TALLINN UNIVERSITY OF TECHNOLOGY
DOCTORAL THESIS
7/2019

Risk Management Model: Human Factor Related Risks and Their Impacts in Road Transportation of Dangerous Goods

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TTÜ PRESS

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This dissertation was accepted for the defence of the degree 03/01/2019

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Defence of the thesis: 06/02/2019, Tallinn

Declaration:
Hereby I declare that this doctoral thesis, my original investigation and achievement, submitted for the doctoral degree at Tallinn University of Technology has not been submitted for a doctoral or equivalent academic degree.

Jelizaveta Janno

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signature

ISSN 2585-6898 (publication)
ISBN 978-9949-83-388-7 (publication)
ISSN 2585-6901 (PDF)
ISBN 978-9949-83-389-4 (PDF)

TALLINNA TEHNIKAÜLIKOOL
DOKTORITÖÖ
7/2019

Riskide haldamise mudel: inimteguriga seotud riskid ja nende mõjud ohtlike kaupade autoveol

JELIZAVETA JANNO

TTÜ KIRJASTUS

Contents

List of Publications

The listed publications below are related to the topic of research and the basis of this thesis. The publications are peer-reviewed papers published and presented here to fulfil the requirements for the PhD degree of Tallinn University of Technology.

Copies of the publications constituting the thesis are included in the appendixes and marked in Roman numerals as follows:

- Janno, J., Koppel, O. (2017). Human Factor as the Main Operational Risk in Dangerous Goods Transport Chain. In: D. Dujak (Ed.). Proceedings of the 17th International Scientific Conference Business Logistics in Modern Management (pp. 63-78). Osijek: Faculty of Economics in Osijek. (ETIS 3.1.).
- Janno, J., Koppel, O. (2018). Interactive Teaching Methods as Human Factors Management Tool in Dangerous Goods Transport on Roads. In: Auer M., Guralnick D., Simonics I. (Ed.). Teaching and Learning in a Digital World. ICL 2017 (619-628). Springer International Publishing AG. (Advances in Intelligent Systems and Computing; 715). (ETIS 3.1.).
- Janno, J., Koppel, O. (2018). Operational Risks in Dangerous Goods Transportation Chain on Roads. LogForum. Scientific Journal of Logistics, 14 (1), pp. 33-41. (ETIS 1.2.).
- Janno, J.; Koppel, O. (2018). Managing Human Factors Related Risks. The Advanced Training Model in Dangerous Goods Transport on Roads. International Journal of Engineering Pedagogy, 8 (4), pp. 70-88. (ETIS 1.1.).

Author's Contribution to the Publications

The author's contribution to the papers used in this thesis are as follows:

- **Publication I.** The research plan was designed in co-operation with the supervisor Dr Ott Koppel and in consultation with co-supervisor Professor Emeritus, Dr Jüri Laving. The data collecting on the identification of OPRs of different parties within the transportation chain was carried out by the research team guided by the author. The data processing and the analysis of risks were carried out based on the methodology agreed upon by the author.
- **Publication II.** The research plan was designed in co-operation with the supervisor Dr Ott Koppel. The data collecting on learning methods of participants of DGTC was carried out by the research team guided by the author. The author performed the data analysis implementing qualitative comparison analysis (QCA) and interpreted conclusions out of the analysis.
- **Publication III.** The research plan was compiled by describing the central issues of OPRs within the DGTC and completing results with common shares related to teaching-learning methods. Data processing and assessment of the results were carried out by the author and looked over by the supervisor Dr Ott Koppel. The author performed the data analysis in co-operation with the co-author.
- **Publication IV.** The idea focused on combining OPRs of dangerous goods transportation (DGT) with best-fit teaching methods with the emphasis on blended learning. The mentioned teaching method was framed in cooperation with supervisor Dr Ott Koppel. The design of the research plan was compiled, and data was collected in the form of interviews. Data processing and assessment of the results were carried out by the author and looked over with the co-author. The data processing and the analysis of risks were carried out based on the methodology agreed upon by the author.

All courses of action are risky, so prudence is not in avoiding danger (it is impossible), but calculating risk and acting decisively. Make mistakes of ambition and not mistakes of sloth. Develop the strength to do bold things, not the strength to suffer.
(Machiavelli, 2015)

Introduction

Dangerous goods (DG) are materials that, due to their inherent characteristics, can form a risk to people, animals or the environment. To diminish these risks, they are subjected to a series of regulations and must be transported according to a set of official rules on the international and local basis. The transportation of DG in Europe is subjected to different regulations and United Nations (UN) recommendations as well as additional regulations on a national basis which may differ slightly from country to country. The high amount of regulations that have to be considered for the transportation of DG, together with the human factor and their possible errors, make it an inefficient and venturesome transportation chain. Besides, a high amount of infractions of transport codes, technical requirements occur every day, leading some of them to the immobilisation of the vehicle and to delays in the shipment.

The increase in chemical sales supposed in 2015 an 8.8% increase in road transport, with 82 billion ton-kilometre, compared with 2014 (Eurostat, 2016). Moreover, the higher the number of vehicles transporting DG the higher the probability of having a higher number of accidents. In the USA, from 2007 to 2016, 164 865 incidents were related to the transportation and handling of DG (U.S. Department of Transportation, 2017). In Europe, there is not a broad accident statistic in this field available. On a national scale, it is shown that DG accidents on roads make up no more than 0.1% of total accidents in Estonia (Eurostat, 2016). However, even though this probability is minimal, the consequences are essential when dangerous substances are involved (Janno, Koppel, 2018c). Due to the chemical characteristics of goods transported, the involvement of DG in an accident often leads to fires, explosions and the release of toxic gases, producing severe consequences to human health, property and the environment.

When a dangerous event happens, caused by a human error, and involving DG, the consequences cannot sometimes be reduced by the moment it has happened. It is therefore essential to apply the preventive measure to reduce the probability of occurrence, or/and magnitude of the consequences (Janno & Koppel, 2017a); (Tomasoni, 2010). The field of research of this study is the dangerous goods transportation (DGT) by roads. Within this thesis, the author **discusses the problem that the risk management in the dangerous goods transportation chain (DGTC) with regards to human-related risks is short-sighted and is focused on the elimination of consequences instead of on ensuring safety proactively**. The thesis **aims to develop a universal risk management model with an emphasis on managing the human factor related risks.**

The awareness of DG production, loading, unloading, storage, and transport, gives the challenge to use DG in the following manner:

1) to optimise, prevent cost and time delays, as well as sustainably avoid waste;
2) to reduce the human display to the possible harmful effects of DG (*e.g. by* reducing emissions and spills) safely and sustainably;
3) to quantify the potential damage or consequences linked to its use, for present and future generations to avoid accidents, injuries, and deaths.

DGTC is a complex system due to the aspect of mobility and dynamicity of its hazard, but also because of external and boundary conditions, and also due to the mode of transport, (*e.g.* the nature of the materials transported, the state vehicle, weather condition, condition of transport infrastructure, proximity to urban centres, traffic density *etc.*) (Tomasoni, 2010). A transport containing DG can have severe effects on the environment if an accident occurs and they often incur a higher cost for the society than non-dangerous goods accidents (Ellis, 2002); (Janno; Koppel, 2018b). Due to this reason, it is essential to focus on improving the efficiency and security of DGT and avoid potential accidents (Janno; Koppel, 2018b). According to the experience and feedback from the carrier companies of Estonia, there is around one-third of the controlled DGT on Estonian roads that have a violation of the law. Most of them are related to improper and incomplete transport documentation (Janno & Koppel, 2017a).

In addition to transportation itself, the efficient and secure transportation is also the demand of the industry. Since companies are producing and sending smaller quantities of goods more frequently, transportation process needs to be more efficient at any stage, and there exists no room for accidents which means that the safety and security must be held at an acceptable level (Svensson & Wang, 2008). Herein, the DGT involves many procedures committed by different parties within the DGTC. Traditionally it starts with the loading procedure at the consignor's and ends with the unloading of the good at the consignee's place. Meanwhile, there may be several loadings/unloadings at intermediate destinations, as well as one or several freight forwarder companies and carriers involved.

A combination of human-related risks while DGT and their management are under the focus of the present thesis which has been conducted on an example of an existing DG transportation system of Estonia mainly. Within the study, previous work in the area of risk management of DGT on roads will be complemented focusing on human-related operational risks (OPRs). The thesis will contribute with input by improving process map case flows of the transportation chain, concerning single mode transports and of DG. As an additional limitation, this study focuses on managing risks when DG is in packaged form, *i.e*., transportation on roads related to transportation in bulk is excluded.

It has been reported that human errors are in fact the most common individual cause of DG related accidents. According to European Communities (EC) data on road transportation of DG it was found that almost half of the accidents were caused by a human error or at least error due to human factor was a significant contributor for the accident, whereas at the same time only some 8% of accidents were caused by a technical failure (Eurostat, 2016); (Janno & Koppel, 2017a). Human mistakes during loading, unloading and transportation operations with DG can compromise human health, environment and property involved. Therefore, risk preventive means concerning procedures, as well as personnel and parties engaged within the DGTC have to be studied jointly to manage risks consciously and sustainably within the entire DGTC. Today, there is no integrated approach to the human factor related risks within the DGTC with the focus on training and educating personnel.

The risk management model presented as a final result will provide valuable information concerning the bottlenecks when transporting DG from the perspective of its different parties and will be able to help to foresee and therefore manage specific risks related by providing the precise guidance on how to train personnel. The *Figure 1* below illustrates the relation of structure of the dissertation with research questions (RQs) and publications To achieve the posted goal, the following RQs are presented and answered in the following topics of current thesis:

1) **What defines the process of risk management associated with the transportation of DG?** (RQ1)

2) **What are the most common risks related to human factors when transporting DG by roads?** (RQ2)
3) **What are the possibilities to manage DG risks during transportation by roads?** (RQ3)
4) **How can the risk management of DG be improved at the level of training?** (RQ4)

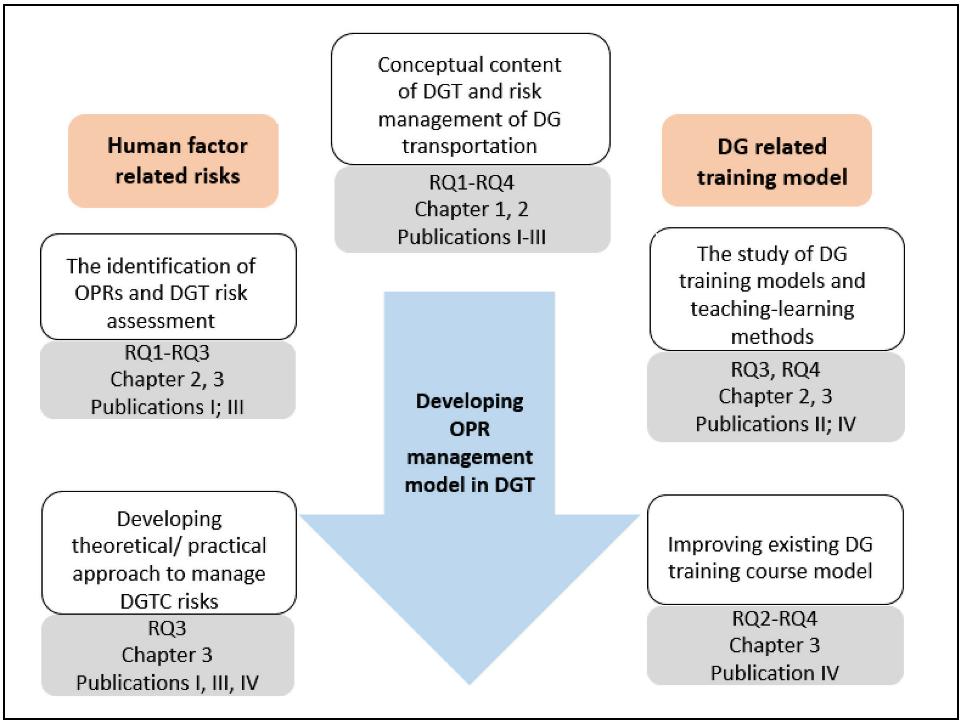

Figure 1. Structure of dissertation in relation to RQs and publications (author's compilation).

This thesis covers international transportation of packed DG by roads with some extension to intermodal transportation where the empirical study is conducted mainly on Estonian companies that represent the typical parties of a transportation chain. Other modes of transportation, as well as the shipping of DG in bulk, is not in the scope of current research. The reasons for focusing on road transportation with some seaway combination is based on the fact that these are the most common ways to transportation DG and takes up the leading share of packed DGT among all the modes.

The universality and generalisation of results are possible due to the international element of DGT and to confirm that the results of this study are therefore internationally validated. The proposed approach for managing risks related to human factors when transporting DG by roads can be recommended for an expanded circle of participants of DGT as also trainer provider companies and supervising institutions (*e.g.* Estonian Road Administration). The latter can implement the risk management model to raise awareness and propose a selection of appropriate risk managing solutions with regards to the human factor related risks. The primary results of the study have been published in peer-reviewed journal papers and presented at conferences on logistics and transportation issues as well as on topics related to learning and teaching methods.

Abbreviations

ADR	European Agreement concerning the International Carriage of Dangerous Goods by Road
CLP	Classification, Labelling and Packaging of substances and mixtures
DG	Dangerous Goods
DGSA	Dangerous Goods Safety Advisor
DGT	Dangerous Goods Transportation
DGTC	Dangerous Goods Transportation Chain
EC	European Commission
EDI	Electronic Data Interchange
EDP	Electronic Data Processing
GDP	Gross Domestic Product
HAZMAT	Hazardous Materials
HSA	Health and Safety Authority
IBC	Intermediate Bulk Container
IMDG Code	International Maritime Dangerous Goods Code
KPI	Key Performance Indicator
LQ	Limited Quantities
LPG	Liquid Petroleum Gas
LSP	Logistic Service Providers
MSDS	Material Safety Data Sheet
NAFTA	North American Free Trade Agreement
Q&A	Questions and Answers
QCA	Qualitative Comparison Analysis
OPR	Operational Risk
PPE	Personal Protective Equipment
PL; PPL	Peer Learning; Peer Project Learning
RQ	Research Question
STEM	Science, Technology, Engineering, and Mathematics
TIP	Transport Integrated Platform
UN	United Nations
UNECE	The United Nations Economic Commission for Europe

1 Dangerous Goods Transportation Chain (DGTC) Risks

1.1 Dangerous Goods Transportation (DGT) by Road

1.1.1 Essentials of DGT

The improvement of road traffic safety is one of the most critical objectives for transportation policymakers in contemporary society and represents a strategic issue for enhancing life quality (Janno & Koppel, 2017a). This is strongly supported by the fact that many studies regarding DGT risk assessment focus on technical aspects and quantitative methods rather than on risks related to human factor that is studied and analysed by applying qualitative methods to formulate outcomes (Janno & Koppel, 2017a); (Janno, Koppel, 2018c). According to the qualitative studies of managing risks in DGT (Krasjukova J. , 2010), there are three main decision criteria in this sphere, which can be accepted as a selection of preventive means derived out of technical, procedural or personnel factors (Janno & Koppel, 2017a). Particular risk preventive means related to the human factor in road transportation of DG that consequently refer to possibly related OPRs (Janno & Koppel, 2017a) are structured as shown in the following *Table 1*.

Table 1. Non-technical risk preventive means in the DGT.

Risk preventive means concerning procedures	**Risk preventive means concerning staff of parties involved**
loading procedures at loading areas according to safety requirements	ADR driver training course
labelling of packaging (clear and easily identifiable labelling of cartons to reduce the risk of picking errors)	safety adviser course for the transportation of DG by road (freight forwarders and logisticians)
loading order and placement of dangerous load in the transport unit	
restricted parking authorisation	work safety and ergonomics training for personnel
fixed traffic routes with the necessity to get the confirmation from institutions in control	
additional road permissions system for third countries	
higher prices for ferry tickets and tunnel passes	economic driving training for drivers
daily temporal and seasonal driving bans	
special procedures when an accident occurs	
compulsory transport documentation and remarks on documents	performance appraisals with personnel
DG shipment tracking system	
marking and labelling the shipment and vehicle	

Source: (Erceg & Trauzettel, 2016); (Janno & Koppel, 2017a); (Janno, Koppel, 2018c); (Krasjukova J. , 2010); (Vikulov & Butrin, 2014)

Concerning the primary research object of the current thesis, specific human-related risk preventive means are defined above. These preventive means are the main ones which are widely in use in the road transportation sector and have become as binding requirements and mandatory procedures in the overall process of DGT (Janno, Koppel, 2018c).

The transportation of DG is an activity which is increasingly international and multi-methodological (Janno & Koppel, 2017a). The transportation of DG by roads in Europe is subjected to different regulations and the United Nations Economic Commission for Europe (UNECE) recommendations: as the UN Manual of Tests and Criteria; the UN Orange Book (UN Recommendations on the Transport of Dangerous Goods - Model Regulations); the European Agreement Concerning the International Carriage of Dangerous Goods by Road (ADR) (Waight, 2015); Directive 2008/68/EC for the inland transportation of DG and Regulation 1272/2008/EC on classification, labelling and packaging (CLP).

In European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR) appear the limitations applicable to the various operators of the logistics chain (buyers, transporters, manufacturers of packaging and tankers *etc.*) giving specific treatment to their field of activity (Janno & Koppel, 2017a); (Lindström & Otterström, 2018). Laws and regulations on the use, loading, unloading, storing, transporting, and handling of DG may differ depending on the operation, the status of the material, and the modality of transportation used (Janno & Koppel, 2017a). Most countries regulate some aspect of DG at UNECE level (United Nations, 2009), that is the most widely applied regulatory scheme. The UN Recommendations on the Transport of Dangerous Goods form the basis of several international agreements, such as UNECE regulations and many national laws (Janno & Koppel, 2017a); (United Nations, 2015).

1.1.2 Dangerous Goods (DG) Transportation Process

Major activities in logistics include both inbound logistics and outbound logistics, and transportation is one of two critical functional areas besides inventory (Choi, Chiu, & Chan, 2016); (Janno & Koppel, 2017a). A transportation chain maps the whole route between the place of origin and the destination as well as describes the transportation for each route segment along the transportation route (Janno & Koppel, 2017a). A typical DGTC may include many parties, from consignors and consignees, freight forwarders and carrier companies (Janno & Koppel, 2017a). From the perspective of the present research, transportation chain starts at consignor's with loading and ends at consignee's with the unloading procedure (Janno & Koppel, 2017a). Considering the possible risks with regards to DG, it is vital for the transportation chain to operate efficiently and effectively by the all corresponding members functioning correctly. In other words, if any member fails to perform, the system will easily collapse and fail to achieve its objectives (Choi, Chiu, & Chan, 2016); (Janno, Koppel, 2018c).

As DG and their transport need special handling and attention due to their risk for the environment and health of people, the training of any persons having to deal with those goods is essential for safe processing (Janno; Koppel, 2018b); (Klaus & Krieger, 2008). Common legal requirements (ADR) states in details that drivers when transporting DG (with small exceptions) must undergo training in the form of a course approved by the competent authority. Concerning chapter 1.3 of the ADR, every employee, which has to commit the duties of DG regulations, needs to be specially trained (Janno; Koppel, 2018b). Other parties involved in operations with DG in packaged form can be: manufacturer or owner of DG, persons carrying out forwarder duties, persons writing and preparing transport documents, persons working for the DG receiving, persons committing packaging procedures, vehicle drivers, who do not need an ADR certificate, persons carrying out carrier and vehicle owner duties (Janno; Koppel, 2018b).

Within the DGTC, the participants with specific legal duties are the consignor, carrier, driver and vehicle crew, packer, filler, loader, unloader, consignee and the DG safety advisor (DGSA). There are generally several duty holders in a particular transportation chain process or even procedure. A person or company can be one or may assume the responsibility of several duty holders depending on the specific activity (Health and Safety Authority, 2012). In the scope of many parties involved in the DGTC, the regulatory issues on information flow along with physical flow may be complicated. According to the *Figure 2* below, solid lines represent the information flow, as dashed lines stand for the physical flow of cargo in the transportation chain with the part of the maritime transport. As the producer in chemical industry (the consignor) is obligated to issue for each product the Material Safety Data Sheet (MSDS) which records safety information to meet the particular needs for safe handling in industry and the companies of customers, and also for safe transportation by different means of transportation in accordance with the relevant DG code. While for the customer (the consignee) the critical safety information is presented in the MSDS, to the shipper the information for safe transport of DG is usually forwarded as a DG declaration (Arro & Ojala, 2007).

According to following *Figure 2* the MSDS is an input into DG declaration document that gives the hazard description according to the relevant DG code that stipulates the safe transportation rules for this particular type of DG, as the International Maritime Dangerous Goods Code (IMDG Code) regulates the transportation of DG in packaged form in maritime, rail as well as road transport. The correctly filled out DG declaration is a vital source of information to facilitate a high safety level at sea. The DG declaration shall be submitted to the master of the ship by the consignor (or his authorised representative before the loading of the ship). The MSDS may be used for issuing the DG declaration if the safe transport information in the MSDS is not in contradiction with that in the appropriate DG code (Arro & Ojala, 2007).

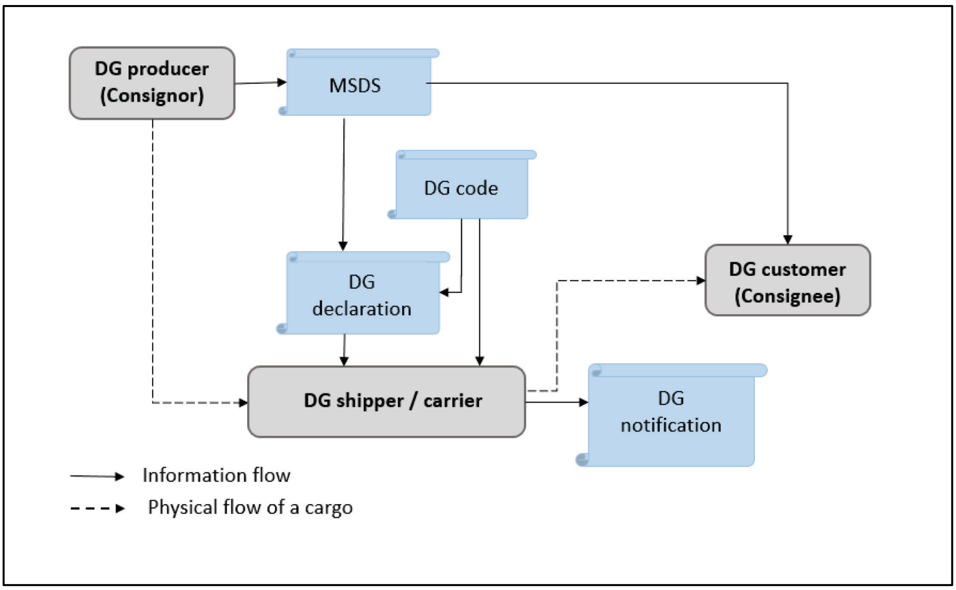

Figure 2. Safety information flow in the DGT ((Arro & Ojala, 2007) C.; adapted by the author).

The DG code includes specific codes with regards to different modes of transportation packaged form as well as solid bulk cargo. The DG code with its specifications with regards to the particular good is a primary input into forming MSDS. These information carriers are vital when preparing the DG declaration if needed for DG shipper/carrier. As according to the European Commission (EC) Directive 2002/59/EC, all DG on ships must be notified to the designated authority before the departure from the berth or in time before the arrival at the port. This aspect is also relevant with regards to intermodal transportation mode. It is essential that the information concerning DG in the notification is the sum of relevant details in DG declarations submitted to the master of the ship before loading. The purpose of DG notifications from ships is to provide land-based rescue teams with factual information about DG on board ships in an emergency at sea (Arro & Ojala, 2007).

