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Article *in* Archives of Transport · January 2015

DOI: 10.5604/08669546.1169208

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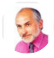

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THE ARCHIVES OF TRANSPORT *ISSN (print):* *0866-9546*
Volume 34, Issue 2, 2015 ***e-ISSN (online):*** *2300-8830*
DOI: *10.5604/08669546.1169208*

RISK MEASURES OF LOAD LOSS DURING SERVICE OF REFRIGERATED CONTAINERS IN SEAPORTS

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Abstract: *The presented paper is concerned with the problems of assessing the risk level for service chain of refrigerated containers in seaports. This issue has been examined with regard to the losses related to the loss of cargo's qualitative values. The paper identifies the links in the service chain as well as related hazards and events resulting in losses. The term "chain" has been defined for the refrigerated container service chain. Material losses generated by the loss of cargo's qualitative values have also been examined. The paper suggests and justifies functional and numeric risk measures. With regard to the examined process the study presents the elements of loss modelling methodology. The risk level has been evaluated using selected calculation examples, considering the impact of the probability of events resulting in losses.*

Key words: *risk analysis, transport chain, refrigerated container, seaport, simulation.*

1. Introduction

Refrigerated containers play an increasingly important role on the contemporary market of transport services. It is estimated e.g. that the quantity of those cargo units transshipped in Polish seaports reaches the level of 10% of all containers serviced in them. Special structure and equipment of refrigerated containers predisposes them for carrying, first of all, perishable cargo, that is cargo particularly sensitive to the impact of external conditions (changes in temperature, humidity or composition of the atmosphere) (Filina and Filin 2004). For this reason, the main reliability requirement formulated in relation to the process of transporting a refrigerated container is to ensure proper quality of the transported cargo. This is particularly important taking account of the fact that the process of transporting refrigerated containers frequently has intercontinental nature and the time of delivery from the sender to the recipient amounts then to more than ten and even more days. A typical transport chain includes then transportation of the load in a refrigerated container by land and sea. Each of the links of such a chain poses a threat to the transported cargo and may be a potential source of losses (Filina-Dawidowicz, 2014; Filina and Filin, 2004). The losses can be an effect of failure to provide e.g. a suitable temperature, relative air humidity or ventilation required when transporting the cargo. For instance, such events may happen both in the case of mechanical damage of a container as well as human error during the service. The possibility of occurrence of such losses means that the considered transport process involves some risk. The risk is treated here as a certain condition of the system of containers' transportation identified with the possibility of occurrence of events resulting in losses. Knowledge making it possible to evaluate this condition (e.g. by means of identification of the so-called risk level) may provide a basis for comparisons of the risk accompanying functioning of particular elements of the studied system or related to particular phases of its operation. The risk level can also constitute a criterion for comparison of projects with alternative solutions, e.g. methods of implementation of selected links in the transport chain.

There have been many different approaches to the definition of risk and evaluation of its level (Bocharnikov et al., 2005; Burduk and Chlebus, 2009; Iwańkowicz and Rosochacki, 2014; Rajewski et al., 2009; Rosochacki and Pijanowski, 2012; Szopa, 2009; 12. Van Thuyet et al., 2007). Typical approaches to prediction of its value include: defining the system, specifying the scope of analyses, identification of hazards and adopting relevant risk measures, as well as determining the methods of determination of their values. Assuming that the first three actions have been conducted properly, it is important to adopt specified risk measures. One of the available papers (Bocharnikov et al., 2005) considers usage of fuzzy measures and fuzzy-integral calculation theory for modeling of risk appearance possibility. However, the issue of risk level analysis requires a special approach. The measures must be legible and understandable and, at the same time, take account of not only the probable nature of the processes leading to losses, but also the probable nature of losses themselves.

