risk estimation and information about undesirable incidents in see transport [7, 17–19] and road transport [20, 21] the probability of risk appearance was estimated. In Table 1 are shown probability of risk appearance for separated processes.

Table 1. Probability of risk appearance

Process	Risk	Probability [%]
1. Loading	Mechanical cargo damage	0.00623
2. Road transport	Cargo theft	0.09353
	Truck theft	0.00954
	Mechanical cargo damage	0.00830
	Loss of property	0.01539
	Delay in transport	0.05000
3. Unloading	Mechanical cargo damage	0.00623
4. Storage in terminal	Mechanical cargo damage	0.00623
	Loss of property	0.01494
	Cargo loss	0.00050
	Prolonged storage	1.50000
5. Loading on ship	Refusal to loading	0.05000
	Mechanical cargo damage	0.00623
6. See transport	Ship sinking	0.00498
	Loss overboard	0.00996
	Cargo theft	0.00770
	Mechanical cargo damage	0.02490
	Loss of property	0.03033

Process	Risk	Probability [%]
7. Unloading	Mechanical cargo damage	0.00623
	Mechanical cargo damage	0.00623
	Loss of property	0.01494
	Cargo loss	0.00050
8. Storage in terminal	Prolonged storage	1.50000
9. Loading	Mechanical cargo damage	0.00623
	Cargo theft	0.09353
	Truck theft	0.00954
	Mechanical cargo damage	0.00830
	Loss of property	0.01539
10. Road transport	Delay in transport	0.05000
11. Unloading	Mechanical cargo damage	0.00623

4. Description of Variant I

In variant I, the containers are transported without using systems for location monitoring and cargo parameters. So, in this case, there is no possibility to determine in real time where an exactly container is. It is possible only in an approximate way (as the stage in transport chain) by the identification number of a container. Taking into account the above, there is no possibility to respond to delays in transportation, which could result in refusal to loading the cargo to ship, prolonged storage time in the terminal, the problems with the synchronisation with other means of transport, etc. Likewise, in the case of truck/trailer or cargo theft, ship sinking or container loss overboard, it is not possible to quickly determine what happened with the cargo. That incident could cause additional costs related i.e. to contractual penalties.

5. Description of Variant II

In variant II, the containers are transported using systems for location monitoring but without additional functionality. In this case, it is possible to determine where the exactly container is. Cause of that, costs of undesirable incidents like theft or container loss, could be reduced. Moreover, it is possible to synchronise transhipment process, reduce the time of

storage in terminal – in the case when vessel arrives faster than expected, and reduce problems with determining loading and unloading terms.

In this variant, it is not possible to identify the container state and other parameters of the cargo. What is more, it is not possible to identify partial cargo theft from the container - these cases represent the majority [9]. Noticing if the cargo is complete is possible practically only during transhipment in the presence of a man - checking the condition of the seals, door and side walls of the container.

Location monitoring systems allow to partial reduction of costs related especially with contractual penalties and synchronisation between transportation processes [23].

6. Description of Variant III

In variant III, the containers are transported using systems for location monitoring and additional functionality – monitoring cargo parameters. For that with basic module were integrated extra sensors, for checking if container doors are open, check if the inside of the container there was no movement, lights or other deviating from standard events and sensors for monitoring cargo conditions like temperature, humidity or shock. Because of that, in the case of transhipment, if the sudden increase or decrease of monitored parameters out of the permissible range was noticed, it could be a proof to prove the guilt of a subcontractor (carrier or shipper). So, therefore, the load is in the responsibility of the subcontractor; he bears the costs of damaged cargo. Such a solution ensures costs reduction related not only to delays in transport and loss of the cargos, but also in case of cargo theft, damaged or loss of property.

7. Assumptions for simulation

For the simulations, the above-presented assumptions were made:
- ▶ Route: Shanghai (China) to Gdańsk (Poland)
- ▶ Transport modes: road, see
- ▶ Costs:
  - ▷ The cost of loading/unloading is 42.50 Euro for each,
  - ▷ The cost of storage in terminal is 4 Euro per day,
  - ▷ The cost of see transport for 20' container is 727 Euro,
  - ▷ The cost of preparing necessary documents and bill of landing is 66 Euro,
  - ▷ The cost of customs procedure is 44 Euro,
  - ▷ The cost of road transport is 1.10 Euro/km.
- ▶ Contractual penalties:
  - ▷ delivery of damaged / incomplete cargo: 20% of charge,
  - ▷ delivery of damaged / incomplete cargo in the case of prior notify the customer: 10% of the load,
  - ▷ delay: 1% for each day of delay.