1.1.3 Roles and Responsibilities of Participants in DGT

The UN Recommendations on the Transport of Dangerous Goods — Model Regulations outlines the steps that need to be taken to ensure the safe carriage of DG (United Nations, 2015). Most of the international or main regional requirements that reflect the UN's provisions, generally do not detail the responsibilities of those involved (Janno & Koppel, 2017a); (Tomasoni, 2010). ADR Chapter 1.4 cites the arrangements concerning safety which must be taken into account by every person involved in the transportation of DG (Janno & Koppel, 2017a). In this chapter the carriers and all others involved in the transportation of DG at high risk are required to adopt, carry out and follow a safety plan that has to include:

1) specific roles of responsibility in the matter of safety;
2) the recording of the DG in question and their typology;
3) the monitoring of the vehicles;
4) definition of the measures to adapt to reduce the safety risks;
5) efficient procedures to identify and face threats, safety violations and incidents connected to safety;
6) the process of evaluation and verification of the safety plans;
7) measures to assure the physical protection of information related to the transport contained in the safety plan;
8) measures to ensure that the distribution of information related to the transport operation, provided in the safety plan, is limited according to necessity (Janno & Koppel, 2017a); (Tomasoni, 2010); (ADR, 2017).

According to general safety measures ADR addresses that the participants in the carriage of DG shall take appropriate actions according to the nature and the extent of foreseeable dangers, to avoid damage or injury and, if necessary, to minimise their effects (Janno & Koppel, 2017a). They must, in all events, comply with the requirements of ADR in their respective fields. When there is an immediate risk that public safety may be endangered, the participants must immediately notify the emergency services and must make available to them the information they require to take action (Waight, 2015). All participants must ensure to take all necessary efforts to reduce the risk of an incident involving DG. In general, a participant must:

1) ensure that a person employed, and whose duties concern the carriage of DG, has received the appropriate training;
2) keep records of such training;
3) comply with specified legal responsibilities;

4) take proper measures to avoid damage or injury;
5) notify emergency services of an immediate risk to public safety (Health and Safety Authority, 2012).

With regards to DGT on roads, there are generally same parties involved as when transporting general goods (Janno & Koppel, 2017a). The main differences are noted related to the responsibilities of participants in the carriage of DG and obligations on those that ADR considers the main participants (Janno & Koppel, 2017a). According to ADR there are mentioned main parties (consignor; carrier; consignee) and so-called other parties (*e.g.* loaders of packages; packers; unloaders of packages *etc.*) (Janno & Koppel, 2017a) as shown in the following *Figure 3.*

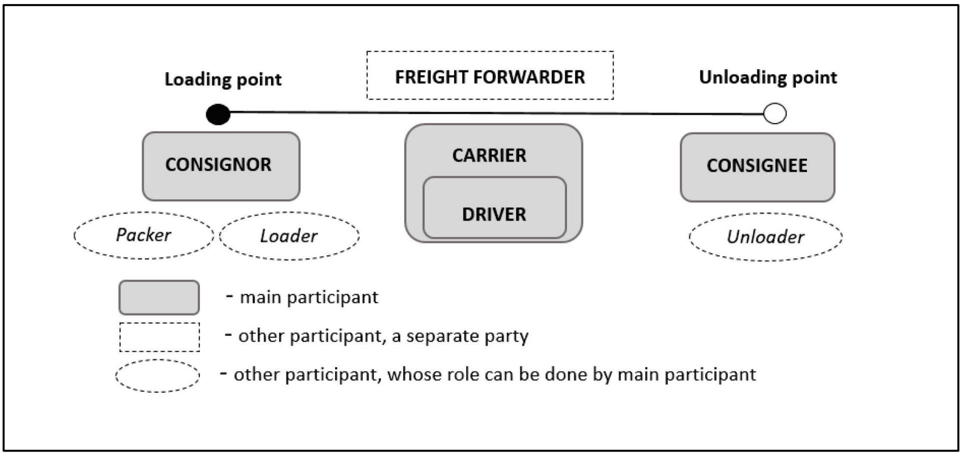

Figure 3. Participants of the DGTC (author's compilation).

The consignor is the enterprise handing over, or that has control of the DG before transportation and may act either on its behalf or for a third party. The consignor may use the services of other participants (packer, loader, *etc.*), then appropriate measures to ensure that the consignment meets the requirements of ADR regulations. However, in many cases, the consignor may rely on the information and data made available by other participants (Health and Safety Authority, 2012). With regards to procedures at consignor related to loading there are additional procedures concerning final packaging, filling (*e.g.* IBC) and loading into a transport unit. The packer is the participant, an individual or business, who is responsible for the final packaging of DG before transport. In many cases, the manufacturer (the consignor) performs this role. The loader (in many cases the consignor) is the participant, an individual or business, who is responsible for loading DG onto a vehicle before transport (Health and Safety Authority, 2012).

The central role within the DGTC maintains to the carrier and the driver separately. Considering that these members of DGT have the most direct contact with DG during the entire transportation process, in this context, it is essential to focus on their specific responsibilities. The carrier is the enterprise performing the physical carriage of DG in or on a vehicle (with or without a transportation contract), *e.g*. logistics company, courier, vehicle owner/operator (who may also be the consignor or driver, as a self-employed vehicle owner/operator) (Health and Safety Authority, 2012). The carrier must in particular:

1) ascertain that the DG are authorised for carriage following ADR (using confirmation from the consignor, or otherwise);

2) ascertain that the consignor has provided all information prescribed in ADR related to the DG before carriage, that the prescribed documentation is on board the transport unit or if electronic data processing (EDP) or electronic data interchange (EDI) techniques are used instead of paper documentation, that data is available during transport in a manner at least equivalent to that of paper documentation;
3) ascertain visually that the vehicles and loads have no apparent defects, leakages or cracks, missing equipment, *etc*.; ensure this is carried out by putting in place a monitoring/audit procedure to assess vehicles and equipment;
4) ascertain that the date of the next test for tank-vehicles, battery vehicles, demountable tanks, portable tanks, tank-containers and multiple element gas containers has not expired and build inspection checks into regular monitoring/audit function;
5) verify that the vehicles are not overloaded;
6) ascertain that the danger labels and markings prescribed for the vehicles have been affixed correctly;
7) ascertain that the safety equipment specified in the written instructions for the driver is on board the vehicle (including fire extinguisher requirements);
8) comply with security measures as appropriate;
9) ensure emergency procedures are in place;
10) ensure both driver and crew are suitably trained in advance of any work involving DG; drivers must also hold an appropriate driver training certificate (Health and Safety Authority, 2012).

There are even more participants involved in the safe transportation of DG that are not mentioned in ADR Chapter 1.4 on the safety obligations of the participants. From the perspective of DGT, the foremost amongst these participates are drivers, who are not mentioned but whose safe driving is perhaps one of the most critical factors for ensuring the safety of the general public during the transportation of DG (Janno & Koppel, 2017a); (Waight, 2015).

The driver is usually responsible for checking that they have the right fire extinguishers, in the correct condition, as well as the other emergency and personal protective kit prescribed in ADR (Janno & Koppel, 2017a). The driver is also usually considered responsible for ensuring the proper paperwork for themselves, their load and, if applicable, the vehicle is present and in order (Janno & Koppel, 2017a); (Waight, 2015). The driver is the participant who is in immediate control of the transport unit and fulfils the driving function. Crew members also have responsibilities, and all crew members must have appropriate training in line with their duties and responsibilities (Health and Safety Authority, 2012). Drivers and crew members must in particular:

1) ensure all crew members to carry on their ADR driver training certificate (drivers) and photo identification;
2) crew members must read and understand transport documentation provided in advance of any transport operation. If an issue should arise with the documentation the crew member must raise and rectify any matter before driving the vehicle;
3) keep readily available in the cab the emergency instructions in writing;
4) check to ensure all vehicle safety equipment and Personal Protective Equipment (PPE) is provided and raise immediately any deficiency or missing items with the carrier;

5) check and ensure the vehicle is plated correctly, placarded and marked; ensure that orange plates, placards and marks are kept clean; also, when not required ensure to remove or cover plates, placards and marks;
6) do not load damaged or leaking packages;
7) do not drive a vehicle that is suspected to be not in compliance with national legislation or the ADR; raise and rectify any issues before driving the vehicle.
8) apart from members of the vehicle crew, no passengers may be carried in transport units carrying DG;
9) members of the vehicle crew must know how to use the fire-fighting extinguishers;
10) crew members may not open a package containing DG;
11) any torch or lighting apparatus used must not exhibit any metal surface liable to produce sparks;
12) smoking must be prohibited during handling operations in the vicinity of vehicles and inside the vehicles;
13) the engine must be shut off during loading and unloading operations, except where the engine has to be used to drive the pumps or other appliances for loading or to unload the vehicle and the laws of the country in which the vehicle is operating permit such use;
14) no vehicles carrying DG may be parked without the parking brakes being applied; trailers without braking devices must be restrained from moving by applying at least one-wheel chock;
15) in the case of a transport unit equipped with an anti-lock braking system, consisting of a motor vehicle and trailer, the electrical connections must be connecting the towing vehicle and the trailer at all times during carriage;
16) if responsible for tank filling or emptying, as may be appropriate *e.g.* for flammable liquids, ensure that there is a good electrical connection to the earth before the emptying or filling operation;
17) ensure no DG residues of the filling substance adheres to the outside of tanks filled or emptied;
18) if involved in the loading operation, initially or during the transport operation, DG must be appropriately secured to the vehicle; if released to unload part of the shipment, remaining DG must be re-secured to the vehicle;
19) driver to ensure vehicle supervision provisions on regular basis filler (Health and Safety Authority, 2012).

Another party whose safety obligations are not mentioned in ADR are freight forwarders. Freight forwarders might not come into direct contact with the goods, even though they will be passing on the documents and instructions to those who are. The role of the freight forwarder is vital in transmitting critical information within the transportation chain and should not be underestimated (Janno & Koppel, 2017a). Other parties that may also be important but that are not directly included into the DGTC are the following:

1) those who manufacture, test and certify packages (incl. tanks and bulk vehicles);
2) those who test DG for their properties;
3) those who provide a classification of the goods;
4) cleaners and decontamination workers;
5) manufacturers and distributors that use other parties (such as freight forwarders) to consign on their behalf (Janno & Koppel, 2017a); (Waight, 2015).

Businesses, whose activities include the consignment, carriage or the related packing, loading, filling or unloading, of DG must appoint one or more DG safety advisers (DGSA). The only duty holders that this obligation applies to, however, are consignors, carrier companies and consignees. For example, a company which only loads and unloads, as well as forwards freights does not need to appoint a DGSA (Health and Safety Authority, 2012).

The role of the DGSA is to help control the risks inherent in such activities concerning people, property and the environment. DGSA generally complete intra-company training (not mandatory), but must be successful in passing the specified exam(s) to gain the qualification, which must be renewed every five years. There are exemptions provided so that businesses with limited exposure to these activities are not required to appoint a DGSA formally (Health and Safety Authority, 2012). These businesses, however, may still require support from a DGSA from time to time. A formally appointed DGSA may be an employee, the head of the company or an external consultant. The DGSA must be suitably qualified and have access to all relevant aspects of the business to carry out this function (Health and Safety Authority, 2012). The primary duties of a DGSA are as follows:

1) monitoring compliance with the requirements governing the carriage of DG;
2) advising its undertaking on the transport of DG;
3) preparing an annual report to the management of its company or a local public authority, as appropriate, on the undertaking's activities in the carriage of DG; the annual reports must be preserved for five years and made available to the national authorities at their request (ADR, 2017); (Health and Safety Authority, 2012).

1.2 Risk Management of DGT by Road

1.2.1 Risk Management Technologies

Supply chains evolve into collaboration networks with a more complicated pattern, the complexity of transportation chains grows with this hand in hand. This leads to the fact that the transportation process with its parties and operations involved is open to many types of risks. The risk management in DGT has been studied from a different perspective and following the topic studied the risk management related to the transportation system in general (Janno; Koppel, 2017b). The problem of risk management is a global problem that requires comprehensive solutions (Stažnik, Babić, & Bajor, 2017). According to the classical definition of a risk, it is a measure of frequency and severity of harm due to a hazard. The hazard in this context is the presence of DG having toxic, explosive, and/or flammable characteristics with the potential to cause harm to humans (and property or the environment if a broader context is considered). In the context of public safety, the risk is commonly characterised by fatalities (and injury) to members of the public (Janno, Koppel, 2018c); (Risk Assessment – Recommended Practices for Municipalities and Industry, 2004).

Risk arising by DGT represents a particular threat which needs strategies and tools to reduce risk rate of society, property and environment (Conca, Ridella, & Sapori, 2016). Several factors contribute to making it difficult to assess risk in transporting DG, including:

1) the diversity of hazards in addition to the main danger characteristic: the substances transported are multiple and can be flammable, toxic, explosive, corrosive or radioactive materials at the same time;

2) the diversity of accident sites: highways, county roads, local roads, in or out of town (75% of road accidents take place in the open country), facilities, pipelines, *etc.*;
3) the diversity of causes: failure mode of transport, containment, human error, *etc.* (Janno & Koppel, 2017a); (Tomasoni, 2010).

All parties that are directly involved in the DGTC have to be familiar with risks and safety procedures in order to transport dangerous cargo safely (Batarlienė, 2008). When analysing accidents related to the transportation of DG, it is essential to determine the type of transportation. When DG are delivered by road, they often pass through urban routes with heavy traffic, large commercial and industrial sites, schools, residential and public buildings. Therefore, the occurrence of an accident is a precondition for the appearance of significant damages and casualties. The choice of mode of transport requires an analysis of the technical and economic characteristics of the different types of transportation, focusing on the features of the vehicles, specifics of the operation, economic efficiency *etc.* (Banabakova & Minevski, 2017).

Risk management in the transportation of DG is essential and a necessary condition for ensuring the security and safety during their carriage. For risk management, it is needed to analyse all types of hazards that may occur at various stages during the transportation of DG. The main steps of the general procedure for risk management are risk analysis, risk assessment and risk reduction as shown in *Figure 4*.

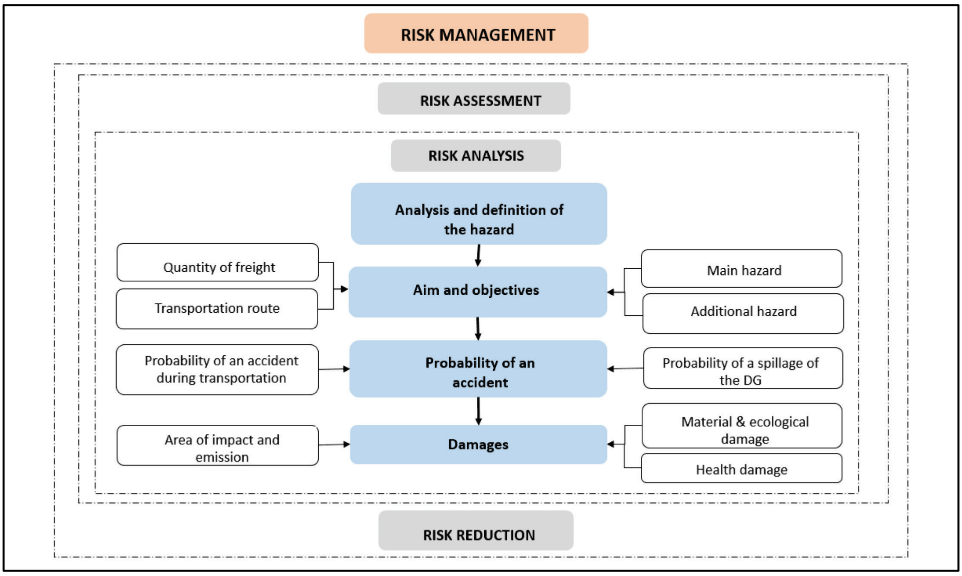

Figure 4. General risk management procedure for DGT ((Banabakova & Minevski, 2017); adapted by the author).

The risk evaluation within the risk analysis process is based on risk criteria which have not yet been standardised internationally. Existing approaches for risk evaluation which have been developed in a national consensus are expressly not to be referred to in this guideline, but it deals with the process of risk evaluation to make the entire process of risk assessment comprehensible (United Nations, 2008). For the risk evaluation at least the following definitions are needed:

1) individual risk is a risk of a person to come to harm;
2) societal risk is a risk of all potentially involved persons to come to harm;

3) external risk (third-party-risk) is a risk of harm caused to persons who are not involved in the transport or risk of harm to property which is not part of the transport system or infrastructure (United Nations, 2008).

DG are solid or liquid substances that have been found to be potentially dangerous when transported by internationally agreed classification (Batarlienė, 2008). DG are classified into nine different classes depending on their predominant hazard (main danger characteristic) (Appendix 5). The regulations for dealing with DGT have the aim to protect direct participants (consignors, consignees and carriers) or indirect parties (members of the public). Regulations place obligations to all who are involved in the DGTC to reduce risks. Safety elements which do not have the same link to an accident concerning their strong impact, support the safety of transportation under normal conditions are the following:

1) packaging;
2) filling degree of tare/cistern (incl. IBC);
3) marking and labelling;
4) mixed loading;
5) technical equipment;
6) special safety equipment;
7) the fixing of shipment;
8) driver training;
9) loading/overloading/unloading actions;
10) documents and their informational content (United Nations, 2009).

In general, there are two main risk factors while transporting dangerous cargo: possible road accidents and possible incidents causing harm (Batarlienė, 2008). Awareness of the fact, that the larger the amount of cargo, the higher the probability of the accident focuses attention on how to regulate the quantity of freight transferred in one shipment. The risk in the DGTC can be reduced by:

1) reduction of freight quantity in one shipment – a smaller amount of DG directly causes the reduced level of harm, influence on people and surroundings;
2) increasing the number of shipments to maintain the same amounts of freight transfers;
3) ensure the quality of the packaging, loading, reloading and fastening of dangerous freight;
4) correctly chosen route (Batarlienė, 2008).

The first and the second actions affect the statistical numbers mainly with regards to the average quantity of DG in one shipment and the share of DG shipments among the total amount of goods being transported. Two last activities carried out by human activity during the direct DGT process.

1.2.2 Human Factor in DGT

It is reported that human error is, in fact, the most common cause of DG related accidents that combine with subsidiary reasons for the accident to happen (Janno, Koppel, 2018c). Human errors may be caused by many different factors such as inadequate training, carelessness or indifference. A potential improvement can be accomplished in the significant share of human-caused accidents, by more efficient education and training, as well as enhancement of the existing safety culture and attitudes towards potential risks in the human behaviour (Bekiaris, Gemou, 2009).

External disasters lead directly to network vulnerability issues that influence overall risk management of a transportation chain. According to several empirical studies (Boone, 2000); (Forigua & Lyons, 2015); (Stažnik, Babić, & Bajor, 2017); (Forum., World Economic, 2012) the most commonly used classification between different types of internal risks within a regular transportation chain can be summed up as follows:

1) physical risk – thefts, losses;
2) OPR - damage through rough handling, delivery failure, customs clearance;
3) employee risk - transport accidents, collisions;
4) risks related to technology in use - technical issues.

OPR is one of the most critical risks in supply chains (Osorio, Manotas, & García, 2017). According to the Basel Committee definition, the OPR is a risk of loss resulting from inadequate or failed internal processes, people and systems or external events. This definition includes human error, fraud and malice, failures of information systems, problems related to personnel management, commercial disputes, accidents, fires, floods (Communications, Bank for International Settlements, 2011). OPR can be summarised as a human risk; it is the risk of business operations failing due to human error (Janno, Koppel, 2018c).

In the DGT, most operations are run in the contribution of personnel involved, that have higher OPRs. Although the probability of OPR emerging in DGT is minimal, consequences can be crucial (Janno, Koppel, 2018c). The problem lies in the fact that the importance of the human factor has been underestimated - it is unknown what are specific OPRs within the DGTC and how severe they are (Janno, Koppel, 2018c). For effective DG risk management, it is essential to pay attention to OPRs within the complete DGTC from the perspective of all parties – consignor/consignee; freight forwarder; transportation company (Janno, Koppel, 2018c). The detailed analysis of the OPRs of different parties allows to understand clearly the contrasts of risks of participants as well as to assess them (Janno, Koppel, 2018c).

Current thesis on risk management and the impact of the human factor in DGT by roads focuses on the main areas of OPR assessment, *i.e.,* risk identification, evaluation and prioritisation within the DGTC. The following risk analysis and development of new management procedures and training models for drivers and operators (DGSA) is in the spotlight of the research. DGT follows a series of transport codes that regulate the official documentation and technical requirements needed for safe transportation of DG. However, having restrictions is not enough to obtain a reliable supply/transportation chain. Based on previous research (Rechkoska; Rechkoski; Georgioska, 2012) legislation should be improved to have a safer supply chain; a more sophisticated technical equipment is needed, and specially trained personnel and services for the transportation of DG is recommended.

One of the main factors with influence in an accident when transporting DG are human errors. Currently, around 50% of the accidents are caused by human errors or an inadequate stowage of the freight. Therefore, the risk associated with the DGT is strongly related to the human factor as all decisions, processes and procedures within a transportation chain are made by different parties involved (Janno, Koppel, 2018c). The human factor is one of the crucial factors involved in an accident with DG. Results of studies focusing on the development of semi-quantitative risk assessments in order to analyse which are the most common human mistakes in the including different members of the DGT supply chain (consignor, consignee, freight forwarder and carrier) remark the incomplete and/or improper transport documentation as one of the main problems in the transportation of DG, that has a link and the necessity to develop better training courses/models for the transportation of DG by road (Janno; Koppel, 2018b). In the scope of this thesis relation between concepts of a training system, training model, training process and training requirements is visualised as shown in *Figure 5.*

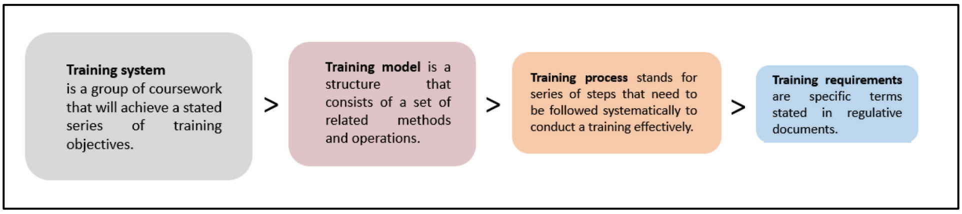

Figure 5. Conceptual relation within a training system (Piskurich, 2003); (Janno; Koppel, 2018b); (author's compilation).

To implement the procedural approach, a designer has to understand the contents of the whole system, its structure, the principle of operation and behaviour (Janno; Koppel, 2018b); (Liebowitz, 1998); (Vodovozov.; Raud, 2009). It becomes challenging to describe complex systems using only procedural techniques. The reason lies in the nature of a modelled object because any procedural model implies a one-sided, incomplete, and prejudiced glance on the original (Janno; Koppel, 2018b); (Vodovozov.; Raud, 2009).

ADR regulates the content of ADR driver training course. The role of DG training courses has an essential impact on the human factors aspect that reveals during DG handling and transportation processes as human factors are crucial why accidents occur within a transportation chain (Janno; Koppel, 2018b). In the scope of DGT by roads, there is no doubt that adequate training of drivers and DGSA may affect the safety aspects of peculiar transportations, such as the one for DG (Janno; Koppel, 2018b).

