# DETERMINATION OF DEPENDABILITY OF THE LOAD HANDLING PROCESS

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**Abstract**

In recent years intermodal transport is one of the most dynamically developing sectors of transport services. From year to year increases the number of transhipped integrated cargo units in the world. Crucial part of intermodal infrastructure are transshipment terminals, which are both handling points and storages for integrated loading units. To transport the cargo smoothly in relation door - to - door, inland terminals, as a point infrastructure should work reliably. The article is about the issue of dependability of the intermodal terminal land in the context of the information flow and its role in the proper implementation of the processes.

**Keywords:** Container terminal, intermodal transport, dependability, event tree analysis

## 1. DEPENDABILITY - LITERATURE REVIEW

Operational dependability [2] is defined as the ability of a facility to meet requirements which have been set for it. In the context of an inland terminal, it will be the ability of the system to fulfil orders. In the simplest of cases, however, two states of a facility, sometimes three, are distinguished. We distinguish the state of ability $s_1$ and inability $s_2$ and a state of partial inability $s_3$. The issue of dependability has been brought up in many studies concerning various systems or technical facilities. Dependability, susceptibility, resistance in a logistics system has been discussed in different studies [1, 2, 3]. The issue of dependability is also described in various branches of transport, e.g. in rail transport [4], air transport [5, 6, 7]. In the study by [8], an assessment method was assessed for road transport using the example of waste transport. Modelling and analysis of dependability for technical facility is described, for example, in studies by [9,10]. Dependability in intermodal transport at inland terminals is presented, for example, in studies by [11, 12] These studies present a systemic approach to dependability assessment; however, there is not processual approach to the assessment of dependability at the container terminal. Therefore, the aim of this article is to determine dependability for the load handling process in the rail-road relationship at the inland terminal. Several operations must be performed to determine the dependability of this process [6]. They are presented in the algorithm in **Figure 1**.

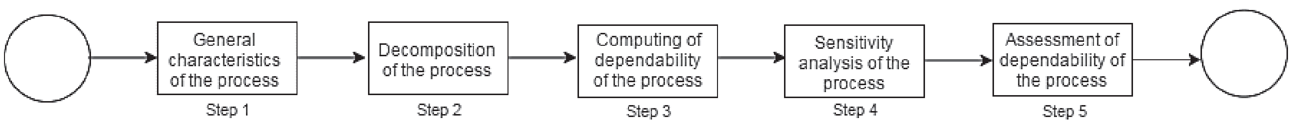


**Figure 1** Method for the assessment of the loading process dependability.
Prepared by the author on the basis of [6]

**Figure 1** presents the individual steps which need to be completed to assess the dependability of the load handling process at the inland terminal. This article presents the first three steps, i.e. general process characteristics, decomposition of the process structure as well as determination of the dependability of the handling process.

## 2. IDENTIFICATION OF THE LOAD HANDLING PROCESS

This chapter presents the characteristics of the handling process. Its general and detailed aims have been formulated. The decomposition of the process has been performed together with the presentation of the load handling process at the inland terminal using the BPMN tool (Business Process Modelling and Notation).

The inland terminal is a complex man-machine-environment system [13, 14, 15]. It is a load handling point where two basic functions can be distinguished. The first of them is the handling of integrated load units (containers, swap bodies and semi-trailers) to put them on various means of transport. The other function involves storage of these units, i.e. warehousing. Depending on the nature of the operations at the terminal, its location and on the clients' cooperation, the storage of units can last from several minutes to several days. It is also possible that units are not stored at all but unloaded from one means of transport onto another to be transported to the client. Man, information and infrastructure are situated at the entry of the system, while the performance of set orders and tasks is situated at the output. The load handling process is moving an integrated load unit (a container, semi-trailer or swap body) using load handling equipment, taking into account various means of transport. The load handling process at the inland terminal can be performed in various relationships; they are presented in the studies [16, 17].

Load handling process

General aim - load transport from point A to point B,

Detailed aim - transport of the container from the moment of entry into the system (rail transport) to the moment of leaving the system (road transport) using load handling equipment.

In this study, the case of load handling in the rail-road relationship will be considered. This process begins the moment containers $e_1$, enter the inland terminal by rail transport. Next, depending on the type of the container, whether it is empty or loaded, the process is executed in a slightly different manner.