8. Evaluation of risk for variants

A data generator was developed for the simulation. In the first step, an identification of potential risks in a transport chain was made, which is shown in Fig. 3. Then, on the basis of the transport chain stage and the risk, it was written in the form of mathematical equations, which allow to draw data from the range corresponding to the probability of occurrence of the risk. Data were generated using normal distribution assuming the probabilities presented in Table 1. The excel function returned a value of 1 in the case of an adverse event appearance associated with a particular type of risk and a value of 0 if it did not occur. Then, based on the type of risk that occurred, a percentage share of the damaged load was generated in relation to the entire carried cargo. If such risks occurred, for example, in the case of a sinking ship, the percentage share of the damaged cargo was taken as 100%.

Costs arising from the occurrence of the risk were calculated on the basis of the percentage share of damaged cargo and other costs arising from the adverse event. The higher the stage of transport, the higher the cost due to the occurrence of contractual penalties or the need to substitute a new cargo for undelivered or damaged cargo.

In case of the simulation of 50 000 transports cases, in 1713 of them risky incidents appear. For all case was established the value of cargo equal to 7142 Euro. The result of the simulation of risk costs is graphically shown in Fig. 4.
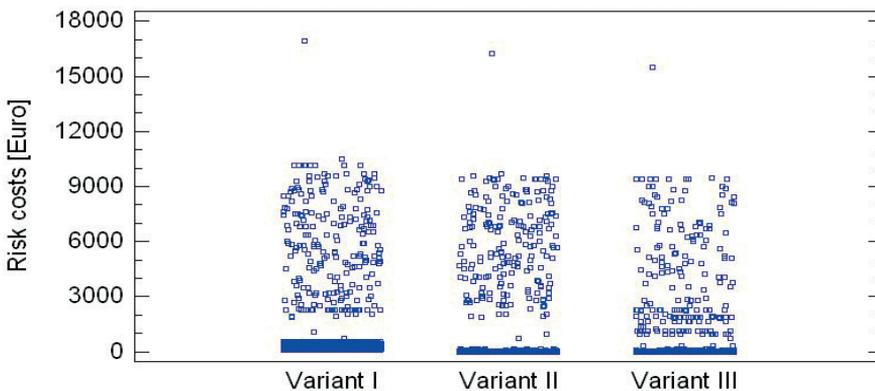

Fig. 4. Risk costs, depending on the variants

On the basis of Fig. 4, it can be stated that Variant I and Variant II produce the results with the greatest range and standard deviation. This is also noticeable, based on the statistical characteristics presented in Table II. As could be expected, with the usage of systems to monitor the location and parameters of the products, the reduction of the cost of risk can be noted. This is due to the fact that the freight forwarder has the option to react to the situation, which causes that the problem is not pulled in time and therefore do not bear the additional costs arising from it. In Fig. 4 it can be seen that variant III also reduced the number of cases of risk associated with variant II. The costs of the risks themselves have not been fully offset but significantly reduced – as can be seen in the increased number of cost cases up to € 3,000. Values that exceed the average are marked with colour.

Table 2.   Descriptive statistics of the performed analyses [euro]

	Average	Standard deviation	Median	Min	Max	Range
Variant I	1021.4	2081.6	377.1	71.4	16927.9	16856.4
Variant II	704.8	2063.5	8.0	0.0	16213.6	16213.6
Variant III	483.5	1618.9	8.0	0.0	15499.3	15499.3
Total	736.6	1945.4	24.0	0.0	16927.9	16927.9

For the conducted analyses, analysis of variance (ANOVA) was performed in order to test the significance of differences between average values. The F-ratio, which in this case equals 33.5, is a ratio of the between-group estimate to the within-group estimate. Since the P-value of the F-test is less than 0.05, there is a statistically significant difference between the means of the 3 variables at the 95.0% confidence level.

In order to determine which groups differ statistically from each other, multiple comparisons were performed, the so-called post hoc test. To perform post-hoc tests, Scheffe, T Tukey (HSD), Fisher (LSD), Bonferroni, Newman-Keuls and Duncan tests are applied. In the analysed case, the Scheffe test, which is considered one of the most conservative post hoc tests, has been used. The results of the test are shown in Table III and in Fig. 5.