All persons, whose duties concern the carriage of DG, must be trained in the requirements governing the transportation of such goods appropriate to their responsibilities and duties (Health and Safety Authority, 2012). Employees must be trained before assuming responsibilities, and such training will be in the areas of general awareness, function-specific, safety and security training. Employees shall only perform tasks, for which required training has not yet been provided, under the direct supervision of a trained person. Personnel must be familiar with the general requirements of the provisions for the carriage of DG (Health and Safety Authority, 2012).

The training provided shall aim to make personnel aware of the safe handling and emergency response procedures. Training shall include elements of security awareness, which will address the nature of security risks, recognising security risks, methods to treat and reduce such risks and actions to be taken in the event of a security breach. It shall include awareness of security plans (if appropriate) commensurate with the responsibilities and duties of individuals and their part in implementing security plans. All training must be periodically supplemented with refresher training to take account of changes in regulations (Health and Safety Authority, 2012).

Drivers of vehicles carrying DG must hold a training certificate issued by the competent authority or the appointed agent. Drivers must have participated in a training course (mandatory) and passed an examination on the particular requirements that have to be met during carriage of DG (Health and Safety Authority, 2012). Drivers must undergo refresher training and testing every five years. Training is available for primary and specialisation training for tanks, Class 1 (explosive substances) and Class 7 (radioactive substances). ADR driver training certificates are recognised by all ADR contracting parties (Health and Safety Authority, 2012).

DGSA must undergo training and examination. The difference from the ADR driver training courses lies in a fact that depending on national regulations there are no approved training providers by countries, nor is it mandatory to attend training provided by commercial trainers. It is however left to individuals to self-learn or attend a training course depending on their situation before sitting the mandatory examination (Health and Safety Authority, 2012). DGSA's must, if they wish to continue acting as a DGSA, re-sit the exams every five years. Certificates are issued by competent authorities and are recognised throughout all ADR contracting countries (Health and Safety Authority, 2012).

All training course system approaches are willing to pursue the same goal: to ensure appropriate training and prevent the accidental release of DG during transportation (Janno; Koppel, 2018b). By implementing specific interactive teaching methods, remarkable improvement of course participants' learning can be achieved. Moreover, OPRs related to human factors' issues can be reduced within the entire DGTC (Janno & Koppel, 2017a); (Janno; Koppel, 2018b).

1.3 Factors Impacting DGT

Risk management when transporting DG on roads combines different areas of activities. Consequently, some factors that impact the area of DGT in particular from the perspective of human factors related to risks and impacts.

The chemical industry is vital to the economic development of the DGT. The chemical industry in EU has shown a significant recovery from the crisis, with an increase in chemical production and sales, although it stills in values below pre-crisis, it is expected to reach a pre-crisis level in a few years (Cefic, 2017). In 2016, the chemical industry moved 3,360 billion Euros in the world. From which 1,331 billion Euros sales were produced in China. In the second place ranks Europe, with 597 billion Euros, followed by North American Free Trade Agreement (NAFTA) with 528 billion Euros in sales (Cefic, 2017). Therefore, an increase is also expected in the transportation of DG in the following years in Europe.

The Estonian chemical industry is a small but export-oriented, well established and specialised sub-sector of Estonian industry. Overall industrial activities account for 20% of Estonian gross domestic product (GDP). That share is higher than the European average, but at the same time well in line with the EU´s 20/20/20 strategy, which in addition to well-known energy, resource and climate goals, sets a target for raising industry's contribution to EU GDP from 15.2% to 20% by 2020. The processing industry accounts for 74% of the whole industry sector (Cefic., 2018). Chemicals and chemical products account for 5.7% of the processing industry, contributing about 0.9% to GDP. The chemical industry has high growth potential and is one of the most competitive industry sectors in Estonia. Traditionally, the export share of Estonian chemical companies' sales has been high, accounting for 66.9% in 2016 based on turnover, the productivity and output rate per worker are among the highest compared to other industry sectors (Cefic., 2018).

With regards to transportation conditions and their relation to DG classification, the identification of DG is the most crucial step in the transportation chain. To establish how DG can be transported safely it is essential first to determine the main danger characteristics of goods, as different DG require different measures to ensure their safe transport. For most carrier companies this step is taken care of by the original manufacturer or supplier and classification information can be seen on labels, safety data sheets and transport documentation (Health and Safety Authority, 2012). However, when producing substances or articles that may pose a danger due to the nature of the substance or article, the consignor of DG has a legal responsibility to classify such substances or articles to transportation separately.

The manufacturer is defined in the regulation on classification, labelling and packaging of substances and mixtures (CLP Regulation) as any natural or legal person established within the Community who manufactures a substance within the Community. The legal responsibility to classify does not apply to logistics companies, freight forwarders, carrier companies *etc.* (Health and Safety Authority, 2012). Guidance on classification under the CLP Regulation and related legal requirements is provided by the Health and Safety Authority (HSA) at Health and Safety Authority - Chemicals Safety Management and Sustainable Use (Health and Safety Authority, 2012). As an extra factor of circumstance with regards to road transportation, ADR provides the classification of all DG into one of nine main hazard classification groups, some of which are sub-divided, thus providing a total of thirteen classes (Appendix 5).

Another aspect that is closely related to the tendencies impacting the risk management of DGT on roads are trends of teaching methods in adult training. There is no specific classification regarding DGSA courses generally. However, ADR driver training courses can be classified according to two aspects: the initial training program and the refresher training program (Janno; Koppel, 2018b). ADR driver training course and safety adviser course for the transport of DG by road involved into DGT are based accordingly to the ADR, Chapter 8.2 and the EC Directive (96/35/EC) on the appointment and qualification of safety advisers for the transport of DG by road, rail and inland waterways (The Council of the European Union, 1996); (ADR, 2017); (Janno; Koppel, 2018b). In addition to these documents, there is the Adult Education Act that sets additional requirements for adult education in Estonia on a national level (Estonian Parliament Riigikogu, 2015). The role of DG training courses has an essential impact on the human factors aspect that reveals during DG handling and transportation processes as human factors are crucial why accidents occur within a transportation chain (Janno; Koppel, 2018b).

The methodological approach of professional training should be student-centred and focused on developing learner autonomy and independence by putting responsibility for the learning path in the hands of the learners (Hannafin & Hannafin, 2010). This approach ensures the fact that after completing the training course a trainee can handle problems in practice independently. Independent action is essential in the scope of DGT.

Most of the problems that occur in DGT are due to human mistakes, and it highlights the fact that education and training are needed for participants that are involved in DGT (Krasjukova, 2012). The change in existing teaching practice today regarding DG training courses is necessary due to continuously increasing number of the possible harm to the health of people and the environment in general, and it is vital that all parties be trained accordingly (Janno; Koppel, 2018b). The appropriate implementation of interactive teaching methods focuses on the learner during the process allowing the training participant to acquire learning outcomes more efficiently (Janno & Koppel, 2018a). DGT by roads faces all these challenges regularly to manage risks more efficiently.

1.4 Conclusions of Chapter 1

The following primary conclusions can be drawn from Chapter I. The following findings relate directly to the research question (RQ) no. 1 and the RQ no 2. presented in the introduction of the thesis.

The probability of DG accidents on the roads is minimal, but the consequences can be crucial when dangerous substances are involved (Janno; Koppel, 2017b). In addition to technical risk preventive means with regards to DGT, there are several risk preventive instruments concerning procedures and staff of parties involved precisely. Due to the significant number of different participants within the transportation chain of DG, the importance of human activities increases and cannot be underestimated. Eventually, it all comes down to what is the level of awareness regarding the safe handling of DG in different stages within the DGTC.

OPR is one of the most critical risks when transporting DG (Janno & Koppel, 2017a). According to this, the process of OPR management of DGT is focused significantly on procedures concerning packaging and filling packages; marking and labelling packages and transport units, mixed loading; fixing of shipment; loading/overloading/unloading actions; documents and their informational content.

The most vulnerable part of the DGTC are issues related to personnel training. The DGTC generally has an international character which leads to the fact that participants have to undergo different DG training courses. The main difference is caused by the use of different methodological approach as the content of ADR driver training course and safety adviser course for the transportation of DG by road are determined by international regulations. In Estonia, DG training courses are formed based on teacher-centred course design mainly (Janno; Koppel, 2018b). As the concept of the learner, with its needs, is changing rapidly, therefore this methodological approach is outdated (Janno; Koppel, 2018b). The existing learning form does not meet efficient risk management within the DGTC that is evolving more complex due to the number of parties involved as well as due to additional risks concerned new DG and their danger characteristics (Janno & Koppel, 2018a); (Janno; Koppel, 2018b). Teaching methods integrated into existing DG training course models in Estonia have to be suitable both with learners' expectations as well as with the scope to minimise OPRs related to human factors.

The process of risk management of human factors associated with the transportation of DG is determined by three main elements – the development of chemical industry, classification of DG according to main hazard characteristic and system of training personnel involved into the DGTC. There are a lot of innovations and constant updates happening in these areas. Therefore, risk management in the DGT has to be directed with the proactive approach in order to ensure safety in the DGTC.

Due to the high risk of DG, there is a must to learn before doing in the content of ensuring safety at any level of handling DG within the supply chain (Janno & Koppel, 2018a); (Janno; Koppel, 2018b). The implementation of ADR and the EC Directive 96/35/EC to transfer the knowledge concerning DG is complex. The identification and implementation of student-based teaching methods focus on learner during the process allowing a training participant to acquire learning outcomes more efficiently and therefore deal with risks during DGT more consciously. Focusing on the human factor related risks jointly by taking into account their possible relations in the transportation process, significant progress can be made in the DGT by roads.

Human-related risk preventive mean lies in practical personnel training. With the focus on the STEM (Science, Technology, Engineering, and Mathematics) learning skills model with regards to professional education, the methodology of qualitative comparative analysis (QCA) is implemented to analyse specific learning methods when preparing personnel related to handling and transportation of DG. Existing theoretical and teacher-centred DG training course model is completed with appropriate suggestions regarding learner-centred interactive teaching methods that best suit specific objectives and meet expected learning outcomes (Janno; Koppel, 2018b).

2 Methodological Approach

2.1 Previous Research on DGT

During the last two decades, studies on the issue of risk assessment on the DGT by different transportation modalities have been carried out (Janno & Koppel, 2017a). The research on road transportation of Hazardous Materials (HAZMAT)[1] follows in three topics in detail:

1) methodologies aimed at improving emergency response based on road properties, weather conditions and traffic factors (Fabiano, Currò, Reverberi, & Pastorino, 2005);
2) methodologies for survey and accident risk analysis from historical data aimed at divulging accident characteristics such as frequency of occurrence, accident consequences, and identification of causal factors (Fabiano, Currò, Reverberi, & Pastorino, 2005); (Yang, et al., 2010); (Shew, Pande, & Nuworsoo, 2013) *via* (Conca, Ridella, & Sapori, 2016)*;*
3) decision making aimed at improving choice of truck capacity (Guo & Verma, 2010) *via* (Conca, Ridella, & Sapori, 2016) and route (Fabiano, Currò, Palazzi, & Pastorino, 2002) *via* (Conca, Ridella, & Sapori, 2016); (Janno & Koppel, 2017a).

Training of safety and DG topics is essential for a risk reduction in the handling of DG and their transports. According to previous research studies on DGT the awareness of different parties of the transportation chain in Estonia, there is a lack of professional knowledge among personnel on the national level (Krasjukova, 2011); (Janno; Koppel, 2018b). In Estonia, a significant lack of learning tools and methods, as well as no ADR based activities to endorse training courses and to increase the proportion of practice are so far in use (Krasjukova, 2012); (Janno; Koppel, 2018b).

The scope of the study on the transportation of DG in Estonia in 2010-2011 was to identify the most limiting aspects related to transportation of packed DG among carriers and freight forwarders of Estonia. Besides, the study aimed to determine the awareness of DG among different parties of the transportation chain (including manufacturers and traders) (Appendix 6)[2].

With regards to accidents with DG that happen in practice of carriers and freight forwarders, it was found that the probability was rather low. Activities with the highest likelihood for DG accident to occur were loading/unloading procedures. Databases with information on DG transportation, such as the US Department of Transportation's Hazardous Materials Information System, shows that more than half of the total number of incidents occur during activities at the transport nodes, *i.e.,* at loading and especially unloading of DG (Svensson & Wang, 2008). The majority of accidents were resulted due to a leakage of DG due to the insufficient package. These problems highlight an existing deficiency at the manufacturer's plant where the product is packed. Finally, problems caused due to improper fastening of a DG load within the transport unit and resulting spillage were named as the third main activity leading to the accident (Appendix 6). These causing activities named above have a significant common element with the human factor.

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[1] Hazardous goods are often subject to chemical regulations. In the United States, the United Kingdom and sometimes in Canada, dangerous goods are more commonly known as hazardous materials (HAZMAT) (Code of Federal Regulations, 2017).

[2] The results originate from student studies supervised by the author.

The choice regarding cooperation partner is challenging and always includes risks. The study on DG know-how of Estonian manufacturers and traders found that the professional experience of a carrier turned out to be the vital factor when selecting the transportation service provider. In addition to professionalism and technical capability manufacturers and traders also named the flexibility and ability to respond quickly to changes as well as commit transportation in short transit time (Krasjukova, 2011). Issues related to carriers and freight forwarders were evaluated as not frequent resulting in not serious consequences.

Both, lack of staff qualification as well as lack of staff competence regarding DGT were found to be issues that impact the most the process of moving goods within the DGTC (Appendix 6).

The fact that volumes of transported DG in the Estonian transportation market are relatively small refers that there is a lack of professional knowledge among personnel in road transportation (Krasjukova, 2011). The level of professionalism that forms based on previous experience and expertise on participants of the DGTC must ensure safe handling and transportation of DG. Studies focused on the critical analysis of ADR implementation concepts in European countries confirmed that there are different preconditions and circumstances in the individual countries and companies implementing the ADR, which leads to diverse implementation strategies (Janno; Koppel, 2018b). Therefore, it is not possible to find the only standard way for successful implementation as well as training concept and know-how transfer (Gusik, Klumpp, & Westphal, 2012). Missing qualified personnel and control organisations complicates the necessary knowledge transfer was found to be an existing problem for the fast and effective implementation of ADR. Furthermore, a more uniform and standardised training concept in the field of DG and the ADR regulations needs to be developed to overcome the described lack of knowledge according to the study (Gusik, Klumpp, & Westphal, 2012).

Specific models, methods and technologies have been studied in the scope of supporting the training of personnel involved in the transportation of DG. Italian developed online training environment Transport Integrated Platform (TIP) is addressed to operators in the transportation sector and combines classroom-based training with online self-learning possibilities on a distance. The platform is continuously upgraded with innovative tools and presents a component of blended learning model where online digital media meets with traditional classroom methods (Benza, et al., 2010); (Janno; Koppel, 2018b); (Staker & Horn, 2012). Interactivity keeps learners active by not allowing them to disconnect from the subject. Latter leads to a better attitude to improve learners' thinking and writing, motivating them for further study and development of new thinking skills (Hoffmann, 2011); (Janno; Koppel, 2018b); (Llobregat-Gómez, Mínguez, Rosello, & Sánchez Ruiz, 2015).

The methodological approach of DG training courses has an essential impact on the human factor aspect that reveals during DG handling and transportation processes (Janno; Koppel, 2018b). The same goal can be achieved in different ways, by applying different methods and training schemes, which appears to be accepted in a particular country of use. The existing gap between the way how training and assessment are performed in European countries and the resulting difference on the effectiveness managing OPRs within the DGTC has to be reduced (Krasjukova, 2012). The contrast can be cut down by synchronising and efficiently updating methods in the view of changing nature of the DGTC and its' participants.

2.2 Approaches to Risk Management of DG

Risk assessment, as a step of a risk management procedure, has vital importance in the evaluation of risks related to accidents when transporting DG. Moreover, it is the determination of both quantitative and qualitative values of risks associated with a specific situation and a recognised threat – the hazard of a particular DG (Nicolet-Monnier & Gheorghe, 1996).

According to one possible definition of the risk, it is an uncertainty of a situation or an event that can have short term or long term negative effects (Sangwan & Liangrokapart, 2015). The source of risk can be classified into two groups: inner insatiability in the organisation and the external environment. The process of general risk management starts by setting up internal and external factors, risks and objectives. The risk assessment is done within three main steps:

1) risk identification;
2) risk analysis;
3) risk evaluation (Jenkins, et al., 2010); (Rao & Goldsby, 2009).

With the risk treatment as the next step in risk assessment stages forms together with the context analysis. It is recommended that the process of risk management is monitored, reviewed, communicated and continuously consulted as visualised in the following *Figure 6.* With regards to transportation chain, more than 90% of the logistics service providers (LSP) and transport companies are aware of their operational and strategic risks, but only 61% have alternative plans if there is a significant interruption in the operations (ABN AMRO, 2015); (Sangwan & Liangrokapart, 2015).

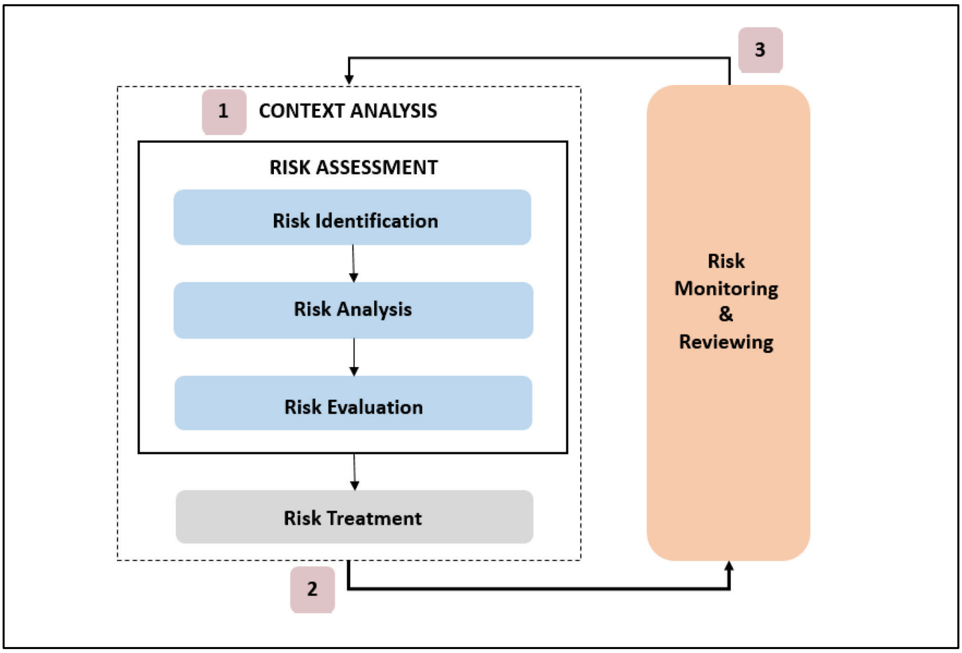

Figure 6. Adjusted risk assessment process ((Jenkins, et al., 2010); (Rao & Goldsby, 2009); adapted by the author).

In the risk assessment definition, many concepts are involved (Royal Society, 1992). The risk is most commonly defined as the combination of the probability (frequency; likelihood) of occurrence of an identified hazard and the magnitude of the consequences of the event as it is described by the formula (1) below (Janno, Koppel, 2018c); (Royal Society, 1992).

$$\text{DG Risk} = \text{Consequence} * \text{Probability} \quad (1)$$

At this point, it is important to emphasise that the hazard and risk are not the same. The risk is a function of hazard, as hazard is related to the intrinsic characteristic of a material, product, condition, or activity that has the potential to cause harm to people, property, or the environment, and it is often defined concerning a probability (European Environmental Agency, 1998); (Janno & Koppel, 2017a). The danger is defined as all processes involved in the chain or sequence of events leading to an undesirable event which could have a destructive nature on population, ecosystems and goods (Janno & Koppel, 2017a). Probability is defined as a value between 0 and 1 and in some words is the likelihood of a sequence of events to an event not desired (Janno & Koppel, 2017a); (Tixier, Dusserre, Rault-Doumax, Ollivier, & Bourely, 2002).

Risk and harm can be defined as a damage occurrence probability that has consequences in the loss of operations (Jenkins, et al., 2010). Developing key performance indicators (KPI) helps to assess the level of risk that affects the supply chain or transportation chain. The KPIs of transportation selection are cost, time and service quality (Sangwan & Liangrokapart, 2015) as shown in the following *Figure 7.* These represent the reliability of companies/participants with their performance involved in the DGTC.

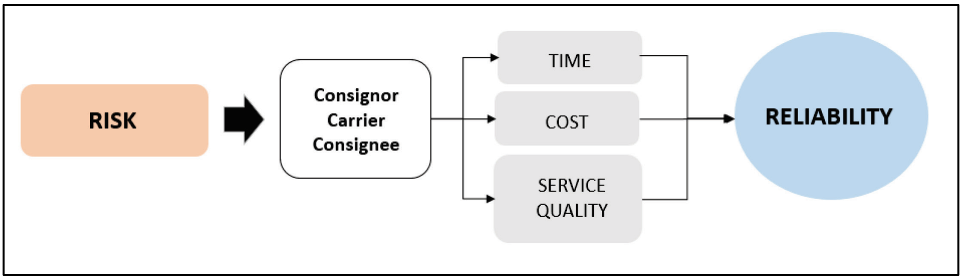

Figure 7. Risk impact on the DGTC performance indicator ((Pedersen & Grey, 1998); adapted by the author).

Loss caused due to risk exposure generally can be classified into six groups: financial loss, performance loss, physical loss, psychological loss, social loss and time loss (Brenchley, 2000); (Sangwan & Liangrokapart, 2015). The loss in reliability of the DGTC refers to the failure in its overall performance that is in case of DGT defined by OPRs. With regards to this thesis studying OPRs in DGT and thereby managing and improving the reliability of transportation chain following questions need to be answered:

1) What OPRs exist in the DGTC?
2) How likely it is for a particular risk to occur?
3) What can go wrong and what are the consequences concerning the whole transportation chain?

Moreover, as human-related risk preventive mean lies in efficient staff training (Janno; Koppel, 2018b), the focus is, therefore, to improve the reliability of DGT by better training of personnel.

2.3 STEM Methodology in Professional Education

STEM covers a wide range of knowledge and skills, which are increasingly in demand in a knowledge-based economy and a rapidly changing world (VicStem., 2016). STEM education and training aim to develop expertise and capability in each field and to develop the ability and skills to work across disciplines through interdisciplinary learning. STEM education and training help to acquire the following skills and capabilities:

1) growing people's understanding and appreciation of the natural and physical world and the broader universe around;
2) interpreting and analysing data and information available;
3) research and critical enquiry – to develop and test ideas;
4) problem-solving and risk assessment;
5) experimentation, exploration and discovery of new knowledge, ideas and products;
6) collaboration and working across fields and disciplines;
7) creativity and innovation – to develop new products and approaches (Government, 2017).

All of these are increasingly important to succeed in a changing and technologically-driven world. STEM skills and capabilities are essential for helping people to develop as active citizens, making informed decisions for themselves and society (Government, 2017).

The importance of creativity and innovation for economic growth and the substantial synergies that exist between STEM and creativity have been studied and concluded from previous research (Government, 2017). Education, training and lifelong learning have a key role to play in responding to these economic and societal imperatives by building a strong base of STEM skills and knowledge for everyone and by enthusing and encouraging people to develop more specialised STEM skills and capabilities (Government, 2017). STEM has become a central topic because of its critical role in the nation's competitiveness (Business Higher Education Forum, 2013); (Sahin, 2013). Indeed, each nation's well-being depends upon how well it educates its members in the STEM, since its economic and national security is derived from technological creativity (Raines, 2012); (Koehler, Faraclas, Giblin, Moss, & Kazerounian, 2013).