The present study tackles the issue of forecasting the level of risk related to transportation of perishable cargo in a refrigerated container with particular focus on the issues of modelling losses. The research covered a selected fragment of the process including the chain of service of such a container in a seaport. A specific type of losses, generated by the loss of qualitative values of cargo, has also been examined. The completed research has given a basis for preparing a proposal of the form of functional and numeric measures of risk with regard to the analyzed issue. The suggested approach may constitute one of effective grounds of efficient management for the examined fragment of the transport process from the point of view of its safety.

2. Identification of the container service chain

The transport of perishable cargo in refrigerated containers is exposed to the impact of hazards of various nature. The collections of those threats are characteristic for and related to the implementation of specified links of the transport process (e.g.: carriage of a container by sea, land, reloading etc.) What is important here is the impact of both the people involved in the provision of a given link and the kinds of impacts of the artificial and natural environment specific for it. This publication examines one of such collections of hazards accompanying the process of container service in a seaport.

The service chain of refrigerated containers in seaports is specific and includes, apart from typical operations like: reloading storage and intra-port transport, additional activities such as: connection of the container to a source of electric supply, a veterinary and customs inspection, monitoring the weather conditions inside the refrigerated container during its stay in the port etc. Each of the above-mentioned activities is a specific link (or its element) of the service chain of a container in the port. Based on the data collected in seaports in Poland and Ukraine the links have been identified and their description – taking account of the approach presented in the paper (Filina-Dawidowicz, 2014) – has been presented in table 1.

As it appears from table 1, in the process of refrigerated container service in a port, we can separate basic and auxiliary links. The former are characteristic for almost each port offering services concerning refrigerated containers. The latter, on the other hand, have a particular nature and are used to carry out additional activities related to servicing the container at a specific order of the forwarder or the needs of the port. At the same time, high diversity of the links implies the diversity of related hazards.

3. Hazards in the refrigerated container service process

As it has already been indicated, the links of the refrigerated container service chain in a seaport are a source of events that may generate losses of various nature (Container Handbook, 2015). For example the research which covered the selected ports in Poland and Ukraine indicates that on average out of 10 000 TEU refrigerated containers serviced in them, in 26 cases a situation occurred in which there was a loss of qualitative values of the cargo, with the addition that in 10 cases the whole cargo was destroyed and in the remaining ones the loss of qualitative values covered 10 to 60 % of the cargo volume.

The losses can materially encumber not only the cargo owner, the port or the insurance company, but also negatively influence the reputation of the port. Therefore, it is vital to have the knowledge and technical means that will reduce the level of the risk associated with each form of losses generated in the container service process to the minimum, including the loss of qualitative values of the cargo during its transportation. One of the elements of such knowledge is recognition and specification of hazards that are potential sources of losses or potentially harmful circumstances. In the case of the technical system examined here hazards should be identified in connection with links forming a specific service chain for a refrigerated container. For this reason, a collection of such hazards may be specific and typical of the chain chosen to be studied (e.g. in terms of location of the system, kinds and number of links, overloading equipment, etc.). Bearing in mind that the present article examines the loss connected with the decreasing of cargo quality, on the basis of the author's own research, collections of events that may lead to the above-mentioned losses with regard to their sources have been defined (table 2).