For empty containers, their status $d_1$ is checked - i.e. whether the container is damaged. Next, the class of the container is assigned $d_{11}$, which provides information about its fitness for use. If the container is not fit, it is placed in the storage yard and explanatory procedures are undertaken to decide what to do next with this container, the process ends at this time $e_2$. If the container is fit, an appropriate class is assigned to it and the load is accepted at the terminal by entering the load into the computer system $d_{12}$. Following that, machine operators place loads $d_{13}$ at the storage yard; if a load is not placed in the storage yard, it is not regarded as an error. It is a situation in which a container from a train can be loaded directly onto a truck. Next, the terminal employee enters instruction $d_{14}$ into the system to release the container, according to the client's order. The last operation is loading $d_{15}$ of a given container onto a truck and the process $e_3$ is completed.

The long path of load handling is the handling of loaded containers. After the load arrives by rail transport $e_1$, the container status is checked in terms of damage to the frame and also broken seals. Next, the containers are entered into the system $d_{21}$. If the containers have not been cleared, customs clearance $d_{22}$ takes places, usually at the inland terminal. If the customs clearance has not taken place, this is not regarded as an error or lack of possibility to perform the task. In this study, it was accepted that a failure to perform customs clearance means that it was not necessary and such containers were cleared earlier, e.g. at the port. The next activity in the discussed process is the placement of containers in the storage yard $d_{23}$. This does not have to be considered an error, like in the case of the empty containers. Next, according to the clients' order, an instruction $d_{24}$ to release the container is issued. The last activity is loading the container $d_{25}$ onto a truck and this is the moment when the process $e_3$ ends. The structure of the load handling process is presented in **Figure 2.**

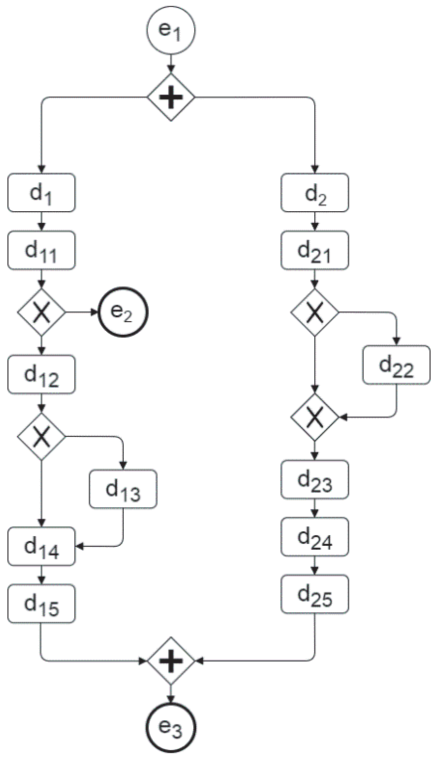


**Figure 2** Structure of the load handling process.
Prepared by the author based on [6]

An event that initiates the load handling process is known as "entering" $e_1$ (acceptance / entry of an integrated load unit into the terminal) and the end event is known as its "exit" $e_3$ (release of an integrated load unit). The analysed process also includes the end of the system marked as $e_2$, which is the end of the process in the case of a damaged, empty container. The path in the serial structure, beginning with $d_1$ applies to the handling of an empty container, while the path beginning from $d_2$ concerns the loaded container. **Figure 2** presents the serial-parallel structure of the load handling process $P_{ol}$, so it can be defined as:

$$P_{ol} = \langle E, D, R \rangle \quad (1)$$

where:

$E = \langle e_i: i=1, \dots, I \rangle$ set of events of process $P_{ol}$,

$D = \langle d_j: j=1, \dots, J \rangle$ set of operations of process $P_{ol}$,

$R = \langle r_k: k=1, \dots, K \rangle$ set of relations of process $P_{ol}$.