With regards to professional training in the field of transporting DG, the teacher-orientated training course model is an issue. The implementation of ADR and EC Directive 96/35/EC on knowledge transfer concerning DG is complex. In Estonia, DG training courses are formed based on teacher-centred course design mainly, *i.e.*, learning activity is performed during classroom lectures supported by a slideshow presentation (Janno; Koppel, 2018b). This methodological approach is outdated as the concept of the learner is changing rapidly (Raines, 2012); (Koehler, Faraclas, Giblin, Moss, & Kazerounian, 2013); (Janno & Koppel, 2018a); (Janno; Koppel, 2018b).

Peer project learning (PPL) is an interactive student-centred method, which can be easily adopted by any instructors who want to change their roles from delivering information to managing a complete set of instructions. PPL is designed to meet the goals of the STEM and consists of peer learning in the classroom and project learning in the lab (practical education) (Pinelaa & Seo, 2015). According to the STEM study cycle presented in *Figure 8*, in PPL, learners take an active role to build up their scientific knowledge through the pre-class reading, conceptual questions in peer instruction, team problem solving, development and presentation of the project (Pinelaa & Seo, 2015).

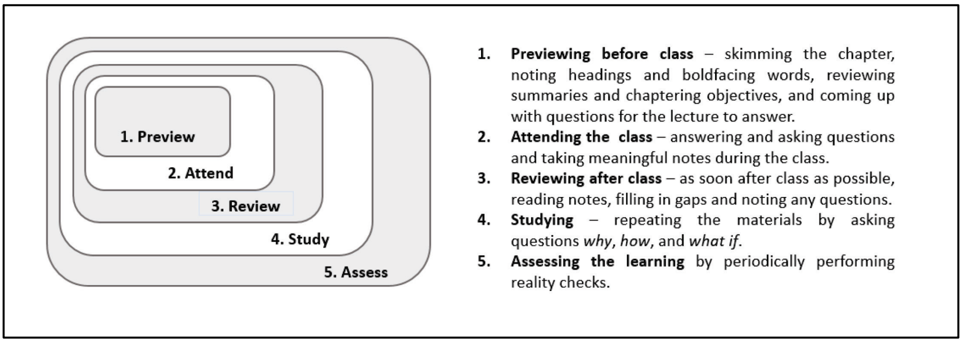

Figure 8. The STEM study cycle ((McGuire, 2013) ; adapted by the author).

Empirical studies have concluded that course acceleration in itself is not a strong enough factor to improve individual learning; however, learning activities where students practice using integrated skills to solve problems allow for more profound and more meaningful student learning (Meyrick, 2011); (Wai, Lubinski, Benbow, & Steiger, 2010). STEM education has attempted to transform the typical teacher-centred classroom by encouraging a student-centred curriculum that is driven by problem-solving, discovery, exploratory learning, and requires students to actively engage in a situation to find its solution (Fioriello, 2010). In the student-centred course model, the primary role of instructors shifts from delivering information to managing a complete set of instructions and process, and that of students also moves from being passive recipients of information to accepting responsibility for the initial exposure to the course content (Michaelson & Sweet, 2008).

2.4 Research Design of the Study

2.4.1 Data Collection and Processing

The focus of the present thesis is to study human factor related risks when transporting DG on roads with an emphasis on the methodological approach of training of personnel as risk management mean. The author discusses that the training methods chosen for DG related in-service training are directly related to managing OPRs within the DGTC. In the present thesis, the DGTC is studied as an international case based on the practical activity of national (Estonian) companies mainly.

A research design is the set of procedures and methods used in collecting and analysing variables specified in the research problem (Janno; Koppel, 2018b); (Ghauri & Grønhaug, 2002). The *Figure 9* illustrates how the research task is conducted within combined research design, by focusing on the two main parts, the human factor related risks and DG training course system in Estonia. Both areas together lead to an improved risk management model of DGT on roads that due to the universality can be implemented both on the national and international level.

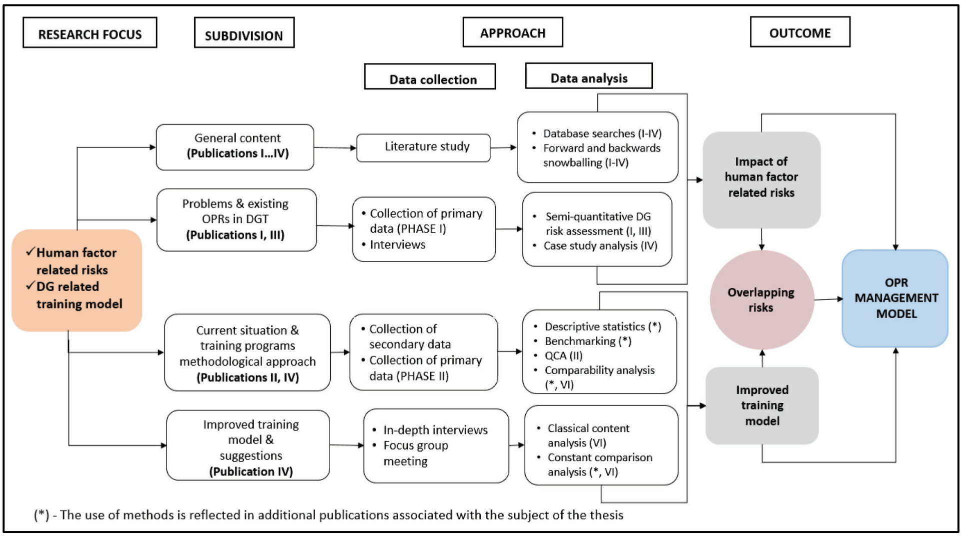

Figure 9. Combined development research design of a study (author's compilation).

The current study presents a combined development research strategy based on studies regarding DG training courses in Estonia as well as on the analysis of teaching methods applied in the professional training of adults with the implementation of ICT possibilities to contribute to effective human factor risk management (Janno; Koppel, 2018b). To approach the research targets, the author focuses mainly on data collection and analysis with support of theoretical background and personal know-how from DGT in practice. The data collection covers a literature study on regulations and previous research on DGT risk management and training methods in adult education.

The study has been since 2008, during which data collection was repeatedly carried out. In this regard, it is important to note that the timing factor does not affect the timeliness of the conclusions drawn from the analysis of the data collected, since, irrespective of trends affecting the DGT, real changes take place with long pending periods and slowly.

The main research instrument for collecting the primary data of the survey is the questionnaire. It is defined as a data collection technique where different respondents are asked to answer the same questions in a prearranged order (de Vaus, 2002); (Zikmund, 2000). There are two types of questionnaires – self-administered and interviewer-administered (Saunders, Lewis, & Thornhill, 2004). The respondents do self-administered questionnaires without any interaction of a second person. The self-administered survey must be developed in a way that all respondents will interpret in the same manner (Dillman, 2000). To manage that, survey questions are often presented as closed questions to obtain rankings, lists, categories, quantities or ratings (Saunders, Lewis, & Thornhill, 2004). Interviewer-administered questionnaires' answers, on the other hand, are recorded by the interviewer (Scholl, 2003).

The data collecting was performed in two phases. In PHASE I primary data was collected in forms of the non-anonymous online questionnaire (carrier companies, freight forwarders) and structured interviewer-administered questionnaire (consignors/consignees) to identify existing OPRs of different parties within the DGTC (Janno, Koppel, 2018c). Secondly, in PHASE II, learners' attitude regarding the current format of courses is collected from all main parties who operate with DG on a daily basis, *i.e*., consignor/consignee, freight forwarder and carrier company (Janno; Koppel, 2018b). Truck drivers are separated from the carrier role to identify their preferences individually. This step of a primary data collection presents a combined online questionnaire survey on learners' attitude and preferences concerning the methodological format of courses (Janno; Koppel, 2018b).

The online questionnaire aimed for carriers and freight forwarders was provided via email invitations to 136 Estonian companies that work with DG on a daily basis with regards to transportation by roads. Altogether 74 full responses were gathered: 17 responses from freight forwarders, and 57 responses from transportation companies. The majority of carriers (39) within a sample represented companies with considerable practice in the field of DGT for over ten years (Janno & Koppel, 2017a). The experience of freight forwarder companies within a sample was considerably even. There were companies (5) with the high competency of over ten years as well as businesses (5) that have such experience for only a few years (Janno & Koppel, 2017a).

For interviews with representatives of consignors/consignees, 11 companies were selected into the sampling to carry out semi-structural interviews. This selection was made based on the total handling capacity of DG per year. The entire products capacity of these companies forms up to 80% of all DG substances handled by consignors'/consignees' companies of Estonia (Janno & Koppel, 2017a). Because of the considerable experience of the companies of the DGTC included in the sample, and the substantial volume of transported/handled DG, reliable conclusions can be drawn from the data collected that can be extended in the context of Estonia. Same criteria of a sample of PHASE I justify the validity of the construct created for data collection (Janno & Koppel, 2017a).

In the scope of PHASE II of data collecting the focus was on learners' attitude regarding the current methodological format of DG training courses in Estonia. The data collecting was performed in the form of an online survey from all main parties who operate with DG on a daily basis, i.e. consignor/consignee, freight forwarder and carrier company (Janno; Koppel, 2018b). The author divided respondents into clusters according to the type of GD training course type which was aimed at them. Clustering was performed as follows:

1) CLUSTER I (truck drivers; ADR driver training course);
2) CLUSTER II (consignors/consignees, freight forwarders, representatives of carrier companies, other participants; DGSA training course) (Janno & Koppel, 2018a); (Janno; Koppel, 2018b).

The author separated drivers from carrier role to identify their preferences individually. The primary objective was to understand attitudes and preferences by clusters towards specific teaching methods respectively (Janno; Koppel, 2018b). The essence of specific methods that were in focus was explained to respondents. A structured questionnaire with close-ended ordinal-scale questions was prepared as main data collecting form, where respondents were asked to decide where they fit along a scale continuum regarding the use of particular teaching method with-in ADR training classes (Janno & Koppel, 2018a); (Janno; Koppel, 2018b).

The distribution of the questionnaire was provided via email invitations (60 companies that work with DG daily) and social media channels addressed directly to speciality-central groups (*e.g.* Estonian truck drivers with an estimated number of 1800 ADR licenced drivers). Altogether 189 replies were gathered (CLUSTER I – 151 respondents, CLUSTER II – 38 respondents). The sample must represent the population as well as possible. Formed sub-samples were not statistically representative enough to draw accurate conclusions concerning population (Janno & Koppel, 2018a); (Janno; Koppel, 2018b).[3] To ensure the representativeness of a sample, the sub-samplings within clusters were formatted in a non-probability sampling technique (Babbie, 2010); (Janno, Koppel, 2018c). Consequently, it is reliable to make general conclusions on DG training course models/ system, but it is insufficient to give an accurate picture of individual attitudes and preferences of all DG transportation chain participants (Janno & Koppel, 2018a).

Finally, according to the research design of a study, individual in-depth interviews with DG training provider companies and representatives is performed. As in-depth interviews are useful when the focus is on getting detailed information about a person's thoughts and behaviours, or the aim is to explore new issues in depth on a particular matter (Boyce & Neale, 2006), this method is suitable for collecting data at this stage of the research (Janno; Koppel, 2018b). Detailed data collection during in-depth interviews with DG training provider companies gives an opportunity to shape better understanding what kind the teaching process would be with the integrated use of interactive teaching methods, including PPL (Janno; Koppel, 2018b).

Due to the non-existing data and incomplete statistics in Estonia with regards to DGT on roads the data collection was performed in 2009 in several stages. Both quantitative and qualitative data on DG risks and DG training course system was performed in a significant part by teaching and supervising students' studies since 2011 at Tallinn University of Technology and TTK University of Applied Sciences (Appendix 6).

The focus group meeting with the aim of validating the primary results of the study gathers together selected experts from DG training activity of Estonia. Focus group research involves a related discussion with a selected group of individuals to gain information about their views and experiences on a topic (Krueger, 2002); (Janno; Koppel, 2018b). Within this research stage, the initially developed training model for drivers and DGSA is in focus. The participants of a focus group influence each other through their answers to the ideas and contributions during the discussion by assessing advanced training model with regards to human risk management (Janno; Koppel, 2018b).

According to Estonian Road Administration, six training institutions are licenced to provide ADR driver training courses, and one of them also focuses on providing DGSA courses (Estonian Road Administration, 2018a); (Estonian Road Administration, 2018b). In-depth interviews and focus group meeting covered the expertise of following ADR experts presented in *Table 2* below.

[3]According to the statistics during the period from 2012-2016 (*i.e.* currently valid certificates) the total number of issued ADR driver licenses in Estonia was 30 539 and the number of issued DGSA training certificates during the same period 118 (Estonian Road Administration, 2016); (Janno; Koppel, 2018b); (Learning., 2017).

Table 2. Competence of experts involved in the study.

ADR expert	Company	Position	Experience in the field of DGT
A	Autojuhi Koolitus, Ltd.	Lecturer	over 10 years of experience
B	Roolikool, Ltd.	Managing Director, lecturer	over 10 years of experience
C[4]	Harju AB, LLC	Managing Director	over 20 years of experience in international transportation
	Association of Estonian International Road Carriers	Member of a roundtable	over 20 years
	ADR Koolitus, Ltd.	Managing Director, lecturer	over 10 years of experience
	Autokool MEWO Ltd.	Lecturer	over 10 years of experience
	TTK University of Applied Sciences	Lecturer, DGSA training courses	over 5 years of experience
D[5]	Estonian Road Administration, Area of Traffic Safety and Public Transportation Examination Department	Chief Specialist	over 5 years of experience

Source: (author's compilation)

This thesis follows the steps of a combined development research design that is defined by a research problem according to which risk management in the DGTC is short-sighted and is focused on the elimination of consequences instead of on ensuring safety proactively. As the research design refers to the logical structure of the study then (Yin, 2009), in the scope of this study both qualitative and quantitative data collection and analysis methods were selected to present relevant results on how to reduce the problem of risk management of DGT on roads.

2.4.2 The Data Analysis

For the analysis of human-related risks and impact in DGT on roads, the author conducted qualitative (system and content analysis, benchmarking, comparability analysis and multiple case study analysis) and quantitative analyses (descriptive statistics, semi-quantitative risk assessment and QCA). The primary tools used for data analysis as well as for the display of results were: Microsoft Excel, web-based online survey tool Google Forms, OSU Risk Management Risk Assessment Tool, and a web-based tool for QCA data processing, Microsoft Excel was used for:

1) the display of initial data in the form of graphs and tables;
2) the transformation of the initial data for its further use in OSU Risk Management Risk Assessment Tool and QCA data processing.

[4] Expert C represents tree different ADR training companies.

[5] Expert D was not involved in the in-depth interviews stage, participated only in the focus group meeting.

The primary method for analysing OPRs is the risks assessment. To assess the risk, then analyse and estimate the level of risk of accidents three different methods (qualitative, semi-quantitative and quantitative) are defined (Dziubinski, Fratczak, & Markowski, 2006); (Janno & Koppel, 2017a). Qualitative methods are used mainly in the validation of safety standards concerning legal rules on transportation behaviour. These rules are usually considered as a minimum requirement that must be used to achieve certain levels of acceptable safety (Janno & Koppel, 2017a). Semi-quantitative methods are applied to identify hazards and to select the so-called related events reasonably foreseeable (credible failure events). The quantitative assessment of risk is complex and involves a series of analysis and calculations, using many simulation models, particularly the physical analysis of the effects (Janno & Koppel, 2017a); (Tomasoni, 2010). Considering the specifics of OPRs in DGT, semi-quantitative risk assessment methodological approach, as presented in *Figure 10*, is adjusted to identify incidents leading to accidents (*i.e.,* risks) and to estimate the level of risk.

Based on this methodology risk probability is scaled in range of 1-5 (1 – rare; 2 – unlikely; 3 – likely; 4 – certain; 5 – imminent) and severity of risk that may arise from the possible event or outcome is scaled in the range of A-E (A – minor; B – medium; C – major; D – catastrophic; E – catastrophic external) (Janno & Koppel, 2017a); (Janno, Koppel, 2018c); (Dangerous Goods Safety Guidance Note, Risk Assessment for Dangerous Goods 2013, 2017). By implementing the semi-quantitative risk assessment method, it finally allows for differentiating OPRs according to their levels into acceptable, tolerable and unacceptable OPRs when transporting DG on roads as according to semi-quantitative risk assessment methodology (Janno, Koppel, 2018c). Results of semi-quantitative risk assessment are further processed with the OSU Risk Management Risk Assessment Tool for generating heat maps (Oregon State University, 2018) based on the data for impact and likelihood for OPRs.

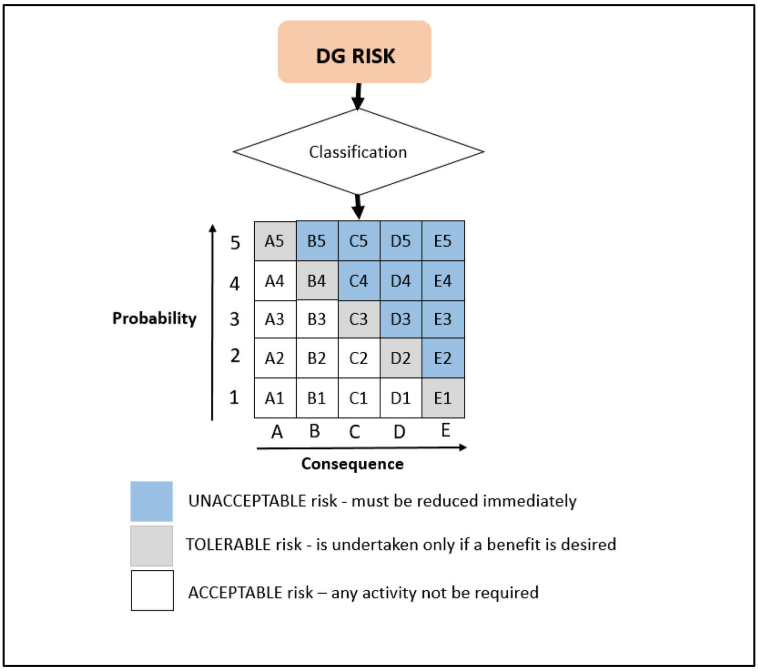

Figure 10. Semi-quantitative DG risk assessment ((Dziubinski, Fratczak, & Markowski, 2006); (Janno & Koppel, 2017a); (Janno, Koppel, 2018c); adapted by the author).

The methodology of QCA is implemented to analyse specific methods as cases due to the set of relations and assess their consistency (Janno; Koppel, 2018b). Applying the methodology of QCA combinations, suitable teaching methods are identified that are effective both in the scope of OPR management as well as from the perspective of learner's needs and expectations (Janno; Koppel, 2018b). QCA is a mean for analysing the causal contribution of different conditions (*e.g.*, aspects of an intervention and the broader context) to an outcome of interest (Janno; Koppel, 2018b); (Ragin, 2008). QCA starts with the documentation of the different configurations of conditions associated with each case of an observed result (Davies, 2016); (Janno; Koppel, 2018b); (Rihoux, Ragin, 2008); (Schneider & Wagemann, 2012). These are then subject to a minimisation procedure that identifies the most straightforward set of conditions that can account for all the observed outcomes, as well as their absence (Davies, 2016); (Janno; Koppel, 2018b). Results are typically represented in statements expressed in ordinary language or as Boolean algebra. According to formula (1) expressed in Boolean notation combination of Condition A *and* (*) condition B *or* (+) a combination of condition C *and* (*) condition D will lead to an *outcome* (→) E (Davies, 2016); (Janno; Koppel, 2018b); (Schneider & Wagemann, 2012).

$$\mathrm{A} * \mathrm{B} + \mathrm{C} * \mathrm{D} \rightarrow \mathrm{E} \tag{2}$$

Boolean algorithms allow identifying regularities that can be expressed with the fewest possible conditions within the whole set of circumstances that are considered in the analysis (Rihoux & Lobe, 2009). With regards to the current study, these algorithms represent the best suitable learning methods for DG training courses in Estonia.

Multiple case study analysis is implemented to analyse practical cases on DGT on roads on the example of Estonia's companies. Case study research can be adopted with real-life events that show numerous sources of evidence through replication rather than sampling logic. The generalisation of results from case studies, from either single or multiple designs, stems from theory rather than on populations (Yin, 2009). By replicating the case through pattern-matching, a technique linking several pieces of information from the same event to some theoretical proposition (Campbell, 1975), multiple case design enhances and supports the previous results.

From the perspective of this study, practical perspective raises the level of confidence of the established methodological approach as well as validates preliminary results of a study. Detected overlapping risks between two types of transportation chains (regular transportation chain *vs* DGTC) are validated within the focus group meeting implementing constant comparison (also constant comparative) analysis. During the first stage (*i.e*., open coding) the focus group data is chunked into small units and a descriptor, or code, is attached to each of the units. During the second stage (*i.e*., axial coding), codes are grouped into categories. In the final stage (*i.e*., selective coding), the researcher develops one or more themes that express the content of each of the groups (Onwuegbuzie, A. J. ,Dickinson, W. B., Leech, N. L., Zoran, A. G., 2009); (Strauss & Corbin, 1998). Implementing methods of analysis within the study leads the author to design a multi-level risk management model where risk management and the impact of human factor meet the challenges and possibilities of DG training system in Estonia.

2.5 Conclusions of Chapter 2

The following conclusions can be drawn from Chapter II. The following findings relate directly to the RQ3 presented in the introduction of the thesis.

Regulations are essential to prevent not only risk but also to reduce the hazard caused by DG (Janno, Koppel, 2018c). Firstly, the risk attached to the transportation of DG by road is a risk that is hard to understand as it is connected to the whole road network and depends on multiple factors such as traffic density, weather conditions, the necessities of undesired events (Janno, Koppel, 2018c). Secondly, this risk is strongly linked to the nature of the transported goods and the presence of exposed humans and materials in proximity to the place of incident (Janno, Koppel, 2018c). Thirdly, the risk of DGT is strongly related to a human factor as all decisions, processes, and procedures within a transportation chain are made by different parties involved (Janno, Koppel, 2018c).

For effective DG risk management in DGT, it is vital to pay attention to OPRs within the complete DGTC from the perspective of all parties. Risk management is not a one-time process (Kremljak, 2016). Within risk assessment, risks should always be identified at the beginning of the project during the up-front planning process, and should also be periodically looked at the remaining process to identify any new risks. Risk management related to the transportation and logistics chain includes activities which reduce the probability of occurrence and/or impact that detrimental supply chain events have on the specific company (Zsidisin, G. A & Ellram, 2003).

In the thesis, the risk management and the impact of the human factor in road transportation of DG is studied on the example of Estonian companies' practice. The research problem defines the research design of this study and spreads the data collection as well as the analysis into several stages (Janno; Koppel, 2018b). To perform the study and draw the relevant conclusions, the following limitations of research have to be considered:

1) the lack of accurate statistical data on DG flows on roads in Estonia;
2) the small share of the transportation of DG in the Estonian transportation market in the European context defines a lack of professional knowledge among personnel (Krasjukova, 2011);
3) limited study group involved in data collection covers the presence of all parties of the DGTC, but is Estonian research centred;
4) data protection issues in Estonia sets limitations on case scenarios with regards to DG accidents.