Table 1. Links of refrigerated containers service chain in seaports

Name of the link	Intended use
1. Reloading of a container on ship board	1. Moving the container from the board of the vessel to the quay or means of land transport (unloading) 2. Moving the container from the quay or means of land transport to the vessel (loading)
2. Temporary placement of the container on the quay	1. Short-term storage of the container on the quay on board of the vessel to wait for its further relocation
3. Reloading of the container within the port	1. Moving the container between: 1. The storage yard and the truck 2. The storage yard and the platform (or in reverse routes) etc.
4. Intra-port transport of the container	1. Moving the container on a port tractor between the port waste dumps or designated parts of the port
5. Moving the container on the storage yard area (transshipment/transport)	1. Moving the container on the yard area to enable transshipment of containers placed in lower layers 2. Moving the container on the terminal area using port trucks
6. Storage of a container on the storage yard	1. Placement of the container on the storage yard and connection of the container to a power source 2. Verification of the external condition of the container and recording the cargo storage parameters
7. Storage of the container on a temporary storage yard [1]	1. Temporary placement of the container on the yard to conduct necessary inspections or wait for further service
8. Veterinary inspection of the cargo	1. Verification of the content of the container by veterinary authorities. 1. Opening the container doors 2. Collecting samples of the cargo 3. Closing and sealing the container 4. Issuing a quality certificate for the cargo
9. Customs and border inspection of the cargo	1. Verification of the content of the container by: customs and border services. 1. Opening the container doors 2. Verification of the content of the container 3. Closing and sealing the container 4. Issuing documents
10. Transport of the container with the recipient/supplier's vehicle	1. Moving the container around the port area in the shipowner's means of transport between on the export/import route
11. X-ray scan of the container [1]	1. Scanning the container in order to test the condition of its content
12. Weighing the container [1]	1. Determination of the mass of the container with the cargo
13. Collecting/decollecting the container [1]	1. Loading the container with the cargo 2. Unloading the cargo from the container and moving it into a vehicle, railroad car or the port cooling unit
14. Transport of the cargo in a cooler truck [1]	1. Transport of the cargo in a cooler truck to unload or load it to a container

[1] Auxiliary links in the containers service process.

Table 2. Examples of typical undesirable events associated with refrigerated containers servicing in seaports

Source of potential damage	Undesirable events	Examples of undesirable events	Frequency of occurrence [%]
Human factor	Human error [1], loss of physical or mental fitness	Damage of the container in consequence of its improper service by a transshipment device (e.g.: overhead crane, crane, container truck). Cooling unit not connected to power supply. Incorrect reading of data from devices monitoring the condition of the cargo in the container. Incorrect setting of cargo storage temperature. Untight closing of the container. Content of the container stolen.	60-70
Technique	Damage	Cooling unit failure. Failure of the power supply system of the cooling unit. Crane string (crane, gantry) ruptured during the container reloading. Fatigue rupture of the container structure.	25-35
Natural environment	Extreme natural phenomena (e.g. hurricane, tsunami, earthquake).	Acceptable storage time within the port exceeded. Depressurization of the container. Uncontrolled relocation of the container and disconnection of power supply. Damage of the container. Damage of the power network supplying the container.	5-15

[1] Deviation from accepted or desired procedure made by a person or a group of people, which may result in unacceptable or unwanted effects (IMO, 2002).

As it has been indicated in the analysis in table 2, the events specified in are an effect of damages, errors or extreme impacts of the nature. For this reason, they are of random type. Table 2 also includes data about the frequency of occurrence for particular groups of such events. This data was obtained on the basis of an expert's assessment made for selected ports in Poland and Ukraine.

4. Risk of the refrigerated container service chain

As it has already been emphasized above, in this paper risk is analyzed with emphasis on the possibility of occurrence of only tangible losses generated by the loss of qualitative values of the cargo. These losses, marked further in the text as $\boldsymbol{S}(\tau,t)$[1] are in general a random stochastic process.

In view of the foregoing, adoption of two forms of measures basic for the issues will be deemed justified to assess the level of the examined risk.

The first of the proposed measures is of the functional type and considers the probabilistic nature of the process under deliberation. On the basis of the approach presented in the paper (Szopa, 2009) it is suggested that this measure should be the probability $\Pi_s(\tau,t)$ of appearance of losses $\boldsymbol{S}$ not smaller than s in the period $(\tau,\tau+t)$ related to the execution of the refrigerated container service chain in a seaport:

$$\Pi_s(\tau,t) = P\left[\boldsymbol{S}(\tau,\tau+t) \geq s\right] \tag{1}$$

The above-mentioned measure provides the possibility of expressing the risk level in the function of time associated with handling a refrigerated container in the port, taking account of the random nature of the size of losses. For this reason, it also gives the basis for a probabilistic assessment of the risk associated with, for example, servicing selected

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[11] In this paper the symbols of random variables have been distinguished with a bold font.

links in the service chain. Owing to the nature of losses analyzed in this paper, their value fits within the scope, $s_{\min} \le s \le s_{\max}$ where: level $s_{\min}$ may define e.g.: a negligibly low value of losses, and level $s_{\max}$ the market value of the cargo transported in a single container.