## 3. DETERMINATION OF DEPENDABILITY OF THE HANDLING PROCESS

Many studies on risk assessment use the following methods: event trees, Markov models, hybrid methods, computer simulations and Bayesian networks. In this study, the event tree method will be used for the assessment of the dependability of the handling process, which is often used in logistics processes. For example, in [18] the Event and Fault Tree Analysis method (EFTA) was presented which made it possible to examine the mechanism of catastrophe (100 fires) in cotton warehouses. The combination of two methods, i.e. Event Tree Analysis and Fault Tree Analysis, allowed for finding issues concerning fire safety. In the study [18], event trees were used for the analysis of inflammable materials on the basis of 580 accidents. 3 events were regarded as accidents: explosion, fire and emissions. In [19] presents an attempt to find a method to assess safety of damaged ships. This research, conducted as the method contained in the SOLAS regulation, does not include a certain type of shops. In another study [20], a risk analysis model was proposed for the assessment of information security. The study presents a combination of the Event Tree Analysis with fuzzy decision theory, twelve different possible scenarios of probability of risk occurrence were analysed using two different methods. The article [21] presents a new approach to the problem of organization and keeping distribution processes in a dependability sate in the context of accompanying information system. The analysis was performed on the basis of an actual logistics system consisting of 13 points using the Event Tree Analysis. The overview above indicates that the Event Tree Analysis tool is used by numerous authors in various logistics systems. This tool will also be used in this article to determine dependability in the load handling process. After decomposition of the structure presented in **Figure 2**, the process was divided into two parts, the first of these applies to the process of handling and empty container, while the other involves a loaded container. Using the Event Tree Analysis, both subprocesses are presented in **Figure 3** and **Figure 4**.