At this point, several aspects refer to insufficient information with regards to DG within the transportation chain among parties involved. There is a definite need for a domestic and international database with the up-to-date info of carriers, freight forwarders *etc.* dealing with DG (Krasjukova, 2012) where information and the know-how can be easily exchanged. Although the limited study group generalisations of research results are applicable widely in Europe due to the universal features of risks as well as common main legal requirements (Janno & Koppel, 2017a) with regards to DGT on roads that settle minimum requirements for DG training courses.

3 Synthesis and Discussion

3.1 Operational Risks (OPRs) of the DGTC

3.1.1 Methodological Considerations and Findings

Risk management is one of the critical issues in planning safe handling and transportation of DG (Janno, Koppel, 2018c). In the first stage of DGT risk assessment, risks are identified. To follow the research design of this study OPRs of different parties within the DGTC are defined based on the practice of Estonian companies. There are plenty of activities when handling and transporting DG that are considered as incidents which do not necessarily lead to accidents (Janno, Koppel, 2018c). To identify which of human factor activities are closer to the emergence of the accident in practice, it is necessary to:

1) examine the DGTC as a complex of loading, transportation, freight forwarding and unloading procedures;
2) identify OPRs from the perspective of the main parties involved;
3) assess risks in the combination of risk consequence and its probability (Janno & Koppel, 2017a); (Janno, Koppel, 2018c).

The data collecting was performed in the form of the non-anonymous online survey among carriers, freight-forwarders and in the form of structured interviews among consignors/consignees. In the scope of this study consignors and consignees were studied jointly as one participant within the DGTC, since in Estonia many companies fulfil both roles. To ensure the representativeness of a survey the samplings were formatted in a non-probability technique where the samples were gathered in a process that does not give all individuals in the population equal chances of being selected (Babbie, 2010); (Janno; Koppel, 2018b). Samplings are also qualified as purposive samplings where subjects are chosen to be part of the sample with a specific purpose in mind that is sufficient to draw objective conclusions concerning the methodological approach of some issues that are fit for the research compared to other individuals (Babbie, 2010); (Janno; Koppel, 2018b).

The survey asked the respondents to state OPRs independently and evaluate the probability as well as the consequence of a particular risk. By defining OPRs with minimal directions from the researcher within the DG, transportation chain makes it possible to evaluate both consequence and probability of these risks as objectively as possible (Janno, Koppel, 2018c). According to structured questions in the questionnaire, in the second part of the survey respondents assessed these indicators in the range of A-E (consequence) and 1-5 (probability) (Janno, Koppel, 2018c). *Table 3* presents an overall rating of DG OPRs from the perspective of different parties. A risk calculation provides the risk score, which is the primary input for the heat map. The risk score in this study represents a combination of letter and number – the letter stands for risk consequence value, and the number describes its probability. According to rating, each risk can be positioned in a DG OPR matrix for final specification as the acceptable, tolerable or unacceptable risk (Janno, Koppel, 2018c).

Table 3. Evaluation of DGT OPRs.

DG OPRs	Consignor/ consignee (*n*=11)	Freight forwarder (*n*=17)	Carrier company (*n*=57)
Inaccurate customer communication	B4	C3	D2
Incomplete transport documentation	C4	C2	D2
Improper transport documentation	D3	C2	D2
Missing transportation permits and licenses	B2	C2	D1
Not safe load securing	C2	C2	D2
Inadequate packaging	D2	C1	D2
Insecure loading/unloading	B1	C1	D2
Wrong classification of DG	B1	C2	D1
Inadequate load securing	B3	C1	D1
The use of incorrect load restraints	B3	C1	D1
An error/accident caused by driver	B3	C1	D1
Improper packing material	B2	C2	D1
Wrong/missing marks and labels on the package	B1	C2	D1
Wrong route planning /choice	B1	C2	D1
Wrong/missing vehicle placards	B1	C1	D1

Source: (authors' survey results, first published in (Janno & Koppel, 2018a); (Janno, Koppel, 2018c))

Implementing the semi-quantitative DG risk assessment methodology, OPRs are differentiated according to their levels into acceptable, tolerable and unacceptable (Janno, Koppel, 2018c). Based on the evaluations for probability (likelihood) and consequence (impact) of each risk, heat maps in the form of matrixes are formed to prioritise OPRs in the DGTC. The risks of highest priority are in the top right quadrant of the heat map. Detailed results of participants' OPR matrixes are presented in *Figure 11* below.

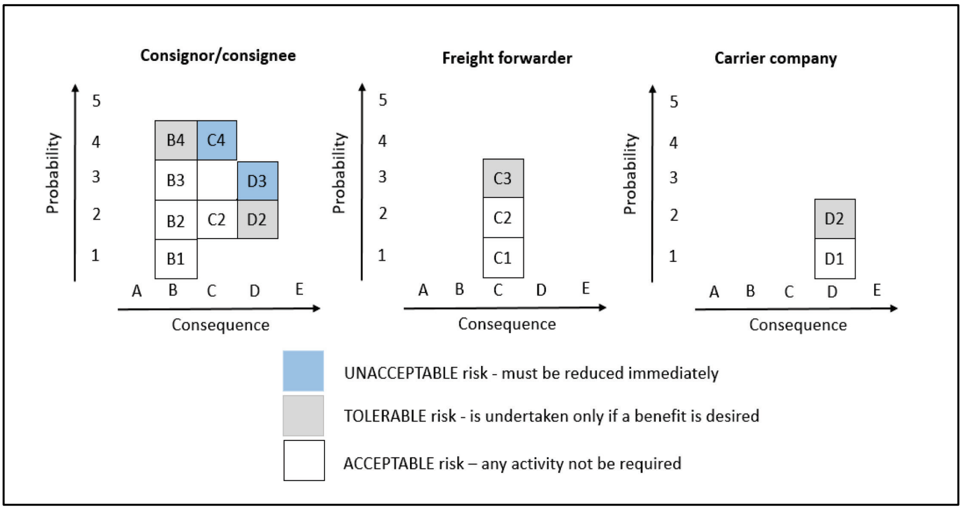

Figure 11. OPR matrixes of the DGTC parties (authors' survey results, first published in *(Janno & Koppel, 2018a)*; *(Janno, Koppel, 2018c)*).

Results of DGT risk assessment states that unacceptable risks are related to incomplete or improper transport documents mainly and exist only from the perspective of consignor/consignee, *i.e.* in the beginning or at the end of the transportation chain. Inaccurate customer communication is a significant concern for all parties and is defined as a tolerable risk from the perspective of all participants (Janno, Koppel, 2018c). In this matter, the deficiency of information flow may be an issue. Even the smallest loss of information between the parties in the DGTC may lead to additional losses and costs (Janno, Koppel, 2018c). Hence, freight forwarder's risks do not need any further action, and the operation of this party can be considered as the most risk-free within the DGTC. Mainly half of the transportation company's OPRs are classified as tolerable risks with significant consequences and with a slight possibility to take place (Janno, Koppel, 2018c).

The human factor has a considerable impact on ensuring safety in DGT (Janno, Koppel, 2018c). Findings indicate that OPRs influence participants' activity differently within the DGTC. The probability of OPRs is the second aspect as the risk is mainly defined due to its consequence and repetitive nature among participants of the DGTC.

3.1.2 Checklist Implementation

Results of the study on DGT OPRs highlight, in particular, the importance of consignor/consignee as the number of different OPRs is the largest, and their scores are the highest (Janno & Koppel, 2017a). Risks related to documentation issues and inaccurate customer communication are identified as highest at all parties within the DGTC. As the further challenge lies in managing risks with highest risk scores at their earliest possible emergence, the author suggests the implementation of checklists at the most critical parts of the transportation chain, *i.e.* place of loading at consignor and place of unloading at consignee. The implementation of the checklist by the carrier company/the driver in the beginning of the DGTC allows to identify potential risks at the earliest stage of the transportation process, while filling in the gaps at the end of the DGT gives the possibility to analyse the process and compare the situation with the original conditions at the beginning.

The checklist is the method that can be used to identify risks. It represents registers of hazards and risks, which are usually drawn upon risk assessments in the past or previous experience. The checklist is a convenient risk detection method that can be implemented at any stage of the product, process, or system lifecycle. The method can be used to identify hazards and risks, and especially after identifying new problems to check if everything is taken into account. The output is a list of inappropriate countermeasures or risks that help to ensure that common problems are not overlooked. The advantage of this method is to integrate widespread knowledge into an easy-to-use system, which in the future can also be used by non-professionals (International Organization for Standardization, 2009); (European Committee for Electrotechnical Standardization, 2010).

The majority of risk factors in the DGTC are identified afterwards relying on gained experience when the risk factor has already been detected (Janno & Koppel, 2017a). Considering that the risks of the DGTC should not be underestimated, the implementation of the universal checklist by transportation companies' risks can be determined accurately. When developing the checklist for carrier companies presented in following *Figure 12*, the author relied on the following known examples:

1) checklist for the police and other officials performing duties on freight carriage in Estonia (in use until June 2018);
2) ADR vehicle inspection checklist - Council Directive 95/50/EC, created by the Health and Safety Authority of Ireland.

SECTION I - GENERAL INFORMATION	**Date:**	**Time:**
1) Place of Inspection		
2) Vehicle &Trailer/Type and Registration Number		
3) Carrier		
4) Driver		
5) Consignor/Place and Conditions at Loading		
6) Consignee/Place and Conditions at Unloading		
7) ADR 1.1.3.6 Quantity Limit Exceeded	YES ☐	NO ☐
SECTION II - INFORMATION OF DANGEROUS GOODS	**Inspected**	**Infringement Detected**
1) Driver Informed of the Transported Goods	☐	☐
2) Goods Authorised for Carriage	☐	☐
3) Documents on Board (Delivery Note, Safety Instructions, Agreement/Authorization, Certificate of Approval of Vehicles; Drivers' Training Certificate	☐	☐
4) Corresponding Data on Goods in Transport Documents	☐	☐
5) Packaging Marking	☐	☐
6) Vehicle/Cargo Visually Inspected	☐	☐
7) Leakage of Goods/Damage of Packages	☐	☐
SECTION III – VEHICLE CONDITIONS & OPERATIONS	**Inspected**	**Infringement Detected**
1) Vehicle/Trailer Authorised for Goods Carried	☐	☐
2) Driver Involved in the Loading Process	☐	☐
3) Vehicle/Trailer Placarding	☐	☐
4) Vehicle/Trailer Technical Condition	☐	☐
5) Mixed Loading Prohibition	☐	☐
6) General and Additional Safety Equipment on Board	☐	☐
7) Safety Equipment Working Properly	☐	☐
8) Loading, Securing of the Load and Handling	☐	☐

Figure 12. Checklist for carrier companies (Appendix 6; adapted by the author).

The checklist for carriers of the DGTC deals with as many as possible circumstances that may indicate the existence of OPRs within the DGTC. The checklist, created by the author, divides risk factors into two:
1) risks associated with the information on DG;
2) risks concerning assets and operations related to the DGT.

Implementing the checklist allows to identify and control the risks in the various stages of the transportation chain, but according to the author, the most critical moments are at the beginning (loading) and the end (unloading) in the DGTC. Inspection at loading/ directly after it helps to identify potential risks at the earliest stage of the DGTC and implement the necessary countermeasures immediately. Inspection during loading/directly after it helps to identify the risks of the transportation process and provides an opportunity to analyse bottlenecks in the entire DGTC. The frequency of filling in the checklist in a single transportation process is not limited to the specific number of times, but in the scope of the productivity of the method, it should be done at least at the beginning and the end of the transportation chain.

3.2 Multi-Level Internal Risks Management

When imposing proactive risk management, it is essential to have reliable preconditions for the major pain points in the transportation process under normal conditions, which in advance reduces risks when transporting DG. This matter has not received so much attention, as management of DG is a rather short-sighted action than proactive operating beyond the standard procedures within the transportation chain (Janno; Koppel, 2017b).

The goal is not to predict what or when is going to happen, but instead to be prepared and to able to respond in an informed and planned manner to minimise the impact of a disruption (World Economic Forum, 2012). Regardless of the mode of transportation DGT can be considered as an advanced level of the transportation chain with normal conditions *i.e.* transported goods are non-dangerous according to ADR requirements. Additional complexity is caused due to extra requirements on personnel qualification as well as on procedures within the DGTC. The risk management of a DGTC with regards to OPRs should, therefore, start at a higher level of a transportation network (Janno; Koppel, 2017b). DG training course system in Estonia is a substantial issue at this point. At the moment professional driver training in Estonia does not include general preparation on DG as there are specific initial and refresher ADR driver training course. Due to regulations, there are particular conditions when it is possible to transportation DG on simplified clauses and in this case, a driver does not need to have a training certificate. There is an apparent contradiction in a fact that professional ADR driver training course does not prepare drivers to manage risks when transporting chemicals under simplified conditions (Janno; Koppel, 2017b).

When framing the preliminary perspective of the overlapping risks between the transportation chain under normal conditions and the DGTC, within this study internal risks with the focus on OPRs were mainly studied on different levels. The first perspective of risks groups with overlapping characteristics among two types of transportation chains is framed and presented in following *Figure 13*.

Presented model links systematically internal risks of a transportation chain with normal conditions (LEVEL I) to specific OPRs of a DGTC (LEVEL II). Results refer to a clear dominance of DG risks that are on a more general internal risk classification level related to operations and factors related to employees.

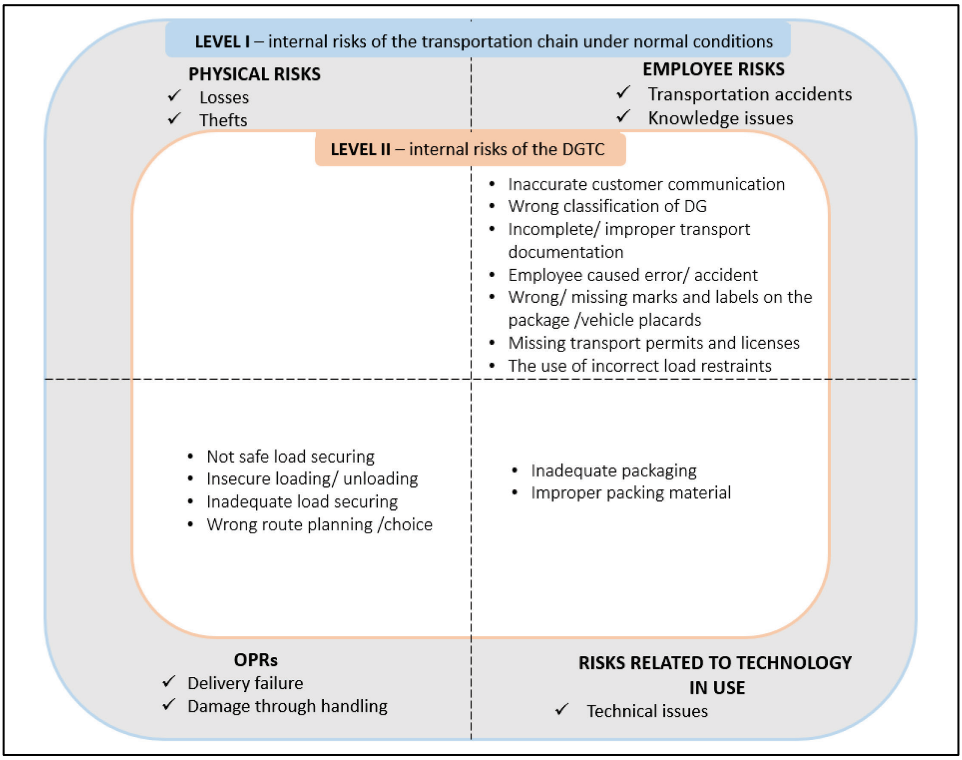

Figure 13. Multi-level internal risks management model (authors' survey results, first published in (Janno; Koppel, 2017b)).

The multiple case study analysis was implemented to validate the model and structure initial risks logically to identify straightforward relations in the scope of overlapping risks. The selection of specific DG case studies was performed purposefully as the aspect of data protection turned out to be a critical constraint (Janno; Koppel, 2017b). Designed sampling was qualified as purposive sampling where subjects are chosen to be part of the sample with a specific purpose in mind that is sufficient to draw objective conclusions concerning the methodological approach of some subjects that fit for the research compared to other individuals (Babbie, 2010); (Janno; Koppel, 2018b).

Due to the lack of information on specific cases in detail on DG, the author at this point relies on examples when transporting packaged DG as well as DG in bulk. The data was collected from different main participants of the DGTC of Estonia per each case. The Types of particular DG have not been mentioned on purpose, as risks due to specific chemical characteristics of a good are not in focus. Within cases presented below in *Table 4*, the aim is to underline the existence of overlapping internal risks between a transportation chain with conditions (LEVEL I) and a DGTC (LEVEL II) according to *Figure 13*. Internal risks of the DGTC are identified as OPRs of the transportation process.

Table 4. Internal risks relations of transportation chains.

Case No.	Remarks on a case study	Internal risks relation
Case 1	✓ Unloading of a 20' tank-container at consignee into a stationary non-portable tank. ✓ The unloading procedure was carried out in a way that the tank-container was under pressure and the good is pressed out into the stationary tank. ✓ The stationary tank was pumped over, and spillage occurred.	OPR → damage through handling → insecure loading/unloading
Case 2	✓ Transporting a full trailer load of IBCs that are less than 90% loaded with liquid chemicals. ✓ Additional slopping of a transport unit in the traffic due to the redundant clucking of a liquid within a transportation package. ✓ To prevent the apparent accident, it was vital to reduce speed in traffic to ensure safety, delay for unloading at consignee.	EMPLOYEES RISK →knowledge issues → employee caused error/accident
Case 3	✓ DG shipment within a groupage shipment. ✓ Another shipment was stacked on the DG shipment and caused the spillage of a DG within a transport unit.	EMPLOYEES RISK → knowledge issues → employee caused error/accident
Case 4	✓ The tank truck drove off the road and fell sideways. ✓ Nearest households were located in a 200-meter radius. ✓ People were evacuated within an 800-meter radius. ✓ There was a high risk of cargo to expand as it started to warm up in a vehicle tank, this could lead to an explosion. ✓ There were no possibilities to let the substance out of the tank, no appropriate means of pumping. ✓ The tank truck was pulled out of the ditch without leakage nor new danger, and nearby inhabitants returned to their residences.	EMPLOYEES RISK → transport accidents → employee caused error/accident

Source: (authors' survey results, first published in (Janno; Koppel, 2017b))

In multiple case study research methodology, cases were studied with the use of internal risks management model for multi-level transportation chain. Linking connections between possible risks of a transportation chain with normal conditions and the DGTC creates an integrated view of overlapping risks of operations in different types of transportation chains and highlights the possibilities to manage DG risks on roads during freight transportation under normal conditions (Janno; Koppel, 2017b).

The results highlight the possibility to bind risks of transportation chains with different procedural characteristics. Based on the identified relationships between internal risks in Case 1, insecure unloading procedure in the DGTC is related to the risk of damage through handling when transporting under normal conditions. Acknowledging these overlapping risks with their possible consequences in a regular transportation chain makes it possible to manage them proactively in advance with regards to the DGTC. Due to a limited number of case studies, the results of a multiple case study analysis does not let make conclusions on prioritisation of overlapping internal risks of transportation procedures on different conditions. However, the fact of the existing relation of internal risks of transportation chains with different characteristics found the proof (Janno; Koppel, 2017b).

3.3 Improved Model of Training Course System

3.3.1 Interactive Teaching Methods as a Risk Management Tool

To manage risks effectively throughout the entire DGTC, proactive risk management concepts have to be implemented. The identification of OPRs in practice creates opportunities to manage internal risks individually from the perspective of each party within the DGTC. The following chapter aims to find possibilities to manage OPRs within the DGTC by providing methodologically efficient DG training courses in Estonia (Janno & Koppel, 2017a).

The following tables *Table 5* and *Table 6* present respondents' attitude and preferences (in the number of respondents and percentage of total share) by clusters concerning different methods that learners have experienced or are willing to undergo when taking DG training courses in Estonia (Janno & Koppel, 2018a); (Janno; Koppel, 2018b).

Table 5. STEM methods evaluation for CLUSTER 1.

Evaluation scale / Method (Category)	1 (most inefficient)	2	3	4	5 (most efficient)
E-learning on a distance (A)	54 (36%)	57 (38%)	28 (18%)	6 (4%)	6 (4%)
Peer-learning (B)	29 (19%)	19 (13%)	73 (48%)	21 (14%)	9 (6%)
Practical tasks (C)	28 (19%)	17 (11%)	19 (13%)	40 (26%)	47 (31%)
Solving case studies in groups (D)	23 (15%)	27 (18%)	26 (17%)	35 (23%)	40 (27%)
Watching, analysing teaching videos (E)	28 (19%)	9 (6%)	20 (13%)	48 (32%)	46 (30%)
Reading individually materials (F)	29 (19%)	38 (25%)	34 (23%)	27 (18%)	23 (15%)
Listening to lectures with assistance of slide presentations (G)	19 (13%)	12 (8%)	34 (22%)	71 (47%)	15 (10%)

Source: (authors' survey results, first published in (Janno & Koppel, 2018a); (Janno; Koppel, 2018b))

Within the structured questionnaire for truck drivers (CLUSTER I) and consignors/consignees, freight forwarders, representatives of carrier companies, other participants (CLUSTER II) interactive teaching methods were firstly explained thoroughly and then proposed to be evaluated in contrast to main existing methodological approach today - classroom lecturing with the support of slideshow. Methods, mentioned above, were selected mainly based on the practice of other countries (i.e. France, the Netherlands) (Janno; Koppel, 2018b).

Table 6. STEM methods evaluation for CLUSTER 2.

Evaluation scale / **Method (Category)**	**1 (most inefficient)**	**2**	**3**	**4**	**5 (most efficient)**
E-learning on a distance (A)	5 (13%)	10 (26%)	15 (40%)	3 (8%)	5 (13%)
Peer-learning (B)	4 (11%)	7 (18%)	10 (26%)	12 (32%)	5 (13%)
Practical tasks (C)	5 (13%)	3 (8%)	12 (32%)	10 (26%)	8 (21%)
Solving case studies in groups (D)	3 (8%)	6 (16%)	7 (18%)	10 (26%)	12 (32%)
Watching, analysing teaching videos (E)	4 (11%)	6 (16%)	10 (26%)	8 (21%)	10 (26%)
Reading individually materials (F)	20 (52%)	7 (18%)	4 (11%)	4 (11%)	3 (8%)
Listening to lectures with assistance of slide presentations (G)	16 (42%)	5 (13%)	6 (16%)	8 (21%)	3 (8%)

Source: (authors' survey results, first published in (Janno & Koppel, 2018a); (Janno; Koppel, 2018b))

Implementing the QCA methodology best suitable combinations of teaching/learning methods were detected. As learners' OPRs within the DGTC differ, as well as expectations toward training courses, two separate truth tables were formed by clusters separately (Janno; Koppel, 2018b). According to methodological approach, categorical variables (conditions) were defined as following: e-learning on a distance (A), peer-learning (B), practical tasks (C*)*, solving case studies in groups (D), *etc.* As a result, combinations of conditions A-G were combined that led to the outcome. Effective methodological approach (outcome W) for DG training courses for drivers (W1; CLUSTER 1) and DGSAs (W2; CLUSTER 2) in Estonia are expressed in Boolean notation below in the form of formulas (3) and (4) (Janno & Koppel, 2018a); (Janno; Koppel, 2018b).

$$(\mathrm{C} * \mathrm{D} * \mathrm{F} + \mathrm{B} * \mathrm{E} * \mathrm{G}) - \mathrm{A} \rightarrow \mathrm{W1} \quad (3)$$

$$\mathrm{E} * (\mathrm{D} * \mathrm{A} + \mathrm{B} * \mathrm{C} * \mathrm{G}) - \mathrm{F} \rightarrow \mathrm{W2} \quad (4)$$

The results underline that the methodological approach differs by learners' category. The results indicate that traditional lecturing with the support of slide presentation is still adequate and suitable teaching method concerning drivers training (Janno; Koppel, 2018b). Learner-centred interactive methods are expected to be implemented within classroom lessons, and individual theoretical learning is outdated with regards to safety adviser course for the transportation of DG by road (Janno & Koppel, 2018a); (Janno; Koppel, 2018b).