The statistical equivalent of the measure (1) is the size:

$$\hat{\Pi}_s(\tau,t) = \frac{N_{S\ge s}(\tau,\tau+t)}{N} \tag{2}$$

where:

$N_{S\ge s}(\tau,\tau+t)$ – number of events occurring in range $(\tau,\tau+t)$ in a statistical sample of analyzed service chains of containers with numbers N and brought about losses (each time) $S \ge s$.

Assuming that stochastic process $\boldsymbol{S}(\tau,t)$ is a process stationary in respect of τ the measure (1) and its estimator (2) can be brought down accordingly to the following forms:

$$\Pi_s(t) = P\left[\boldsymbol{S}(t) \ge s\right] \tag{3}$$

$$\hat{\Pi}_s(t) = \frac{N_{S\ge s}(t)}{N} \tag{4}$$

The assumption of stationarity of the loss process considered here is, however, very questionable. It may be adopted, for instance, in the case when the service chain consists of a single link, which is a direct overloading of the container from the vessel to other long-range transport mean.

To provide rough estimates of the risk accompanying the selected period $(0,t)$ of the container service chain implementation it is suggested to adopt the following numeric data:

- expected value $s_o(t)$ of losses $\boldsymbol{S}(t)$ determined for the analyzed range $(0,t)$:

$$s_o(t) = \mathrm{E}\left[\boldsymbol{S}(t)\right] \tag{5}$$

and variance $\mathrm{d}^2(\mathrm{t})$:

$$d^2(t) = \mathrm{D}^2\left[\boldsymbol{S}(t)\right] \tag{6}$$

The estimators of measures (5) and (6) are respectively the following quantities:

$$\hat{s}_o(t) = \frac{\sum_{i=1}^{N} S_i(t)}{N} \tag{7}$$

where:

S_i - values of losses incurred during the implementation of the *i*-th chain of service up to moment *t*,

$$\hat{d}^2(t) = \frac{\sum_{i=1}^{N}\left(S_i(t) - \hat{s}_o(t)\right)^2}{N-1} \tag{8}$$

It should be noted that measures (5) and (6) do not take openly into account the distribution of random variable $\boldsymbol{S}(t)$.

On the basis of the analysis of the deliberations presented in (Rajewski et al., 2009) it is assumed that when studying the risk accompanying the implementation of the service chain considered here it may be useful to introduce a custom unit of time, equated with a one-time implementation of such a chain. Assuming the following formulation for such an approach: $t = 1$, the forms of measures (3) ÷ (8) can be expressed in a new form, accordingly:

$$\Pi_s(1) = P\left[\boldsymbol{S}(1) \ge s\right] \tag{9}$$

$$\hat{\Pi}_s(1) = \frac{N_{S\ge s}(1)}{N} \tag{10}$$

$$s_o(1) = \mathrm{E}\left[\boldsymbol{S}(1)\right] \tag{11}$$

$$d^2(1) = \mathrm{D}^2\left[\boldsymbol{S}(1)\right] \tag{12}$$

$$\hat{s}_o(1) = \frac{\sum_{i=1}^{N} S_i(1)}{N} \tag{13}$$

$$\hat{d}^2(1) = \frac{\sum_{i=1}^{N}\left(S_i(1) - \hat{s}_o(1)\right)^2}{N-1} \tag{14}$$

Computational example 1

Considering the research findings relating to the events resulting in the loss of qualitative values of the cargo presented before and assuming that:

(i) the container content was perishable cargo weighing M = 10 000 kg,
(ii) the average unit cost of the cargo was *C* = 1.5 EUR/kg,
(iii) in the case of events that do not lead to a total loss of qualitative values, the loss of quality covered on average 50% of the cargo mass,
(iv) the value of the loss is determined by the product of the unit cost of the cargo and the mass of the damaged cargo,

the value of measures of risk (13) can be identified as below:

$$\hat{s}_o(1) = \frac{\mathrm{n_1MC} + 0{,}5\mathrm{n_2MC}}{N} = 16 \text{ EUR/cont.} \qquad (15)$$

where:

$n_1 = 10$ – the number of undesirable events, the effect of which the loss of qualitative values of the whole cargo,

$n_2 = 16$ – the number of undesirable events, the effect of which the loss of qualitative values of a part of the cargo,

$N = 10^4$ – the size of the examined statistical sample corresponding here to the number of completed service chains.

The received value obviously corresponds to the level of risk specified ex post on the basis of the examined statistical sample. For this reason, from the point of view of safety management for new systems servicing refrigerated containers in seaports, it can have only estimated character. The obtained level of risk, which, in the examined perspective, determines the average value of losses referred to the service chain of a single container also needs to be discussed. Using the approach adopted at the formation of measures (11) and (12) it is also possible to assess the risk accompanying implementation of *m* similar service chains of containers e.g. belonging to one owner or constituting a shipful of cargo. For this purpose, we can use the following relation:

$$s_{om}(1) = \mathrm{E}\left[m\boldsymbol{S}(1)\right] = m\mathrm{E}\left[\boldsymbol{S}(1)\right] \qquad (16)$$

$$d_m^2(1) = \mathrm{D}^2\left[m\boldsymbol{S}(1)\right] = m^2\mathrm{D}^2\left[\boldsymbol{S}(1)\right] \qquad (17)$$

In such a perspective, the risk related to the service of some batches of containers is defined, which may provide a more legible measure for parties interested in risk analysis and safety management in the port.

In order to assess and compare the risk accompanying the implementation of particular links in the service chain we can propose, like in the case of the approach presented when preparing formulation of measures (9) ÷ (14), the agreed formulation in the form of *t=j*, where marker j is attributed with a subsequent ordinal number of subsequent links in the service chain of the container.

A separate issue are the issues of predicting the values of measures (3), (5) and (6). Two typical approaches are possible at this point: (i) using statistical methods taking account of the knowledge associated with already completed service chains, (ii) using probabilistic methods supported in the process of modelling by expert knowledge. However, regardless of selecting a specific method in both cases the following probability forecasts are subject to determination: occurrence of events generating losses and the size of those losses. This is a complex issue, above all with regard to the stochastic nature of both processes leading to occurrence of losses (e.g. destructive processes in elements of concrete structures of reloading devices, psychophysical processes etc.) and processes affecting their size. The issue of estimation of probabilities of events resulting in the occurrence of losses is tackled by the reliability science. However, reliability analysis does not cover the problems of modelling and evaluation of losses.

In the case examined by this paper the size of losses reflected in a one-time implementation of the container service chain in the simplest perspective is a function of two random variables: the mass of damaged (i.e. deprived of qualitative values) cargo ***M***(1) during a one-time implementation of the service chain and the unit market price of the cargo ***C***(t_s) specified for the time of its sale t_s:

$$\boldsymbol{S}(1, t_s) = \boldsymbol{S}\left\{\boldsymbol{M}(1), \boldsymbol{C}(t_s)\right\} \qquad (18)$$

It should be noted here that the nature of distribution of random variable ***C***(t_s) depends on the economic conditions and forecasted for the moment of sale.