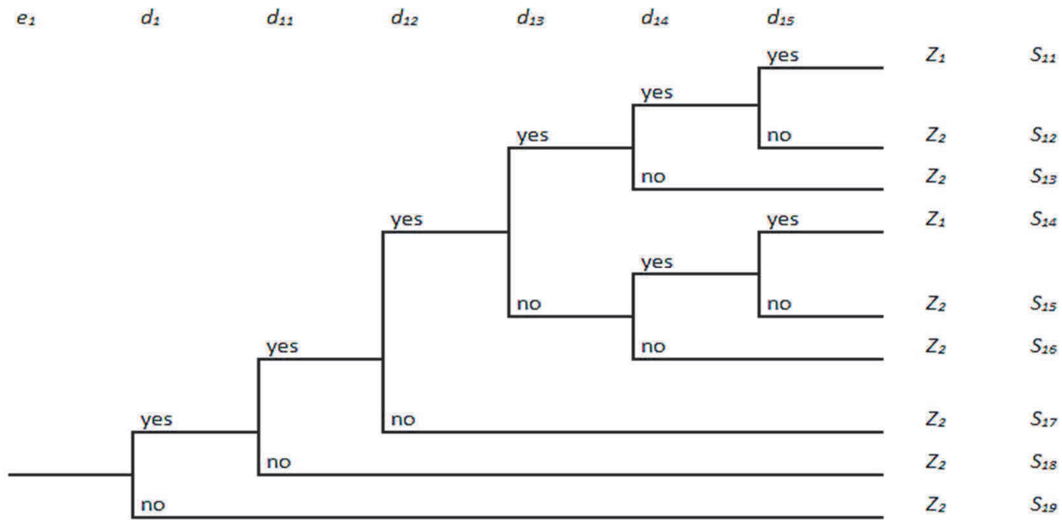


**Figure 2** Event Tree Analysis for the empty container handling process $P_{olp}$

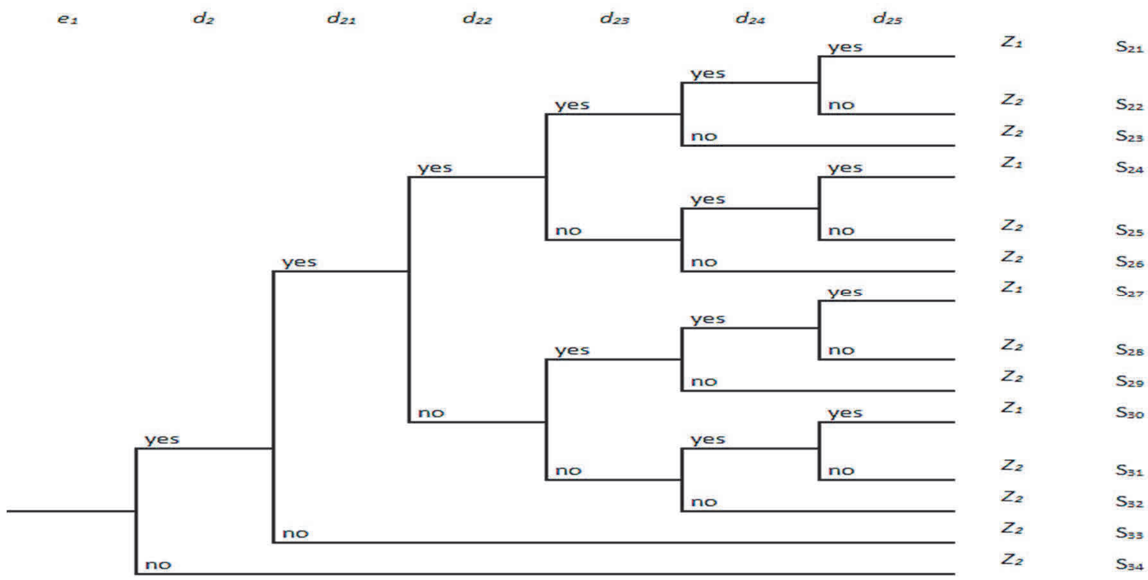


**Figure 3** Event Tree Analysis for the loaded container handling process $P_{oll}$

The ETA method was used to determine all 23 possible sequences of the handling process. The performance of sequence $S_i$, was marked as $Z_1$, a failure to perform sequence $S_i$ was marked as $Z_2$. The analysed load handling process $P_{ol}$ at the land terminal will perform its function in a reliable manner if all subordinate processes are reliable. Therefore, the dependability of the process is equal to:

$$R_{ol} = P\ (P_{olp})\ x\ P\ (P_{oll}) = (S_{11} + S_{14})\ x\ (S_{21} + S_{24} + S_{27} + S_{30}) \quad (2)$$

Research was performed at the inland terminal, making it possible to calculate the probability $P_x(d_i)$ of individual actions for an empty container and a loaded container, the $P(e_1)$ is 1. The results are presented in **Table 1**.

**Table 1** Table of probability of occurrence of individual actions

| Empty container | | Loaded container | |
|---|---|---|---|
| $d_i$ | $P_x(d_i)$ | $d_i$ | $P_x(d_i)$ |
| $d_1$ | 1.00 | $d_2$ | 1.00 |
| $d_{11}$ | 0.99 | $d_{21}$ | 0.99 |
| $d_{12}$ | 0.99 | $d_{22}$ | 0.84 |
| $d_{13}$ | 0.99 | $d_{23}$ | 0.91 |
| $d_{14}$ | 1.00 | $d_{24}$ | 0.99 |
| $d_{15}$ | 1.00 | $d_{25}$ | 0.99 |

Considering formula 2 and data from **Table 1**, dependability of the load handling process at the container terminal can be calculated, therefore:

$$R_{ol} = 0.98 \times 0.97 = 0.95 \quad (3)$$

The dependability of the handling process at the inland terminal equals 0.95. To guarantee that dependability of the handling process is as high as possible, both processes of handling an empty container $P_{olp}$ and a loaded one $P_{oll}$ must be implemented in a reliable manner. The lower probability index applies to the loaded container handling process. This value was influenced the most by actions related to customs clearance $d_{22}$, as well as the placement of containers at the storage yard $d_{23}$. This results from the fact that non-performance of actions does not mean an error, but simply the lack of necessity of performing this action.

## 4. CONCLUSIONS

Inland terminals must operate in a reliable manner to make it possible to transport loads from the shipment point to the collection point. The development of a structure of the handling process made it possible to determine two subprocesses of handling. The use of the ETA tool made it possible to determine 23 structures of the load handling process. In the analysed case, the dependability of the load handling process is influenced by the dependability of the handling process of an empty container $P_{olp}$ and a loaded container $P_{oll}$ .

## REFERENCES

[1] JODEJKO - PIETRUCZUK A., PLEWA M., Reliability-based model of the cost-effective product reusing policy, Safety and Reliability: Methodology and Applications - Proceedings of the European Safety and Reliability Conference, ESREL 2014, pp. 1243-1248.

[2] NOWAKOWSKI T., ZAJĄC M., Analysis of reliability model of combined transportation system. (2005) In the proceedings of conference ESREL, Vol. 2, No. 2005, pp. 1473-1477.