In-depth interviewing was chosen suitable for collecting data within the next stage of the research (Janno; Koppel, 2018b). Essential findings of interviews that are relevant input for improving DG training course models considering STEM methodology with the integrated use of interactive teaching methods and implementing blended learning (Janno; Koppel, 2018b) are presented in *Table 7*.

Table 7. Main findings of in-depth interviews.

Trainer[6] / **Research question**	**Trainer A**	**Trainer B**	**Trainer C**	**Trainer D**	**Trainer E**
Design of existing training course	Teacher-centred/ student-centred	Teacher-centred	Teacher-centred	Teacher-centred/ student-centred	Teacher-centred/ student-centred
Active-learning methods in use	Discussions	Discussions	Discussions	Discussions	Discussions / Q&A
Current use of ICT	No	No	No	No	Not significant use
Comments on results of previous studies	A great contri-bution of a trainer are expected	More practical aspects should be included; active-learning methods can be used without the ICT	Existing approach supports learners' expecta-tions	DG related information has to be introduced within the occupa-tional training of drivers	Important information in the scope of further activities
Changes in existing training	Partial e-learning	Improving handout materials	Improving handout materials	Provide additional voluntary DG related training to companies	Involvement of more expert lecturers
Comments on further developments of training system	Focus on knowledge; license issued to trainers individually (not to a training providing company)	Ask for systematic feedback on training course	Changes in the supervision of an ADR regulations training system	Greater emphasis on DGSA training	Audio lecturing possibilities should be studied; slow transition onto blended learning

Source: (authors' survey results, first published in (Janno; Koppel, 2018b)

[6] Trainers A-D are lecturers of ADR driver training courses; Trainer E stands for providing safety advised course for the transport of DG by road.

The intention of comparability analysis was not to compare companies (Trainers A-E) or their services, but to identify opinions and views regarding teaching methods in use and the integration of ICT opportunities and interactive teaching methods into existing ADR regulations training course system in Estonia (Janno; Koppel, 2018b). Findings from individual interviews confirm the aspect that ADR regulations training courses in Estonia are primarily teacher-centred since the only mainly used learners-centred method is a discussion (Janno; Koppel, 2018b). However, some points indicate the fact that training providers are interested in implementing new approaches to carry out training courses, including with the support of ICT possibilities. None of the interviewed trainers in Estonia is taking advantage of ICT opportunities with-in ADR driver training course. On the other hand, implementing partial e-learning is considered as further development within the existing course model (Janno; Koppel, 2018b).

Based on the results of QCA on detecting suitable combinations of teaching/learning methods within DG training courses and the results of in-depth interviews with lecturers of DG training courses providing companies of Estonia, preliminary DG training course models with the implementation of interactive and e-teaching methods were developed as presented in *Figure 14*. With regards to STEM learning, the intention is to focus on a learner-centred approach to encourage learners to engage in a situation to find solutions actively.

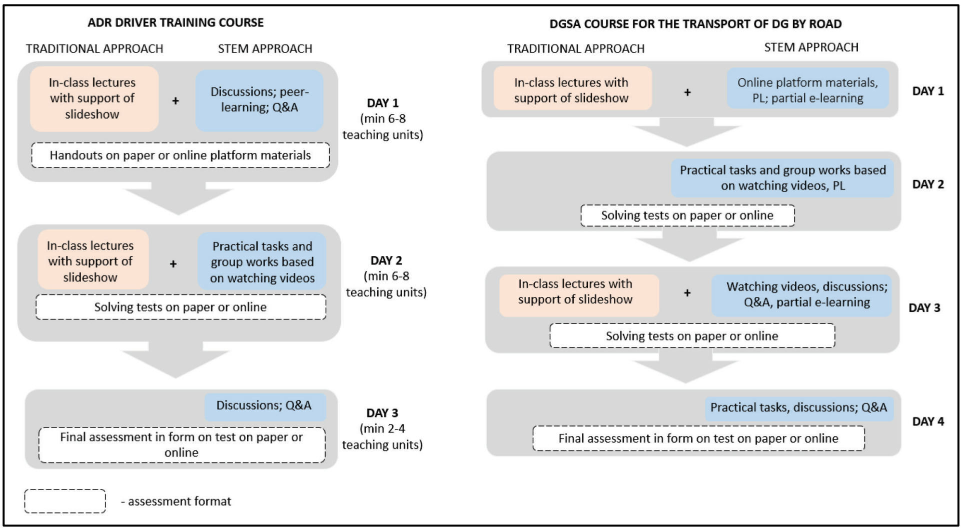

Figure 14. Advanced DG training course models (authors' survey results, first published in (Janno; Koppel, 2018b).

Due to possible risks with high consequence within the DGTC and the fact that people involved are adults, the training of employees of transportation chain of DG has to be detailed and practical giving a learner the opportunity to acquire the knowledge using different methods (Janno; Koppel, 2018b). Developed DG training course models are considered for implementing in practice for piloting. Herein opinions of all parties have been viewed with regards to applying STEM learning techniques into DG training courses in Estonia (Janno; Koppel, 2018b).

3.3.2 Focus Group Findings and Critique of Results

The aim of the focus group meeting after analysing the data and shaping primary conclusions was to present the preliminary results of the research on managing human-related risks and impact when transporting DG by roads. Meeting with DG training provider companies and a representative of Estonian Road Administration focused on collecting opinions with regards to the relevance of risk management and impact of the human factor in DGT (Janno; Koppel, 2018b) on the operational, tactical, and strategic levels. These include respectively approach in the scope of risks identification, the implementation of the checklist, and the applicability of proposed STEM education principles by the author in DG training courses in Estonia. In addition to validation of the result so far, the focus group meeting was to provide an input to determine risk impact for the DGTC performance indicator (time, cost, service quality) that affects its reliability.

Considering comments made by experts of the focus group following remarks and critique on results of the study at this point were framed:

1) The most critical are the risks associated with employees and their activities within the DGTC. Companies representing different parties of the DGTC do not feel the need to manage risks within their activities nor feel responsible for how their operations affect the entire process of transportation. Freight forwarder notices and perceives the least responsibility for risks within DGTC. That might be since this party is considered not to be the primary participant in the DGTC.
2) Customer relations as an OPRs within the DGTC is critical and underestimated. Consigner/consignee are often not familiar with the issue of risks in practice within DGTC. More information about the risks of other parties within DGT would increase everybody’s awareness.
3) The implementation of the checklist when transporting specific DG as agreed within the DGTC. However, any additional documentation is time-consuming. The approved use of developed checklist might be efficient with regards to risk identification with a minimum of time loss, that cannot be guaranteed when implementing security plans according to ADR provided for participants engaged in the carriage of high consequence DG or high consequence radioactive material (ADR, 2017)
4) Participants of DGT are not aware of DGSAs of different parties within the DGTC. The driver cannot reach the adviser to ask for advice in a critical situation or does not know who is the right person to contact.
5) The content of driver's occupational training should include necessary information on DG and their hazard characteristic. Drivers must be able to tell the difference between DG and not dangerous ones. Moreover, considering that, under certain conditions, the transportation of DG in limited quantities (LQ) is allowed without passing the course, in this case, the drivers must also be aware of the risks of DGT.
6) Teaching methods make a difference with regards to human-related risk management (Janno; Koppel, 2018b). It was important for trainers to get to know about the efficiency of the PL methodology from the learners’ perspective on OPRs management. Specific methods must be used purposefully with regards to specific topics, which mainly depend on the quality of the training material used by the trainer. The method chosen must support the acquisition of learning material and its content (e.g. watching videos on labelling packages and placarding vehicles). In Estonia, e-learning is not an alternative in the scope of ADR driver training course.

7) Transition to interactive DG course models has to be introduced into practice step-by-step to take into account both trainers' possibilities as well as learners' readiness for a renewed approach to learning (Janno; Koppel, 2018b). Due to personal learning habits and preferences, learner needs for different learning as well as self-/final-assessment options. When implementing blended or e-learning learners' ICT skills have to be considered (Janno; Koppel, 2018b).
8) The DGSA trainee is more independent learner than the trainee who is undergoing ADR driver training course (Janno; Koppel, 2018b). Therefore, methods that support independent learning (e-learning opportunities) should be included in the safety adviser course for the transportation of DG by road to a greater extent. Implementation of the advanced methodological approach of DG training courses in Estonia should begin with DGSA training (Janno; Koppel, 2018b).
9) Voluntary DGSA and the possibility for flexible training within safety adviser course for the transportation of DG by road. The flexible choice of topics from the content of the DG training courses, depending on the specifics of the companies, would increase their awareness of DG and related (operational) risks among other participants of the DGTC (terminals, warehouses *etc.*).
10) The assessment has to be focused on content knowledge not checking facts. During self-assessment as well as final-assessment the use of materials (Internet) should be allowed (Janno; Koppel, 2018b). Unlimited access to materials directs the learner to find a solution to the problem. The assessment has to be more integrated into the learning process and, learners will also take responsibility for it (Janno; Koppel, 2018b); (Schreurs & Dumbraveanu).
11) Increasing supervision. Training license has to be trainer based (not the training company based), and training companies should not be responsible for arranging examination at training institutions.
12) The further development of DG training course models with the implementation of virtual reality solutions with the variety of specialised simulations for education and training purposes (Janno; Koppel, 2018b). Simulating complex incidents and accidents with DG on roads may have a positive effect on managing risks, as drivers/ DGSA may never face similar situations in practice unlike the awareness of a danger that is acquired through simulation (Janno; Koppel, 2018b).[7]

Comments and the critique of ADR experts of Estonia on results of the study was the primary input for the measurement of the reliability of the DGTC according to KPIs of transportation. According to KPIs of transportation selection, these are cost, time and service quality. The following *Table 8* divides the results of the study on their operational, tactical and strategic extent with regards to human-related risk management. This finding relates directly to the RQ4 presented in the introduction of the thesis. Within this model, the impact on the transportation chain's main KPIs is specified for each activity through increasing (↑) or decreasing (↓). These metrics determine the reliability of the whole process of the DGT.

[7] Similar simulations are in use for training of fire and medical emergency situations on the example of the German Chemical Industry (Janno & Koppel, 2018a). Firefighters can train their behaviour on complex transport accidents with DG on motorways, rails, and country roads. Most of the firefighters have not been called very often to those accidents in their daily business. Within virtual training spaces, it is possible to train staff's behaviour and to cope with complex operations (Janno; Koppel, 2018b); (Richert, Shehadeh, Willicks, & Jeschke, 2016).

Table 8. The extent and impact of risk management means.

Extent	Risk management method	Cost	Time	Service quality	Total reliability
Operational	Short-term risk identification and the checklist implementation	-	↑	↑	↑
Tactical	Advanced DG training course system	↑	↓	↑	↑
Strategic	Multi-level internal risk management	-	↓	↑	↑

Source: (author's compilation)

As a result, three different types of risk management means were proposed in the scope of managing human factor related risks and impacts in DGT by roads. In the context of the reliability of the DGTC indicators represent the following:

1) the cost includes direct outlays related to the implementation of the risk managing method within the transportation chain;
2) the time factor covers the range of the DGTC from the moment of loading of DG at the loading point till the unloading at the consignee's place of unloading.
3) the quality of service in the DGTC within the entire transportation process.

From the perspective of the extent of the possible impact on transportation chain reliability submitted approaches can be combined into the three-tier model with operational, tactical and strategic level. The overall aim to increase the reliability of DGTC is achieved, as the overall performance of the KPIs on the reliability of the transportation chain is positive from the perspective of each risk management mean individually. From the perspective of the RQ4 presented in the introduction of the thesis, the risk management of DG can be improved at the level of training on the tactical level and has a positive effect on the total reliability of DGTC.

At this point of research, the main criticism with regards to the outcome, a three-tier model to manage human-related risks, is that it defines their impacts descriptively (qualitatively). The estimated total reliability of the DGTC also doesn't give the detailed view of the impacts of different parties of the transportation process respectively. The outcome of the development research of this study was validated form the conceptual point of view but not implemented in practice. Piloting in the form of testing the model takes time as identifying changes of impacts after implementing presented risk management means on operational, tactical and/or operational level will take time. The risk management of DGT is a continuous and time-consuming process, which needs to be addressed on a consistent basis.

3.4 Further Research

In this research work, a proposed model for managing OPRs and their impacts when transporting DG by roads is introduced. Risk-mitigating activities covered by the front-line model are independent of the participants - i.e. regardless of the multiplicity of participants and the complexity of the transportation chain, the risk managing means proposed by the author may be implemented individually by one or more participants within the DGTC. The current research concerns risk management of OPRs with restrictions and the topic calls for further research.

Further research related to the issue of human factor related risks and their impacts on road transportation of DG has to be the continuous activity with regards to efficient risk management within the DGTC. Key recommendations for future research related to the primary results of the study are as follows:

1) The more detailed and up-to-date data on transported DG by UN classes would give a better understanding of the future risks at different stages of the DGTC.
2) More in-depth analysis of the overlapping risks of participants of the DGTC to exclude duplicated activities and identify who has the highest potential for hedging a particular OPR in its activity.
3) The implementation and impact assessment of advanced risk management tools within the scope of DGT security. To obtain comparable results, it is essential to agree on specific metrics on how to evaluate the efficiency of approaches on operational, tactical and strategic levels. The assessment should differentiate risks and their impacts over the entire transportation chain and separately by the activities of each participant.
4) The study on the performance of piloting advanced DG course training system both from trainer companies' as well as learners' perspective. Based on the conclusion that transition to interactive DG course models has to be introduced into practice gradually, a series of step-by-step activities with regards to implementing new methods and the assessment of their impact of OPR management has to be developed.
5) Study possibilities to improve learners' attitude towards interactive teaching methods within DG training course system in Estonia. The study showed the drivers' strong unwillingness to learn through e-courses. Further research related to this issue has to keep up with changes and consider changing learner concept consistently.
6) Quantifying the KPIs reliability of the DGTC chain with values of the metrics to be able to identify the most / least important component of reliability.
7) Guided studies to assess the costs of external costs of a transportation chain, i.e. investments concerning capability/preparation for participation in the DGTC.

Most of the further research aims should be achievable through the combination of existing analytical methods. The collection of data has to be simpler and more operational. With this conceptual framework on the continuous study of human-related risks and their impacts, the developed risk management model can be complemented in time, making it more detailed and precise with regards to increasing safety in DGT by roads.

Conclusions

The author studied the field of the human factor related risks and their impacts in DGT which needs a distinct approach in risk management in the scope of proactive activity. **The central problem of the thesis accented the short-sightedness of risks management in the DGTC with regards to human-related risks as the focus is on ensuring safety mainly, not on the elimination of consequences.** The author of the thesis **aimed to emphasise the importance of not underestimating OPRs within the DGTC** and proposed the universal model for preventive risk management on operational, tactical and strategic levels of DGT.

In order to achieve the set goal, the following was done during the research in order to answer the RQs of the study:

1) The theoretical content confirmed the DGTC as a complex system due to the variability of participants and their responsibility, mobility and dynamicity of its hazards. These are the main features defining the process of risk management associated with the DGT (RQ1).
2) OPRs by different parties of the DGTC were identified and assessed. The checklist as a quick response instrument to identify OPRs at critical points of the DGTC was proposed. Hence, became clear what the most common risks are related to human factors when transporting DG by roads (RQ2).
3) Associating OPRs of DGT with the internal risks when moving goods under normal conditions by roads leads to the possibility to manage DG risks through multi-level internal risks management model (RQ3).
4) The most suitable ways of providing DG training courses were identified from the perspective of learners' attitude to guarantee effective and efficient risk management of DG risks during transportation by roads. The advanced DG training course system with the integrated use of interactive methods was developed and assessed with regards its feasibility in Estonia (RQ3).
5) The OPR management model in DGT on operational, tactical and strategic levels with qualitative metrics to evaluate the total reliability of the DGTC was developed. From the perspective of training personnel, DG training courses improve the reliability of the DGTC form the tactical point of view (RQ3 and RQ4).

The risk management model which determines the preventive means for ensuring safety within DGT was developed using semi-quantitative DG risk assessment, QCA, comparability and multiple case study analysis. As a result, all participants in the DGTC can manage OPRs on three levels: operational, tactical and strategic. These preventive activities have an impact on the hedging of risks in the transportation chain as a whole, as well as in the previous and subsequent levels as presented in following *Figure 15*.

Risk management is one of the critical issues during planning safe handling and transportation of DG (Janno & Koppel, 2017a). Based on the study the author proposes specific risk-management activities that confirm the practical contribution of the results in the study. The author is confident that the proposed OPR management approach for the DGT by roads allows foreseeing human-related internal risks of the DGTC and enables to manage them proactively depending on the extent of the impact of the risk.

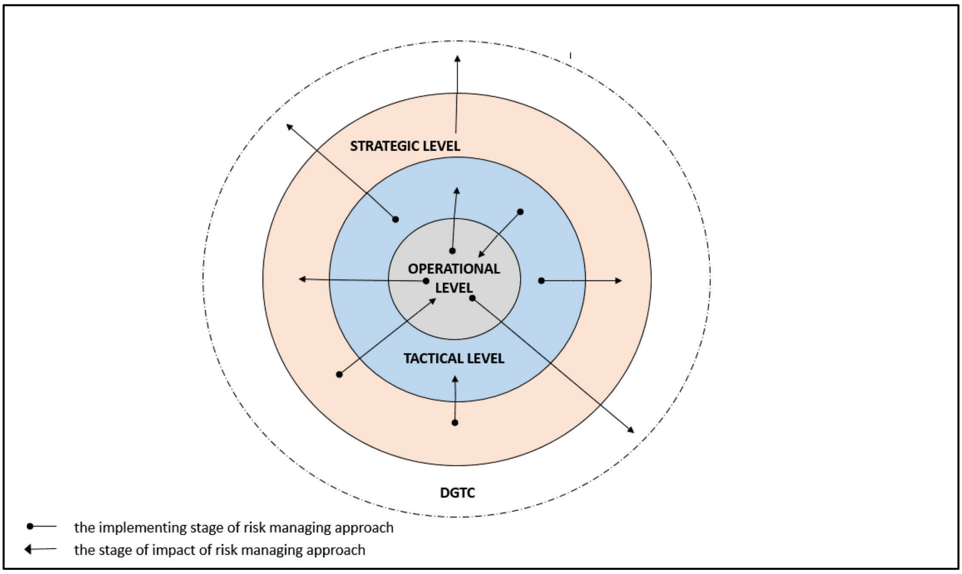

Figure 15. OPR management model in DGT (author's compilation).

At the operational level of risk management, the proper and up-to-date identification of OPRs is guaranteed by implementing the checklist at critical points of the transportation chain. According to results from semi-quantitative risk assessment incomplete or improper transport documentation is considered as the most severe risk in the DGTC from the perspective of consignor/consignee. The importance of consignor's/consignee's activities highlighted due to a large number of different OPRs and highest scores in total. The implementation of the checklist for carriers creates conditions to identify the existence of OPRs within the DGTC on the primary level.

The change in existing teaching practice today regarding DG training courses is necessary due to many aspects. Continuously increasing number of the possible harm to the health of people and the environment in general as well as the rapidly changing concept of learner are primary subjects that indicate to development towards a learner-centred approach in DG training course system (Janno; Koppel, 2018b). At the tactical level of the risk management model, the advanced DG training course system was proposed as OPRs management mean. With the integrated implementation of interactive teaching methods advanced course models focus on learner during the process allowing a training participant to acquire learning outcomes more efficiently. Improving STEM skills and capabilities within advanced DG training models, learners will be able to make more informed decisions with regards to managing risks within DGTC.

Findings, with regards to the internal risks, when transporting under normal conditions, can mitigate the OPRs associated with DG, was confirmed, as overlapping risks were defined. Based on this, the author formed the multi-level internal risks management model as risk management means at the strategic level of risk management in DGTC. The more overlapping risk related to transportation chain under normal conditions are identified at this level, the more efficient is the entire risk management. Finally, this leads to less necessity to deal with OPRs at the tactical and operational levels of DGTC.

The primary theoretical and methodological contribution of the thesis was to collect appropriate database with regards to DGT information in Estonia and establish a relevant theoretical platform for sustainable research in the field of DGT with the focus on managing human-related risks and their impacts. Relying on over 15 years of experience in international road transportation in an Estonian private property carrier company and having considerable experience in the DGT by roads, the author is convinced that irrespective of any direct and indirect costs involved in the implementation of one or another risk managing means, has a vital importance. Firstly, it creates a critical attitude among risk-takers in the DGTC with regards the prevention of OPRs, and secondly, its impact in practice increases the reliability of the transportation chain, that is the primary objective of transportation logistics.

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Acknowledgements

The following people and organisations are acknowledged for their contributions and input to the research:

PhD Supervisor
Dr Ott Koppel

PhD Co-Supervisor
Prof. Emeritus Dr Jüri Laving

Research Assistance
Students of Tallinn University of Technology and TTK University of Applied Sciences

People and Organisations
Mr Ergo Urb; Ergo Transport Grupp, Ltd.
Mr Enn Edussaar¸ Autojuhi Koolitus, Ltd.
Mr Timo Korhonen; Roolikool, Ltd.
Mr Tõnu Mägi; ADR Koolitus, Ltd.
Mr Andrus Raamat; Estonian Road Administration, Area of Traffic Safety and Public Transportation Examination Department
Mr Meelis Bergmann; Krimelte, Ltd., Production Department
Mr Janari Talvistu; Krimelte, Ltd., Production Department
Mr Raul Matsar; TNT Express Worldwide Eesti, LLC; Service Quality, Customs, Dangerous Goods
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Joonas Henri
Laura Isabel
Mom
Dad

Abstract

Risk Management Model: Human Factor Related Risks and Their Impacts in Road Transportation of Dangerous Goods (DG)

When DG are transported by roads, it is critical to follow both legal requirements as well as meet suggested safety regulations in order to prevent accidents during activities with chemicals that are harmful to people, assets and environment (Janno & Koppel, 2017a). The author discusses the problem that the risk management in the dangerous goods transportation chain (DGTC) with regards to human-related risks is short-sighted and focuses on the elimination of consequences instead of ensuring safety proactively. The thesis aims to develop a universal risk management model with an emphasis on managing the human factor related risks on different levels of activity in the DGTC.

The developed model approaches the risk management of the DGTC from operational, tactical and strategic levels and provides qualitative key performance indicators (KPIs) to evaluate the total reliability of the transportation chain. For designing the model, the author with the assistance of the research team collected and analysed data for nearly ten years on the example of Estonia, performed repetitive studies and published articles with preliminary results.

The study was carried out on the principle of combined development research design where both qualitative and quantitative methods were implemented. Firstly, in several phases collected data on operational risks (OPRs) enabled to differentiate human factor related risks into acceptable, tolerable and unacceptable risks and form OPR matrixes separately by participants. Next, implementing the methodology of qualitative comparison analysis (QCA) combination of the best suitable teaching methods were identified. That was the basis for developing improved learner-centred DG training course models for drivers and dangerous goods safety advisers (DGSAs). Finally, OPRs of the DGTC were studied according to overlapping possibility with transportation under normal conditions. Besides, the focus group meeting with experts on DGT by roads was carried out to validate preliminary results of data analysis.