Assuming that $\boldsymbol{M}(1)=\boldsymbol{k}(1)M_l$, where: $\boldsymbol{k}(1)$ is a random variable which value is determined by a percentage of damaged mass M_l of perishable cargo transported in the container, the form of function (18) is assumed as below:

$$\boldsymbol{S}(1,t_s)=\boldsymbol{k}(1)M_l\cdot\boldsymbol{C}(t_s) \tag{19}$$

Assuming that the value of losses is determined by relation (19) and that random variables $\boldsymbol{k}(1)$ and $\boldsymbol{C}(t_s)$ are independent, measures (16) and (17) assume accordingly the following form:

$$\mathrm{s_o}(1)=\mathrm{E}\left[k(1)\mathrm{M}_l\right]\mathrm{E}\left[C(\mathrm{t_s})\right] \tag{20}$$

$$d^2(1,t_s)=M_l^2\left\{\begin{array}{l}\mathrm{D}^2(\mathrm{k}(1))\mathrm{D}^2(\mathrm{C}(t_s))+\\ \mathrm{D}^2(\mathrm{k}(1))\left[\mathrm{E}(\mathrm{C}(t_s))\right]^2+\\ \left[\mathrm{E}(\mathrm{k}(1))\right]^2\mathrm{D}^2(\mathrm{C}(t_s))\end{array}\right\} \tag{21}$$

Measures (20) and (21) are the basic numeric parameters of the distribution of random variable $S(1,t_s)$. Practical assessment of their value may be carried out using expert's methods. Assuming that the form of the function of density of probability *g(s)* of variable $S(1,t_s)$ is known the value of measure (9) can be identified from relation:

$$\Pi_{s_a}(1,t_s)=\int_{s_a}^{s_{\max}}g(s)ds \tag{22}$$

In order to determine specific values of probabilities defined with the above relationship it is essential to have knowledge of the characteristics of probability distributions of both random variables: $\boldsymbol{M}(1)$ and $\boldsymbol{C}(t_s)$.

Computational example 2

Modelling the losses related to the loss of cargo's qualitative values during the implementation of the refrigerated container service chain in a seaport must be taken into consideration.

Assumptions for calculations:

$M_l=1{,}0\cdot10^4$ kg

$\mathrm{E}\left[\boldsymbol{C}(t_s)\right]=2\ \mathrm{EUR}$

$\mathrm{D}^2\left[\boldsymbol{C}(t_s)\right]=0{,}1\ \mathrm{EUR}$

and – estimated on the basis of the above data – probability distribution of variable $\boldsymbol{k}(1)$:

$P\left[\boldsymbol{k}(1)=0{,}2\right]=0{,}0005$

$P\left[\boldsymbol{k}(1)=0{,}4\right]=0{,}0006$

$P\left[\boldsymbol{k}(1)=0{,}6\right]=0{,}005$

$P\left[\boldsymbol{k}(1)=1\right]=0{,}001$

$P\left[\boldsymbol{k}(1)=0{,}0\right]=0{,}974$

It has been also assumed that the distribution of random variable $\boldsymbol{C}(t_s)$ is a normal distribution truncated in zero.

In order to determine probability (22) simulative tests have been conducted on a sample including $n=1\cdot10^4$ experiments. A single experiment included an examination of $r=1\cdot10^5$ implementations of service chains. For each experiment the value of variable $\boldsymbol{C}(t_s)$ was generated randomly and for each r implementation – the value of variable $\boldsymbol{k}(1)$. Figure 1 presents the empirical form of probability distribution of losses reflected in a one-time implementation of the container service chain $\boldsymbol{S}(1,t_s)$. On the basis of the obtained results it was also possible to determine the average value of variable $\boldsymbol{S}(1,t_s)$ and its standard deviation. The following was obtained for the data assumed above: $\hat{s}_o(1,\boldsymbol{t}_s)\approx 32.82\ \mathrm{EUR}$ and $\sqrt{\hat{d}^2(1,\boldsymbol{t}_s)}\approx 5{,}68\ \mathrm{EUR}$. This shows that e.g. during implementation of the same service chain of a batch of refrigerated containers with m=500 pieces the potential average losses amount to $m\cdot\hat{s}_o(1,\boldsymbol{t}_s)=16410\ \mathrm{EUR}$.