Table 3.   Multiple comparison using Scheffe test at 95% of confidence interval [euro]

	Mean	Stnd. error	Lower limit	Upper limit	Homogeneous Groups
Variant III	483.5	46.7	940.5	1102.2	X
Variant II	704.8	46.7	623.9	785.6	X
Variant I	1021.4	46.7	402.7	564.4	X

This table shows the mean for each column of data. It also shows the standard error of each mean, which is a measure of its sampling variability. The standard error is formed by dividing the pooled standard deviation by the square root of the number of observations at each level. The table also displays an interval around each mean. The intervals currently displayed are based on Scheffe's multiple comparison procedures. They are constructed in such a way that if all the means are the same, all the intervals will overlap at least 95.0% of the time.

The last part of the analysis was to make a comparison of medians using the Kruskal-Wallis test. Which tests the null hypothesis that the medians within each of the 3 columns are the same. The data from all the columns are first combined and ranked from smallest to largest. The average rank is then computed for the data in each column. The result of the test was 2134.1 and the P-value equalled 0.00, which demonstrates that the groups differ significantly from each other. The results coincide with the preliminary assessment of the graph shown in Fig. 4. To determine which medians are significantly different from which others, the Box-and-Whisker plot was prepared (Fig. 6).
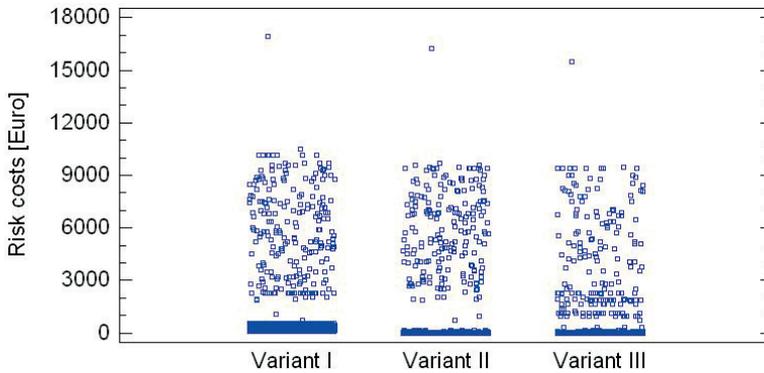
Fig. 5. Result of the comparison of average with Scheffe interval with 95% confidence interval
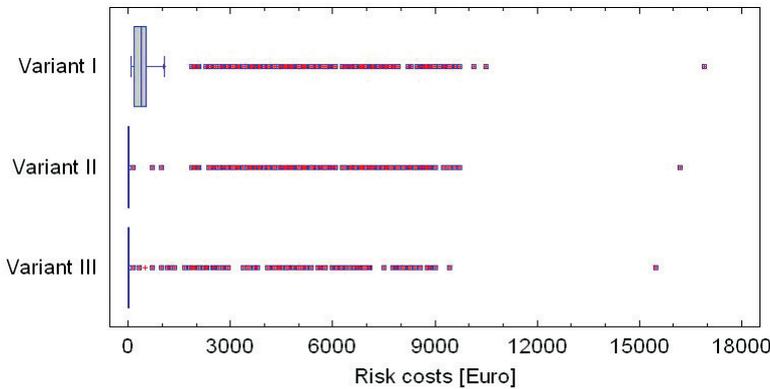

Fig. 6. Box-and-Whisker Plot for variants

Making a comparison of average and median values, it was found that the best results were obtained for Variant III where devices for monitoring localisation and cargo parameters was used. This method allows obtaining lower costs than in the case of container transport without any monitoring by an average of 52.7%. What is more, using the system for only monitoring localisation helps to reduce costs by 31.0%.

Figure 7 shows the cost of an adverse event, which was come out for the simulation. As could be noticed, the higher costs are in road transport in last transportation process. It is noticeable that for stage 10 the risk costs are lower than for stage 2. Both stages have the same type of carriage, while the cost difference results from higher contractual penalties. The disruptions in later transport are spotted the greater cause financial losses. This is due to lack of supply time, what in the occurrence of an adverse event is the greatest issue.