The methodological approach to the problem differentiated the risk management on three different levels. According to the author's proposal, the management of OPRs can take place on the operational, tactical and strategic levels, allowing to assess the impact of risk preventive means on to reliability of the transportation chain (cost, time, and service quality). Theoretical outcomes of the study represent establishing the platform of present status on DGT and related risks in Estonia. Empirical outcomes focus on the risk management model with the critique and possibilities to implement it in practice. Further research has to focus on the continuous study of human-related risks and their impacts and developing more detailed and precise risk management model with regards to increasing safety in DGT by roads.

Keywords: dangerous goods, human factor, operational risks, dangerous goods training course system, semi-quantitative risk assessment, qualitative comparison analysis, the risk management model.

Lühikokkuvõte

Riskide haldamise mudel: inimteguriga seotud riskid ja nende mõjud ohtlike kaupade maanteetranspordis

Ohtlike veoste transport kujutab suurt ohtu sõltumata transpordiliigist. Ohtlike kaupade transportimisel maanteedel on oluline, et järgitaks nii seaduslikke nõudeid kui ka soovituslike ohutusnõudeid, et vältida õnnetusi, mis kahjustaksid inimeste tervist, nende vara või omaksid keskkonda kahjustavat mõju. Eelnevad uuringud antud valdkonnas kinnitavad et, inimteguri tähtsus ohtlike kaupade transportimisel on alahinnatud.

Väitekirja fookuses on probleem, et ohtlike kaupade veoahela riskide juhtimine seoses inimtegevusest tulenevate riskidega on lühinägelik ja keskendub pigem tagajärgede likvideerimisele, kui ennetavatele tegevustele seoses ohutuse tagamisega. Uurimuse eesmärgiks on töötada välja riskide haldamise mudel, mis keskendub inimteguriga seotud riskidele ohtlike kaupade veoahela erinevates etappides.

Autori poolt välja töötatud mudel lähtub veoahela riskide haldamisest operatiivsel, taktikalisel ja strateegilisel tasandil ning pakub selle usaldusväärsuse hindamiseks kvalitatiivseid mõõdikuid. Ligikaudu kümne aasta jooksul teostas autor koos erinevate uurimisrühmadega andmete kogumist ning analüüsi (peamiselt Eesti näitel), teostas koduvuuringuid ning avaldas teadusartikleid esialgsete uurimistulemustega.

Tulenevalt probleemist kujundas autor selle lahendamiseks ning eesmärgi saavutamiseks kombineeritud arendusuurimuse strateegia, milles ühendas nii kvalitatiivsete kui ka kvantitatiivsete meetodite kasutamise. Eesmärgi saavutamiseks läbis autor järgmised olulised uurimuslikud etapid:

1) inimteguriga seonduvaid riske eristamine aktsepteeritavateks, lubatavateks ja vastuvõetamatuteks ning veoahelas osalejate lõikes riskimaatriksite koostamine;
2) sobivate õpetamismeetodite tuvastamine kvalitatiivse võrdlusanalüüsi tulemusena;
3) täiustatud õppijakesksete koolituskursuste mudelite välja töötamine (autojuhtide ja ohutusnõunike jaoks);
4) ohtlike kaupade ja tavaveoahela kattuvate tegevusriskide tuvastamine;
5) esialgsete tulemuste valideerimiseks fookusgrupi kohtumine ohtlike kaupade valdkonna ekspertidega Eestis.

Autori ettepanekul võib tegevusriskide haldamine toimuda operatiivsel, taktikalisel ja strateegilisel tasandil, võimaldades hinnata riskiennetusvahendite mõju veoahela usaldusväärsusele kulu, ajafaktori ja teenuse kvaliteedi alusel. Uuringu teoreetiline väljund on aluseks (andmed ja metoodika) ohtlike kaupade transpordi olukorrale ja sellega seotud riskide staatusest Eestis. Empiirilised tulemused keskenduvad riskide haldamise mudeli kujundamisele, selle kriitikale ning võimalustele selle rakendamiseks praktikas. Edasised uurimissuunad antud valdkonnas peavad tagama inimtegevusega seotud riskide ja nende mõjude jätkuva uurimise ja mudeli täiustamise, et suurendada ohutust seoses ohtlike kaupade transportimisega maanteedel.

Märksõnad: ohtlikud kaubad, inimtegur, tegevusrisk, ohtlike kaupade alane koolitussüsteem, kombineeritud riskianalüüs, kvalitatiivne võrdlusanalüüs, riskijuhtimise mudel.

Appendix 1

PUBLICATION I

Janno, J., Koppel, O. (2017). Human factor as the main operational risk in dangerous goods transport chain. In: D. Dujak (Ed.). Proceedings of the 17th International Scientific Conference Business Logistics in Modern Management (pp. 63-78). Osijek: Faculty of Economics in Osijek.

Drafts as conference proceedings:

- Krasjukova, J. (2011). Innovations in Dangerous Goods Transport Process Organization and Technology. The 23rd NOFOMA Conference, Harstad, Norway, June 9-10, 2011.
- Krasjukova, J. (2012). Practical Output of Dangerous Goods Training on example of Estonia's Carriers. NOFOMA 2012 The24th Annual Nordic Logistics Research Network Conference 7-8 June 2012, Naantali, Finland. Ed. The University of Turku. Turku University Press.

HUMAN FACTOR AS THE MAIN OPERATIONAL RISK IN DANGEROUS GOODS TRANSPORTATION CHAIN

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Abstract

When packaged dangerous goods (DG) are transported by road, it is critical to follow both legal requirements as well as meet suggested safety regulations in order to prevent accidents during activities with chemicals that are harmful for man, assets and environment. Due to the fact that there are multiple parties involved into handling and transportation procedures, plenty of different risks can occur during these activities with DG. As the importance of human factor has been underestimated, this paper focuses on analysing different types of risks within a dangerous goods transportation chain related to specific participant. By analysing and prioritising risks, the most critical of them are identified and evaluated upon possible harm to entire chain. The paper presents a combined overview study based on theoretical aspects and which is supported by results of previous studies regarding risk assessment of DG transport in practice. Additional results of research regarding how involved parties in Estonia evaluate possible harms resulted by their activities while handling and transporting DG confirm the main finding that human factor is one of the crucial factors why accidents occur. Despite the limited study group generalisations of research results are applicable widely in Europe due to the universal features of risks as well as common legal requirements (The European Agreement concerning the International Carriage of Dangerous Goods by Road; *i.e.* ADR). In scope of further research, results of present study are milestones to focus on managing risks affected by human factor in road transport of DG.

Key words: dangerous goods, road transport, ARD regulations, risks, human factor

1. INTRODUCTION

All substances that induce severe risk for health, that can harm people, environment and surrounding properties, or other living organisms, are characterized as dangerous goods (DG) (Tomasoni, 2010). Dangerous goods transport (DGT) includes all goods - liquids, gasses, and solids - that include radioactive, flammable, explosive, corrosive, oxidizing, asphyxiating, biohazardous, toxic, pathogenic, or allergenic materials (Berman et al., 2007) and (ADR, 2017). In scope of road transport these are all the substances and materials described in Annex A and B of the ADR, the European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR, 2017). Regulations are essential to prevent not only risk, but also to reduce hazard. In the transport of DG the key problem is how to optimize transport and distribution, minimizing the risk of accident (Tomasoni, 2010).

Major activities in logistics include both inbound logistics and outbound logistics, and transportation is one of two critical functional areas besides inventory (Choi *et al.*, 2016). A transportation chain maps the whole route between the place of origin and the destination as well as describes the individual transportation for each route segment along the transport route. A typical transportation chain of DG may include many parties, from consignors and consignees, freight forwarders and carrier companies. From the perspective of present paper, transportation chain starts at consignor's with loading and ends at consignee's with unloading procedure. Considering possible risks in regards with DG, it is vital for transportation chain to operate efficiently and effectively by all the corresponding members function properly. In other words, if any member fails to perform, the system will easily collapse and fail to achieve its objectives (Choi et al., 2016).

DG logistics is a complex system of which the DGT system is a specific subsystem which can be in turn be modelled in several other subsystems (Tomasoni, 2010). The scope of this paper is to survey operational risks within the DGT system based on transportation chain where three different parties are involved – consignor/ consignee, carrier and freight forwarder. When a dangerous event happens, caused by human error, and involving DG, the consequences cannot sometimes be reduced or contained. So, it is essential to apply preventive measure to reduce the probability of occurrence, or/and magnitude of the consequences (Tomasoni, 2010). The aim is to evaluate impacts of risks that are resulted by different operations within the transportation chain during the transport process of DG.

Based on conducted survey research and interviews with different parties of a DG transportation chain in Estonia, a comprehensive operational risk impact assessment framework is developed. Results can be used in further researches to determine proper risk management tools in order to minimize the risks arising from transportation or maximize the level of security in DGT.

2. LITERATURE REVIEW

During the last twenty years, several researches have been carried out by different researchers on the issue of risk assessment on the DGT (Conca et al., 2016). These studies were focused especially on safe transportation using pipelines (Citro & Gagliardi, 2012 via Conca et al., 2016), railway transportation (Liu et al., 2013; Saat et al., 2014 via Conca et al., 2016), and road transports (Fabiano et al., 2002, 2005; Yang et al., 2010 via Conca et al., 2016). The research on road transport of HazMat (Hazardous Materials) follows three topics. The first is related to methodologies aimed at improving emergency response based on road properties, weather conditions and traffic factors (Fabiano et al., 2005). The second is based on methodologies for survey and accident risk analysis from historical data aimed at divulging accident characteristics such as frequency of occurrence, accident consequences, and identification of causal factors (Fabiano et al., 2002; Yang et al., 2010; Shew et al., 2013 via Conca et al., 2016). The last topic focuses on decision making aimed at improving choice of truck capacity (Guo & Verma, 2010 via Conca et al., 2016) and route (Fabiano et al., 2002 via Conca et al., 2016).

As a fact the improvement of road traffic safety is one of the most important objectives for transport policy makers in contemporary society, and represents a strategic issue for enhance life quality. This is strongly supported by the fact that many studies regarding DGT risk assessment focuses on technical aspects and quantitative methods rather than on risks related to human factor that is studied and analysed by applying qualitative methods to formulate outcomes.

According to the qualitative studies of managing risks in DGT (Krasjukova, 2010) there are three main decision criteria in the sphere of DG road transportation, which can be accepted as sets of preventive means derived out of technical, procedural or personnel factors. Particular risk preventive means related to human factor in road transport of DG that consequently refer to possibly related operational risks are structured as following.

1) Risk preventive means concerning procedures within DG transportation chain:
    a. loading procedures at loading areas according to safety requirements;
    b. labelling of packaging (clear and easily identifiable labelling of cartons to reduce risk of picking errors);
    c. loading order and placement of dangerous load in the transport unit;
    d. restricted parking authorization;
    e. fixed traffic routes with the necessity to get the confirmation from institutions in control;
    f. additional road permissions system for third countries;
    g. higher prices for ferry tickets and tunnel passes;
    h. daily temporal and seasonal driving bans;
    i. special procedures when accident occurs;
    j. compulsory transport documentation and remarks on documents;
    k. DG shipment tracking system;
    l. marking and labelling the shipment and vehicle (Erceg & Trauzettel, 2016; Krasjukova, 2010).
2) Risk preventive means concerning personnel and parties involved:
    a. ADR training for drivers;
    b. ADR training for safety advisers (freight forwarders and logisticians);
    c. work safety and ergonomics trainings for personnel;
    d. economic driving training for drivers;
    e. performance appraisals with personnel (Krasjukova, 2010).

In relation to the main topic of this paper specific human related risk preventive means are defined above. Preventive means, pointed out, are currently widely in use in road transport sector and have become as binding requirements and compulsory procedures in the overall process of DGT.

Transport is always associated with human risk factors that cannot be completely excluded. This paper deals with human related risk preventive means in details by the evaluation of possible harms resulted by activities while handling and transporting DG within the transportation chain. In following parts, the semi-quantitative method to evaluate impacts of operations within the DG transportation chain is applied and results are presented. Despite the limited study group adequate data is collected and operational risk assessment is performed on example of DG transportation chain parties of Estonia.

3. BACKGROUND

3.1. ADR regulations

In ADR appear the limitations applicable to the various operators of the lo gistics chain (buyers, transporters, manufacturers of packaging and tankers *etc.*) giving specific treatment to their field of activity. The regulation topics of law ADR are as following:

1) the method of identification of DG;
2) the lists of DG permitted for transport on the roads;
3) the modality regarding transport, type of packaging and the connected approval tests;
4) the planning and construction of the tankers;
5) the checks and the recognition of technical suitability of the vehicles used to transport the DG;
6) the training and recognition of the vehicle drivers (Tomasoni, 2010).

Laws and regulations on the use, loading, unloading, storing, transporting, and handling of DG may differ depending on the activity, status of the material, and modality of transport used. Most countries regulate some aspect of DG at UNECE (The United Nations Economic Commission for Europe) level (UNECE, 2010), that is the most widely applied regulatory scheme. The UN Recommendations on the Transport of Dangerous Goods form the basis of several international agreements, such as UNECE regulations and many national laws (UN Recommendations on the Transport of Dangerous Goods, 2015).

The transport of DG is an activity which is increasingly international and multi methodological. Regulations involved can therefore not disregard connect itself to international level to sustain a future integrated logistics syst em with multi method efficiency (Tomasoni, 2010).

3.2. Responsibilities of parties involved into DGT

With regards to transportation of DG on roads there are traditionally same parties involved as when transporting general goods. The main difference is noted related to responsibilities of participants in the carriage of DG and obligations on those that ADR considers the main participants. According to ADR there are main parties (consignors; carriers; consignees) and so-called other parties (loaders of packages; packers; fillers; tank-container/ portable tank operators; unloaders of packages or of tanks/ bulk vehicles) mentioned.

There are even more participants involved in the safe transport of DG that are not mentioned in ADR Chapter 1.4 on safety obligations of the participants. From the perspective of transportation chain of DG the foremost amongst these are drivers, who are not mentioned but whose safe driving is perhaps one of the most critical factor for ensuring the safety of the general public during the transportation of DG. The driver is usually responsible for checking that they have the right fire extinguishers, in the correct condition, as well as the other emergency and personal protective kit prescribed in ADR. The driver is also usually considered responsible for ensuring the correct paperwork for themselves, their load and, if applicable, the vehicle is present and in order (Waight, 2015).

Another party whose safety obligations are not mentioned in ADR are freight forwarders. A freight forwarders might not come into direct contact with the goods, even though they will be passing on the documents and instructions to those who are. The role of freight forwarder is vital in transmitting critical information within the transportation chain and should not be underestimated. Other parties that may also be important but that are not directly included into transportation chain of DG are the following:

1) those who manufacture, test and certify packages, tanks and bulk vehicles;
2) those who test DG for their properties;
3) those who provide a classification of the goods;
4) cleaners and decontamination workers;
5) manufacturers and distributors that use other parties (such as freight forwarders) to consign on their behalf (Waight, 2015).

The UN Recommendations on the Transport of Dangerous Goods — Model Regulations outlines the steps that need to be taken to ensure the safe carriage of DG (UN Recommendations on the Transport of Dangerous Goods, 2015). Most of the international or major regional requirements that reflect the UN's provisions, generally do not detail the responsibilities of those involved (Tomasoni, 2010). ADR Chapter 1.4 cites the arrangements concerning safety which must be taken into account by every person involved in the transport of DG. In this chapter the carriers and all others involved in the transport of DG at high risk are required to adopt, carry out and follow a safety plan. This must include:

1) specific roles of responsibility in the matter of safety;
2) the recording of the DG in question and their typology;
3) the monitoring of the vehicles;
4) definition of the measures to adopt to reduce the safety risks;
5) efficient procedures to identify and face threats, safety violations and incidents connected to safety;
6) procedure of evaluation and verification of the safety plans;
7) measures to assure the physical protection of information connected to the transport contained in the safety plan;
8) measures to assure that the distribution of information connected to the transport operation, contained in the safety plan, is limited according to necessity (Tomasoni, 2010; ADR, 2017).

3.3. Risks

On a national scale it is shown that DGT accidents on the roads make up no more than 0.1% of total accidents (Eurostat, 2016). But, even though this probability is minimal, the consequences are important when dangerous substances are involved. Regulations are essential to prevent not only risk, but also to reduce hazard. Firstly, the risk attached to the transport of DG by road is a risk that is hard to understand as it is connected to all the road network and depends on multiple factors such as traffic density, weather conditions, the necessities of undesired events (road accidents, natural phenomenon *etc.*). Secondly, this risk is also strongly linked to the nature of the transported goods and to the presence of exposed humans and materials in proximity to the place of incident. For example, the transport of fuel such as petrol or GPL (*a.k.a.* liquefied petroleum gas, liquid propane gas, LPG, LP Gas) can provoke considerable fire or the explosion of the tankers in which it is transported, with heat, excess pressure and missile effects (Tomasoni, 2010). Thirdly, the risk of DGT is strongly related to a human factor as all decisions, processes and procedures within a transportation chain are made by different parties involved.

According to classical definition of a risk it is a measure of frequency and severity of harm due to a hazard. The hazard in this context is the presence of DG having toxic, explosive, and/ or flammable characteristics with the potential to cause harm to humans (and property or the environment if a broader context is considered). In the context of public safety, risk is commonly characterized by fatalities (and injury) to members of the public (Risk Assessment – Recommended Practices for Municipalities and Industry, 2010).

Risk arising by DGT represents a particular threat which needs strategies and tools to reduce risk rate of society, property and environment (Conca *et al*, 2016). Several factors contribute to making it difficult to assess risk in transporting DG, including:

1) the diversity of hazards in addition to main danger characteristic: the substances transported are multiple and can be flammable, toxic, explosive, corrosive or radioactive materials at the same time;
2) the diversity of accident sites: highways, county roads, local roads, in or out of town (75% of road accidents take place in open country), facilities, pipelines, *etc*.;
3) the diversity of causes: failure mode of transport, containment, human error, *etc.* (Tomasoni, 2010).

4. PROBLEM DESCRIPTION

DGT is a worldwide problem of growing interest, mainly because of the increasing transported volumes of materials that can be classified as DG, and because of a global challenge in the goods transportation performance (Tomasoni, 2010). Based on statistics the transport of DG in the EU-28 slightly increased from 74 billion tkm in 2013 to 75 billion tkm in 2014 (+1.5%). The largest specific product group was flammable liquids, taking over more than half of the total. Two other groups, gases (compressed, liquefied or dissolved under pressure) and corrosives, accounted for 14% and 10% respectively. This represents very little change compared with previous years showing a very similar distribution between product groups (Eurostat, 2016).

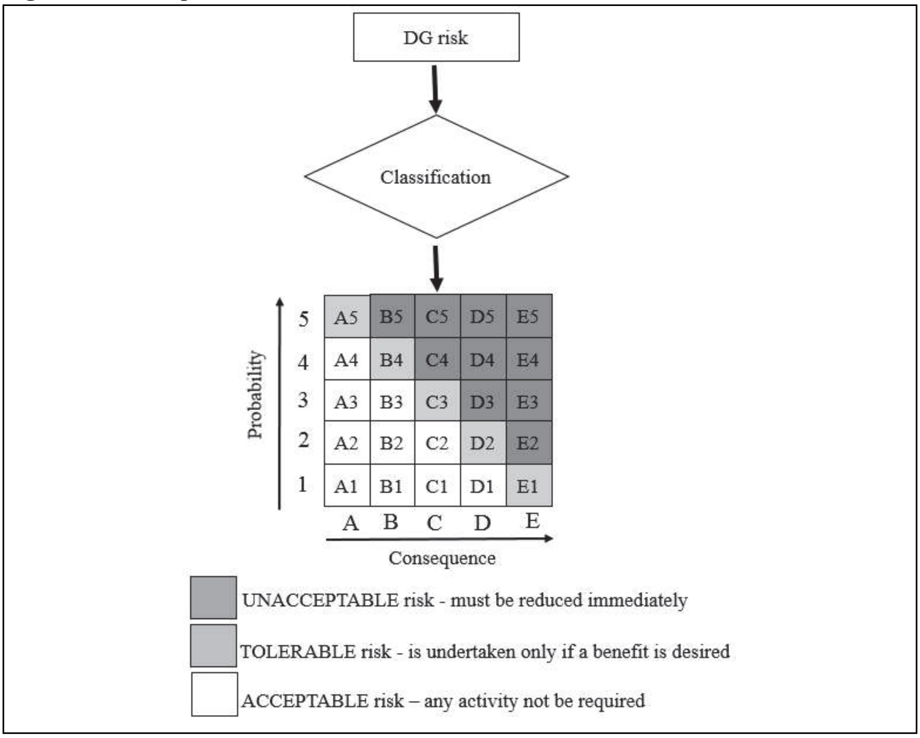
When the transport network crosses heavily populated areas, a large number of persons could be affected by an accident such as a toxic spill or an explosion (Leonelli *et al.*, 1999). There is a substantial difference between incident and accident. The accident begins with an incident (Crowl *et al.*, 2007). An incident is defined as an event involving the transportation of DG that results in an unanticipated cost to the shipper, carrier or any other party (Tomasoni, 2010). In scope of this paper incident is considered as an operation or a procedure involved into the transportation chain of DG. It has been reported that human error is in fact the most common individual cause of DG related accidents. According to European Community's data on road transportation of DG it was found that almost half of the accidents are caused by a human error, or at least error due to human factor was a major contributor for the accident, whereas at the same time only some 8% of accidents were caused by a technical failure (Eurostat, 2016).

Risks facing different parties and their operations within the transportation chain of DG can result from factors both external (culture, regulations, board composition) and internal (accounting controls, information system, requirement, supply chain) the organisation (A Risk Management Standard, 2012). Operational risks in logistics as well as in DGT have both external and internal key divers. Operational risk can be summarized as human risk; it is the risk of business operations failing due to human error. Industries with lower human interaction are likely to have lower operational risk (Investopedia). In the DGT, most operations are run in contribution of a personnel involved, apparently operational risks are higher. Despite the fact that the probability of operational risk emerging in DGT is minimal, consequences can be crucial. The problem lies in the fact that the importance of human factor has been clearly underestimated - it is unknown what are exact operational risks within the transportation chain of DG and how severe they are. For effective DG risk management it is important to pay attention to operational risks within complete transportation chain of DG from the perspective of all parties – consignor/ consignee; freight forwarder; carrier. The aim of present paper is to commit detailed analysis of operational risks of different parties that allows to understand clearly the contrasts of risks of participants as well as assess them.

5. METHODOLOGY

To assess the risk, then analyse and estimate the level of risk of accidents three different methods: qualitative, semi-quantitative and quantitative are defined (Dziubinski *et al.*, 2006). Qualitative methods are used mainly in the validation of safety standards with regard to legal rules on the transport behaviour. These rules are usually considered as a minimum requirement that must be used to achieve certain levels of acceptable safety. The semi-quantitative methods are applied to identify hazards and to select the so-called incidental events reasonably foreseeable (credible failure events). The quantitative assessment of risk is complex and involves a series of analysis and calculations, using many simulation models, particularly the physical analysis of the effects (Tomasoni, 2010).

Figure 1. Semi-quantitative DG risk assessment



Source: Dziubinski et al., 2006, adapted by authors

Considering the specifics of operational risks in DGT, semi-quantitative risk assessment methodological approach, as shown above (Figure 1) can be adjusted in order to identify incidents leading to accidents (*i.e.* risks) and to estimate the level of risk. Based on this methodology risk probability is scaled in range of 1-5 (1 - rare; 2 – unlikely; 3 – likely; 4 – certain; 5 – imminent) and severity of risk that may arise from the possible event or outcome is scaled in range of A-E (A – minor; B – medium; C – major; D – catastrophic; E – catastrophic external) (Dangerous Goods Safety Guidance Note, 2013).