The analysis of the results presented in figure 1 indicates a significant value of the variability coefficient of variable $\boldsymbol{S}(1,t_s)$, which in the examined event amounts to $v=\sqrt{\hat{d}^2(1,\boldsymbol{t}_s)}/\hat{s}_o(1,\boldsymbol{t}_s)=0{,}17$. Thus, there is a quite high probability of occurrence of losses at the level significantly exceeding the above average value. For instance, the probability that the value of losses exceeds this level by 20% is 0.17.

a)

b)

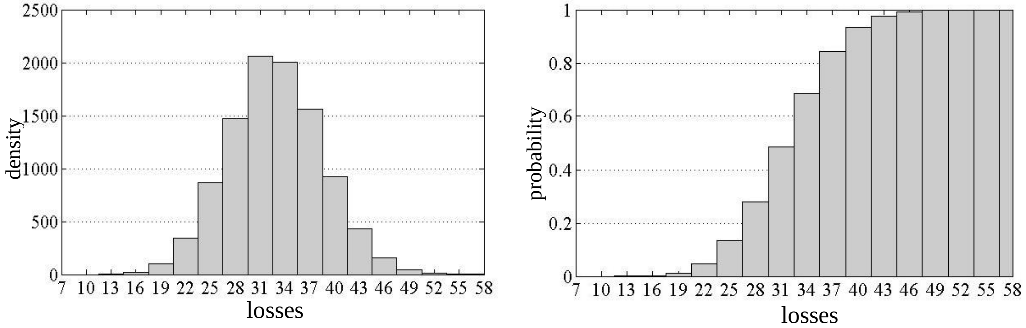

Fig. 1. Empirical form of losses distribution $S(1, t_s)$: a) probability density function, b) cumulative distribution function

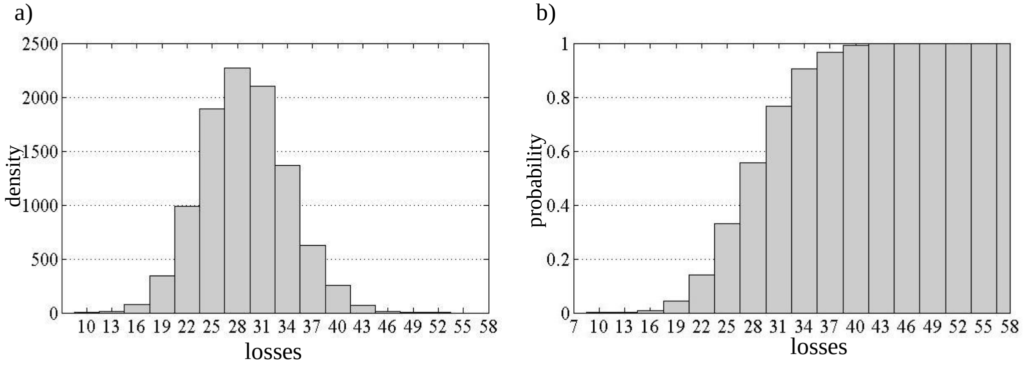

Fig. 2. Empirical form of losses distribution $S(1, t_s)$ including the reduction of probability of damage of the whole mass of the cargo of the changed distribution of variable $k(1)$:a) probability density function, b) cumulative distribution function

Using the suggested approach we can, among others, prepare analyses covering the impact of changes in the probability distribution of the degree of damage to the cargo on the level of losses. Figure 2, for instance, presents the empirical form of the probability distribution of losses for the case taking account of the limitation of the likelihood of a particular event leading to damage of the whole mass of the cargo from the level of 0.001 to the value of 0.0008. As a result a reduction in average losses from 12% (from the level 32.82 EUR to 28.87 EUR) has been obtained.

The examples of assessments presented above may provide, above all, a significant basis for undertaking technical and organizational activities leading to modification of the chain of service of containers towards increasing its level of reliability and – as a result – reduction in the number of events generating cargo damage.