Costs on the stage of carriage by sea or first road transport and storage in the terminal are similar. Using systems for position monitoring helps to a slight reduction of risks cost in each process in transport chain, and can considerably reduce the cost of storage in containers terminal. Systems, which permit to monitor additional parameters, help to noticeably reduce costs in each stage of the transportation chain.
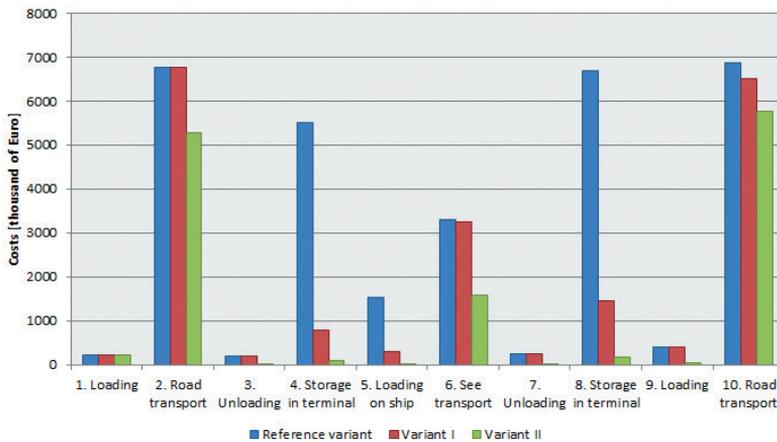
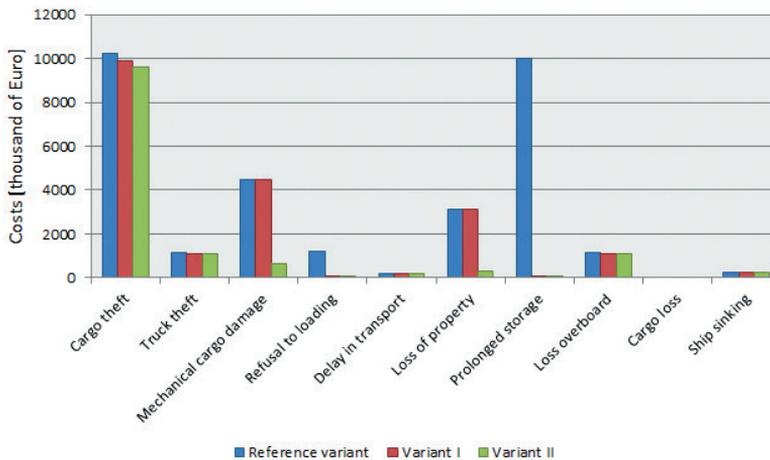Fig. 7. Costs of adverse event by processes in presented supply chain

Fig. 8. Costs of adverse event by risk type in presented supply chain

Figure 8 shows the cost of an adverse event by risk type. For the performed simulations, the biggest costs were for theft cases. Per 50000 transport cargo theft occurred 102 times and truck/ trailer theft 11 times. Cost of that incident could be reduced by additional cargo insurance, which is not obligatory. The problem could appear for high-risk countries. For that country, the insurance rate is significantly higher than normal. What is more for transport through sea territory of that country (i.e. Somalia or Republic of South Africa) insurer could refuse cargos insurance because of frequent cases of piracy. Cargo insurance could cover the costs associated with its mechanical damage or loss of cargo property. Increased costs connected with the storage time in terminal could be decreased if cargo forwarder is informed about a position of container [24]. It allows to synchronise each process in transport chain and reduce the time of storage between cargo movement [25].

9. Conclusion

Conducted tests made it possible to confirm the benefits of implementing a system for positioning and monitoring cargo parameters, especially for high-value goods. Devices for monitoring location and cargo parameter allows obtaining lower costs than in the case of container transport without any monitoring systems by an average of 52.7%. What is more, using system for monitoring only location can be helpful to reduce costs by 31.0%. These results showed that using those systems could bring great benefits. The simulations show that the riskiest stage is a road transport - for theft and mechanical damage cases. On the other hand, sea transport is the riskiest in terms of cargo properties lost or lost cargo. For this type of adverse event, it is advisable to carry out further research and develop prognostic models. According to statistics, consumers bear the cost of 20% of the value of products - this is due to the disruption in transport chain. Improving the efficiency of transport operations and reducing the risk can thus reduce the final costs of goods. What is more besides reduction of costs those could increase customer service levels.

In the next stage of research, it is planned to develop some intelligent forecasting methods to predict risk. It is planned to use artificial neural networks and genetic algorithms for this purpose. If developed methods will allow for effective risk forecasting, it is planned to implement them in own type of Transport Management System (TMS).

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