[3] KARKULA M., BUKOWSKI L. Computational intelligence methods - joint use in discrete event simulation model of logistics processes. Book Series: Winter Simulation Conference Proceedings. 2012

[4] RESTEL F.J., The Markov reliability and safety model of the railway transportation system. Safety and Reliability: Methodology and Applications - Proceedings of the European Safety and Reliability Conference, ESREL 2014.

[5] KIERZKOWSKI A., KISIEL T., The simulation model of logistic support for functioning ground handling agent, taking into account the probabilistic time of aircrafts arrival. CLC 2013: Carpathian Logistics Congress - Congress Proceedings. pp: 463-469

[6] KIERZKOWSKI A., KISIEL T., Simulation model of security control system functioning: A case study of the Wroclaw Airport terminal, Journal of Air Transport Management (2016), http://dx.doi.org/10.1016/j.jairtraman.2016.09.008

[7] KIERZKOWSKI A., Method for management of an airport security control system, Proceedings of the Institution of Civil Engineers - Transport (2016), http://dx.doi.org/10.1680/jtran.16.00036

[8] GIEL R., MŁYŃCZAK M., PLEWA M. The assessment method of the organization of municipal waste collection zones. Theory and engineering of complex systems and reliability: proceedings of the Eleven International Conference on Depandability and Complex Systems DepCoS-RELCOMEX, 2016, Brunów, Poland.

[9] VALIS D., ZAK L., et. al, Selected mathematical functions used for operation data information, In 22nd Annual Conference on European Safety and Reliability (ESREL), Amsterdam, Netherlands, September, pp. 1303-1308.

[10] VALIS D., ZAJĄC M. Vulnerability of container terminal infrastructure. Niezawodność infrastruktur krytycznych. Proceedings of XLI Winter School of Reliability.

[11] KIERZKOWSKI A., ZAJĄC M, Analysis of the reliability discrepancy in container transshipment. In 11th International Probabilistic Safety Assessment and Management Conference and the Annual European Safety and Reliability Conference, 2012. pp. 826-831.

[12] ZAJĄC M., Application of a five-phase reliability model of combined transportation system, European Safety and Reliability Conference (ESREL 2006) Location: Estoril, PORTUGAL Date: SEP 18-22, 2006r.

[13] ZAJĄC M., ŚWIEBODA J. The method of error elimination in the process of container handling. In Military Technologies (ICMT), 2015 International Conference on IEEE, 2015, pp. 1-6.

[14] WOŹNIAK W., STRYJSKI R., MIELNICZUK J., WOJNAROWSKI T. Concept for the Application of Genetic Algorithms in the Management of Transport Offers in Relation to Homogenous Cargo Transport. (2015) In 26th IBIMA Conference, Madrit pp. 2329-2339.

[15] WOŹNIAK W., WOJNAROWSKI T. The method for a fast selection of the profitable transport offers derived from the freight exchange market. Proceedings of the 25th International Business Information Management Association Conference - Innovation Vision 2020: From Regional Development Sustainability to Global Economic Growth, IBIMA 2015 Amsterdam.

[16] ŚWIEBODA J., ZAJĄC M. Analysis of Reshuffling Cost at a Container Terminal. In: Dependability Engineering and Complex Systems. Springer International Publishing, 2016. p. 491-503.

[17] ZAJĄC P. Evaluation method of energy consumption in logistic warehouse systems, Springer, 2015

[18] WEN-HUI J. Study on Fire Risk and Disaster Reducing Factors of Cotton Logistics Ware-house Based on Event and Fault Tree Analysis. Procedia Engineering 135.2016. pp. 417-425.

[19] GERIGK M.K. Modeling of event trees for the rapid scenario development, Safety and Reliability: Methodology and Applications - Nowakowski et al. (Eds), ESREL 2014. pp. 275-280.

[20] GUSAMO et al. Information security risk analysis model using fuzzy decision theory. International Journal of Information Management. 36(1). 2016. pp. 25-34.

[21] WOŹNIAK W., STRYJSKI R., MIELNICZUK J., WOJNAROWSKI T. The concept of the profitability for the transport orders acquired from the transport exchange market. Proceedings Of The 27th International Business Information Management Association Conference. IBIMA 2016; Milan; Italy 2016.