5. Conclusions

When designing the processes of servicing refrigerated containers in seaports an important role should be played by risk analysis accompanying such processes. Its results give, among others, the basis for comparison of selected concepts concerning solutions of service chains and indication of those links in them for which the level of risk reaches maximum values. Obtaining numeric assessments in this respect is possible after formulation of the form of risk measures.

The paper has suggested measures making it possible both to evaluate the risk with regard to the selected periods or links in the service chain as well as consider the total time of its execution.

An important element of risk estimation is modelling and assessment of losses. The paper presents an approach to this issue using random variables describing the degree of damage and the unit cargo sale price.

Owing to the nature of analyzed losses, assessment of the risk level in the suggested perspective requires identifying the distribution of probabilities of events resulting in losses as well as the unit sale price of the cargo. The conducted numeric experiment pointed out that the risk assessment conducted with the use of presented approaches may constitute one of the bases for drawing up quantitative analyses covering the actions aiming at reduction of events resulting in losses.

The presented elements of risks assessment methodology related to implementation of the service chain of a refrigerated container may constitute a basis for preparation of analyses also covering losses of different nature, also with regard to other kinds of cargo.

References

[1] BOCHARNIKOV, V., FILINA, L. and SVESHNIKOV, S., 2005. Risk analyses of refrigerating containers service in seaports on the basis of fuzzy measures and fuzzy-integral calculation theory. *Systems: journal of transdisciplinary systems science,* 10(1), pp. 1-12.

[2] BURDUK, A. and CHLEBUS, E., 2009. Evaluation of the risk in production systems with a parallel reliability structure. *Eksploatacja i Niezawodność – Maintenance and Reliability,* **2**(42), pp. 84-95.

[3] CONTAINER HANDBOOK, Cargo loss prevention information from German marine insurers [Homepage of GDV. 2002], [Online]. Available: www.containerhandbuch.de, [2015].

[4] FILINA, L. and FILIN, S., 2004. Some problems of overload and storage of refrigerating containers in the port territory. *Archives of Transport,* **16**(1), pp. 13-19.

[5] FILINA, L. and FILIN, S., 2008. An analysis of influence of lack of the electricity supply to reefer containers serviced at sea ports on storing conditions of cargoes contained in them. *Polish Maritime Research,* **15**(4), pp. 96-102.

[6] FILINA-DAWIDOWICZ, L., 2014. Rationalization of servicing reefer containers in sea port area with taking into account risk influence. *Polish Maritime Research,* **21**(2), pp. 76-85.

[7] IMO, 2002. *Guidelines for Formal Safety Assessment (FSA) for use in IMO rule-making process.* MSC/Circ. 1023 and MPEC/Circ. 392. INTERNATIONAL MARITIME ORGANIZATION.

[8] IWAŃKOWICZ R, R. and ROSOCHACKI, W., 2014. Clustering risk assessment method for shipbuilding industry. *Industrial Management & Data Systems,* **114**(9), pp. 1499-1518

[9] RAJEWSKI, P., BEHRENDT, C. and KRAUSE, P., 2009. Analysis of operating conditions of polish fishing vessels. *Eksploatacja i Niezawodność – Maintenance and Reliability,* **2**(42), pp. 76-83.

[10] ROSOCHACKI, W. and PIJANOWSKI, S., 2012. Unormowania podstawowych pojęć z zakresu analizy bezpieczeństwa maszyn. *Bezpieczeństwo Pracy: nauka i praktyka,* , pp. 19-21.

[11] SZOPA, T., 2009. *Niezawodność i bezpieczeństwo.* Oficyna Wydawnicza Politechniki Warszawskiej.

[12] VAN THUYET, N., OGUNLANA, S.O. and DEY, P.K., 2007. Risk management in oil and gas construction projects in Vietnam. *International journal of energy sector management,* **1**(2), pp. 175-194.