In the risk assessment definition, many concepts are involved. Risk is most commonly defined as the combination of the probability (frequency; likelihood) of occurrence of a defined hazard and the magnitude of the consequences of the occurrence as it is described by formula (1) below (Royal Society, 1992).

$$DG\ Risk = Consequence * Probability \quad (1)$$

At this point it is important to emphasize that hazard and risk are not the same. Risk is a function of hazard, as hazard is related to the intrinsic characteristic of a material, good, condition, or activity that has the potential to cause harm to people, property, or the environment, and it is often defined in terms of a probability (EEA, 1998). Danger is defined as all processes involved in the chain or sequence of events leading to an undesirable event which could have a destructive nature on population, ecosystems and goods. Probability is defined as a value between 0 and 1 and in some words is the likelihood of a sequence of events to an event not desired (Tixier *et al.*, 2010).

In the risk evaluation it is essential to say that the zero risk does not exist. In DGT the zero risk is excluded as long as the DG moves along the transportation chain from starting point to point of destination. In the process of DGT there is always a level of acceptability, even if the perception of hazard, danger, and also of risk is not so easy to quantify (Tomasoni, 2010). The risk assessment may include an evaluation of what the risks mean in practice to those affected. This will depend heavily on how the risk is perceived. Risk perception involves people's beliefs, attitudes, judgements and feelings, as well as the wider social or cultural values that people adopt towards hazards and their benefits. The way in which people perceive risk is vital in the process of assessing and managing risk. Risk perception will be a major determinant in whether a risk is deemed to be "acceptable" and whether the risk management measures imposed are seen to resolve the problem (EEA, 1998).

This paper focuses on evaluating operational risks of different parties within the transportation chain. In order to map risks within a transportation chain of DG, risks were evaluated among different parties in Estonia affected to identify what they mean to them. Data collection was performed during a comprehensive survey research with the focus to evaluate frequency (probability) and possible harms resulted (consequences) by their activities while handling and transporting DG. The survey covered companies related to DGT by road – consignors and consignees, freight forwarders and carrier companies. Due to the fact that the majority of carrier and freight forwarding companies in today's market situation have somehow been related to the transportation of DG - all of these companies turned out to be in the selection. Consignor and consignee companies as a single party were selected according to their primary activity. Most of them represent companies that produce different chemicals, building materials or use hazardous materials on a daily basis in their activity. By implementing semi-quantitative risk assessment method, it finally allows to differentiate operational risks according to their levels into acceptable, tolerable and unacceptable operational risks when transporting DG on roads as on figure upon (Figure 1).

6. RESULTS

This chapter describes results of DG risk assessment based on conducted survey research and detailed interviews among different parties of a DG transportation chain in Estonia. Based on ADR Chapter 1.4 on safety obligations of the participants of transportation chain of DG and according to ADR Chapter 1.10, which cites the arrangements concerning safety which must be taken into account by every person involved in the transport of DG operational risks of all parties are defined. As a first step of risk assessment, operational risks of different parties were defined on a basis of Estonian companies that represent different roles within the DG transportation chain.

The data collecting on operational risks within the transportation chain was performed in forms of non-anonymous online survey (carrier companies, freight forwarders) and structured interviews (consignors/ consignees). To ensure the representativeness, the sub-samplings were formatted in a non-probability sampling technique where the samples are gathered in a process that does not give all individuals in the population equal chances of being selected (Babbie, 2010). Within this study samplings are also qualified as purposive samplings where subjects are chosen to be part of the sample with a specific purpose in mind that sufficient to draw objective conclusions concerning methodological approach of some subjects are more fit for the research compared to other individuals (*Ibid.*). The distribution of the online questionnaire was provided via email invitations (136 companies that work with DG on a daily basis). Altogether 74 replies were gathered: 17 responses from freight forwarders; 57 responses from carrier companies. Some main descriptive statistics for research sample of carrier and freight forwarder companies and their shares of total sample is presented below in Table 1 and Table 2. According to these tables the majority of carriers within a sample represent companies with a considerable experience in DG transport. The experience of freight forwarder companies is considerably even. Based on volume of handled DG per year 11 most important consignors/ consignees were selected for interviews. The total products capacity of these companies form up to 80% of all dangerous goods substances handled by consignors/ consignees' companies of Estonia.

Table 1. Working experience in DG transportation

Experience in DG road transport in years	< 1	1-2	2-5	5-10	> 10
Carrier	2 (4%)	0 (0%)	5 (9%)	11 (19%)	39 (68%)
Freight forwarder	2 (12%)	5 (29%)	2 (12%)	3 (18%)	5 (29%)

Source: Authors

Table 2. Average number of DG shipments

Average number of DG shipments per month	1-2	3-5	6-10	> 10
Carrier	20 (35%)	3 (5%)	4 (7%)	30 (53%)
Freight forwarder	6 (35%)	3 (18%)	2 (12%)	6 (35%)

Source: Authors

According to questionnaire responses and additional detailed interviews, main activities that involve risks while handling and transporting DG from the perspective of consignors/ consignees, freight forwarders and carriers are presented below in Table 3. The table is supplemented with some descriptive statistics that indicates on how highly was peculiar operational risk evaluated as an operational risk that is influenced by human factor from the perspective of specific party itself within a DG transportation chain. Parties named operational risks independently and evaluated them on a scale from 1 to 5 points. Hence, 1 point was for the smallest influence and 5 points for the greatest influence of a human factor by specific operational risk. Taking into account the fact that there were different number of companies involved info sub-samplings, the highest possible score for evaluating operational risks differ hereby. It is also important to note that many operational risks have a repetitive nature in case of activities of different parties (*e.g.* improper/ incomplete transport documentation; inaccurate customer communication).

Table 3. DG operational risks named by participants

Consignor/Consignee *(11 companies; max score 55 of points)*	**Freight forwarder** *(17 companies; max score of 85 points)*	**Carrier company** *(57 companies; max score of 285 points)*
Improper transport documentation (51p)	Incomplete transport documentation (37p)	Incomplete transport documentation (140p)
Incomplete transport documentation (44p)	Inaccurate customer communication (46p)	Missing transport permits and licenses (108p)
Inaccurate customer communication (29p)	Wrong route planning (26p)	Not safe load securing (105p)
Wrong classification of DG (21p)		Inadequate load securing (89p)
Improper packing material (22p)		The use of incorrect load restraints (86p)
Inadequate packaging (31p)		Wrong / missing vehicle placards (89p)
Missing marks and labels on the package (21p)		Inaccurate customer communication (137p)
Wrong marks and labels on the package (19p)		Wrong route planning/ choice (85p)
Insecure loading/ unloading (25p)		Driver's caused error / accident (80p)

Source: Authors

By defining operational risks within the DG transportation chain makes it possible to evaluate both consequence and probability of these risks. According to structured questions in the questionnaire, respondents evaluated these indicators in the range of A-E (consequence) and 1-5 (probability). Following table (Table 4) presents an overall rating to DG operational risks from the perspective of different parties. Rating represents a combination of letter and number – the letter stands for risk consequence value and the number describes its probability. According to rating, each risks can be positioned in a DG operational risk matrix for final specification as acceptable, tolerable or unacceptable risk.

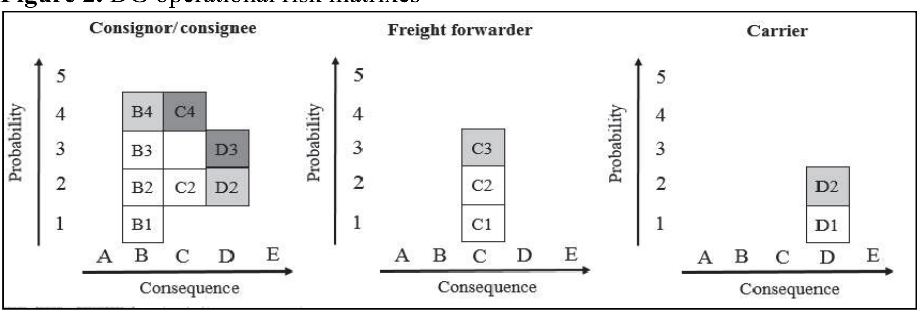
Table 4. Ratings of DG operational risks

DG operational risk	Consignor/ consignee	Freight forwarder	Carrier
Inaccurate customer communication	B4	C3	D2
Incomplete transport documentation	C4	C2	D2
Improper transport documentation	D3	C2	D2
Missing transport permits and licenses	B2	C2	D1
Not safe load securing	C2	C2	D2
Inadequate packaging	D2	C1	D2
Insecure loading/ unloading	B1	C1	D2
Wrong classification of DG	B1	C2	D1
Inadequate load securing	B3	C1	D1
The use of incorrect load restraints	B3	C1	D1
Driver's caused error / accident	B3	C1	D1
Improper packing material	B2	C2	D1
Wrong / missing marks and labels on the package	B1	C2	D1
Wrong route planning /choice	B1	C2	D1
Wrong / missing vehicle placards	B1	C1	D1

Source: Authors

By implementing semi-quantitative DG risk assessment methodology operational risks are differentiated according to their levels into acceptable, tolerable and unacceptable. Detailed results of participants' operational risk matrixes are presented below (Figure 2).

Figure 2. DG operational risk matrixes



Source: Authors

Figure 2 shows existing operational risk matrixes of consignor/ consignee; freight forwarder and carrier separately in combination of consequence of an incident and its probability within the DG transportation chain. The results underline how differently operational risks influence participants' activity within DG transportation chain. The empirical result indicates consignor's/ consignee's and carrier's risks as most severe when handling and transporting DG by roads. Based on results of risk assessment, unacceptable risks are related to incomplete or improper transportation documents and exist clearly outstanding only from the perspective of consignor/ consignee, *i.e.* in the beginning or at the end of the transportation chain. Inaccurate customer communication is a great concern for all parties and is defined as tolerable risk. This may indicate on deficiency of information flow. Even the smallest loss of information between the parties of DG transportation chain may lead to additional costs. Hence, freight forwarder's risks do not need any additional activity and the activity of this party can be considered as the most risk free within the DG transportation chain. Mainly half of carriers' operational risks are classified as tolerable risks with major consequences and with a slight possibility to take place. Identifying operational risks of different parties in Estonia within the DG transportation chain increases the awareness of role of human factor when handling and transporting DG.

7. CONCLUSION

Risk management is one of the key issues during planning safe handling and transportation of DG. Examining risks by means of semi-quantitative risk assessment method it allows to focus strictly on operational risks that are resulted by activities of different parties within DG transportation chain. There are plenty of activities when handling and transporting DG that are considered as incidents but do not necessarily lead to accidents. In order to identify which of human factor activities are closer to emergence of the accident in practice it is necessary to:

1) examine the transportation chain of DG as a complex of loading, transportation, freight forwarding and unloading procedures;
2) identify operational risks from the perspective of main parties involved;
3) assess risks in the combination of risk consequence and its probability.

The human factor has a considerable impact on ensuring safety in DGT. The number of DG operational risks of different parties and detailed operational risks assessment confirm that human factor is one of the crucial factors why incidents turn into accidents. Accidents within the DG transportation chain are caused mainly due to the number of parties involved, repetitive nature of operational risks at parties involved and the possible consequence of an event. Probability is a secondary aspect when assessing DG operational risks. Results of the study highlight, in particular, the important role of consignor/ consignee as the number of different operational risks is the largest and their levels the highest. In the scope of further studies, the exact knowledge of operational risks in practice creates opportunities to manage these risks individually (from the perspective of each party separately) within the DG transportation chain. The focus of further studies is to find possibilities how to manage operational risks within the DG transportation chain by providing methodologically effective ADR regulations training courses.

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Appendix 2

PUBLICATION II

Janno, J., Koppel, O. (2018). Interactive Teaching Methods as Human Factors Management Tool in Dangerous Goods Transport on Roads. In: Auer M., Guralnick D., Simonics I. (Ed.). Teaching and Learning in a Digital World. ICL 2017 (pp. 619-628). Springer International Publishing AG. (Advances in Intelligent Systems and Computing; 715).

Drafts as conference proceedings:

- Janno, J. (2013). Jätkusuutliku arengu tagamine ohtlike kaupade transpordilogistika vaatenurgast. Jõks, K.; Vaht, R. (Toim.). TalveAkadeemia 2013, Teaduslikud lühiartiklid, kogumik 11/2013 (lk 139-148). Tallinn: MTÜ Talveakadeemia.

Interactive Teaching Methods as Human Factors Management Tool in Dangerous Goods Transport on Roads

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Abstract. This paper studies the methodological essence of ADR regulations training courses for drivers and safety advisers. The aim of research is to advance existing teacher-centred course model in Estonia with learner-centred methods that best suit specific objectives and meet expected learning outcomes. In Estonia, ADR regulations training courses are formed based on teacher-centred course design mainly. This methodological approach is outdated as the concept of learner is changing rapidly. The aim of this research is to make study based proposals, what kind of interactive methodological approach training course model meets the best trainees' expectations in Estonia.

The paper presents a combined development research strategy based on studies regarding ADR regulations training courses in Estonia as well as on analysis of teaching methods applied in professional training of adults. Data collecting on learners' attitude and preferences regarding current methodological format of courses is collected by implementing questionnaires with structured questions from consignors/consignees, freight forwarders carrier companies and drivers. Based on learners' needs and expectations, different interactive teaching methods are examined. Implementing methodology of qualitative comparison analysis (QCA) combination of best suitable teaching methods are identified.

Theoretical outcomes represent detailed review of existing ADR training courses system, training opportunities and so far implemented methods. Empirical outcomes focus on introducing suitable interactive teaching methods within the existing format of ADR regulations training courses. Finally developed ADR training course model with a new learner-centred methodological approach considers all major parties involved into transportation chain of dangerous goods. Further researches related to this issue include discussions with ADR training courses providers and introducing an actual action plan regarding the implementation of new interactive methodological approach of ADR regulations training courses in Estonia. There is also a need for measuring exact impact of new methodological approach on operational risk management.

Keywords: ADR regulations training courses · Interactive teaching methods · Qualitative comparison analysis

M. E. Auer et al. (eds.), *Teaching and Learning in a Digital World*,
Advances in Intelligent Systems and Computing 715,
https://doi.org/10.1007/978-3-319-73210-7_72

1 Introduction

The transportation of dangerous goods (DG) by road involves always risks. If substances are mishandled, injury and property damage risks are increased. From the perspective of road transport this concerns primarily main parties of a transportation chain, *i.e.* consignors/consignees and carrier companies (including drivers), but also freight forwarders, and third parties. A transport containing DG can have a serious impact on the environment if an accident occurs and these often incur a higher cost for the society than non-dangerous goods accidents. This is one reason why it is very important to focus on improving the efficiency and security for DG transport and avoid potential accidents [21].

The content of ADR regulations training is regulated by The European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR). Effective training may affect the safety aspects in peculiar transportations, such as the one of dangerous goods transport (DGT) by road. The role of ADR regulations training courses has an essential impact on the human factors aspect that reveals during DG handling and transportation processes as the human factors are crucial why accidents occur within a transportation chain. Training may not only include regulations, technical and procedural aspects, but also important psychophysical aspects such as how to manage fatigue [3, 19]. The provider of training may be different according to national legislations. It can be the role of the employer (in the US and Canada) to ensure appropriate truck-driver training for the transportation of DG. In Sweden and the Netherlands, as well as in Estonia, a competent national authority must accredit training institutions or trainers and monitor the examination of truck drivers [13]. However, all training system approaches pursue the same goal: to ensure appropriate training and prevent the accidental release of DG during transportation. By implementing specific interactive teaching methods remarkable improvement of course participants' learning can be achieved. Moreover, operational risks related to human factors' issues can be reduced within entire transportation chain of DG.

Problem discussed in scope of this paper is a part of a broader study and refers to outdated methodological approach in carrying out ADR trainings in Estonia, both for drivers and safety advisers. Based on conducted survey research among representatives of different parties of a DG transportation chain in Estonia, best suitable interactive teaching methods are studied. Results can be further implemented in ADR regulations training course model development to be an effective human factor management tool. All this will contribute to improved security and efficiency of DGT by road.

2 ADR Regulations Training Courses

2.1 Literature Review

The global trend of increasing traffic due to globalization leads to a higher number of DGT [8]. Several studies focused especially on the critical analysis of ADR implementation concepts in European countries [*Ibid.*]. Chances and challenges coming along with the ADR ratification were illustrated and the concept/recommended procedures of how to train involved people in the framework of DG was developed on a basis of deep analysis and critics of current training methods.

Specific models, methods and technologies have been also studied in scope of support the training of drivers involved in the transport of DG [5]. Italian developed online training environment (TIP – Transport Integrated Platform) is addressed to operators in the transport sector and combines classroom based training with online self-learning possibilities on a distance. The platform has been continuously upgraded with innovative tools and presents a component of blended learning model where online digital media meets with traditional classroom methods [5, 22]. Implementing blended learning methodology within classes keeps students active not allowing them disconnect from the subject. This leads to a better attitude to improve learners' individual thinking and writing, motivating them for further study and development of new thinking skills [9, 14].

Training of safety and DG topics is very essential for a risk and accident minimization in the handling of DG and their transports. According to previous research studies on DGT the awareness of different parties of transportation chain in Estonia there is a lack of professional knowledge among personnel on the national level [11]. According to comparative analysis of teaching methods of ADR driver training courses of France, the Netherlands and Estonia, remarkable differences were identified [12]. In Estonia a significant lack of learning tools and no ARD based activities to endorse training courses and to increase the proportion of practice are so far in use [*Ibid.*].

Human related risk preventive mean lies in efficient personnel training. In following parts of this paper the methodology of QCA is implemented in order to analyse specific methods as cases due to set of relations and assess their consistency. Existing teacher-centred ADR training model will be completed with appropriate suggestions regarding learner-centred interactive teaching methods that best suit specific objectives and meet expected learning outcomes.

2.2 Background

As DG and their transport need special handling and attention due to their risk for the environment and health of people, the training of any persons having to deal with those goods is very essential for a safe processing [10]. Common legal requirements (ADR) states in details that drivers when transporting DG (with small exceptions) shall undergo training in the form of a course approved by the competent authority. Concerning chapter 1.3 of the ADR, every employee, which has to commit the duties of DG regulations, needs to be specifically trained [1]. Other parties involved within operations with DG can be: manufacturer or owner of DG, owner of tank containers, persons carrying out forwarder duties, persons writing and preparing transport documents, persons working for the DG receiving, persons committing packaging procedures, filling personnel of tanks, vehicle drivers, who do not need an ADR certificate, persons carrying out carrier and vehicle owner duties [2, 15].

Persons mentioned above often carry obligations of dangerous goods safety advisers (DGSA) as they are involved in operations with DG in road transportation. A DGSA is a consultant or an owner or employee of an organization appointed by an organization that transports, loads or unloads DG in the European Union and other countries [20]. There is no specific classification regarding DGSA courses generally. However ADR driver training courses can be classified according to two aspects. See Fig. 1 which visualises the content of training programs and training courses, highlighting common and distinctive elements of ADR driver training courses.

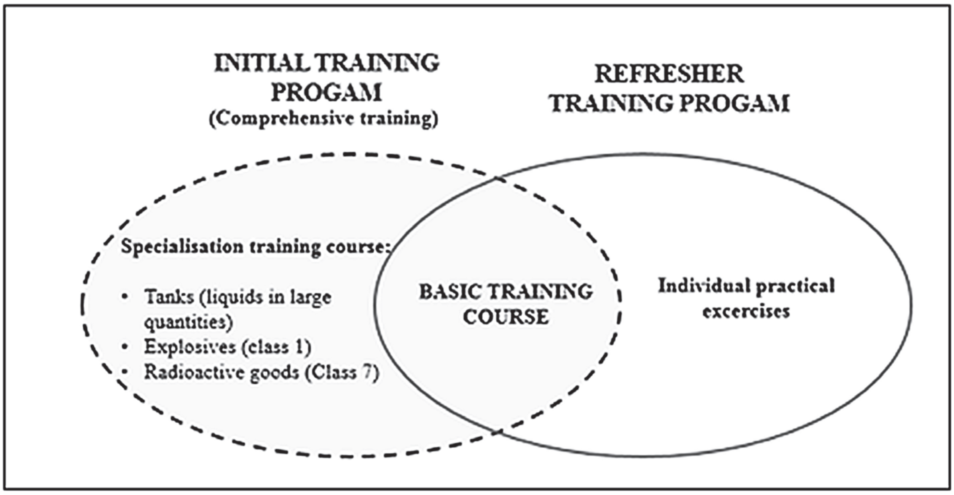

Fig. 1. Content of ADR driver training programs Source: [12]; adapted by authors

Firstly, training programs are identified on the basis of the level of the training program (initial or refresher training program) and secondly, training courses within programs are divided according to specificity (basic or specialisation training course). The minimum duration of theoretical element of each initial training course or part of the comprehensive training course are set according to common legal requirements. The overall duration of the comprehensive training course may be determined by the competent authority, which shall maintain the duration of the basic training course and the specialization training course for tanks, but may supplement it with shortened specialization training courses for Class 1 (explosives) and Class 7 (radioactive materials) [16]. Refresher trainings have to be undertaken by drivers (as well as by DGSAs) at regular intervals in every 5 years. As the form of training program is defined by compulsory topics and minimum learning hours only, it is free to choose the methodological approach to conduct the training itself [12].

2.3 Problem Description

The primary purpose of teaching at any level of education is to bring a fundamental change in the learner [23]. Due to the high risk of DG there is a must to learn before doing in the content of ensuring safety. The ADR implementation and the knowledge transfer concerning DG is complex. In Estonia, ADR regulations training courses are formed based on teacher-centred course design mainly, *i.e.* learning activity is performed during classroom lectures supported by slideshow presentation. ADR regulations training courses are mostly in-class and theoretical proceedings, even in cases, where a practical example would be considered necessary, as in the case of fire confronting and first aid issues. In most cases, in-class training is followed with the use of books, issued by the training organisations/companies, slide presentations and internal tests [12].

Today this methodological approach is clearly outdated as the concept of learner with its needs is changing rapidly. Moreover, existing learning form does not meet efficient risk management within the transportation chain that is evolving more complex due to the number of parties involved as well as due to additional risks concerned new DG and their danger characteristics. The aim of present paper is to perform the analysis and identification of teaching methods suitable to be integrated into existing ADR professional training courses in Estonia with the scope to increase the proportion of practice and thereby to minimize operational risks related to human factors in further studies.

3 Methodology

3.1 Data Collection

A research design is the set of methods and procedures used in collecting and analysing measures of the variables specified in the research problem research study [7]. The research design of this study is defined by the research problem according to which the methodological approach of ADR regulations training courses in Estonia is outdated as the concept of learner is changing rapidly. In scope of this paper data collecting on learners' attitude regarding current format of courses is collected from all main parties who operate with DG on a daily basis, *i.e.* consignor/consignee, freight forwarder and carrier company. Respondents were divided into clusters according to the type of ADR regulation training course type which is aimed at them. Clustering was performed as following:

1. CLUSTER 1 (truck drivers; ADR driver training course),
2. CLUSTER 2 (consignors/consignees, freight forwarders, carrier companies, other participants; ADR DGSA training course).

Truck drivers have been separated from carrier role in order to identify their preferences individually. The main objective is to understand attitudes and preferences by clusters toward specific teaching methods respectively. The essence of specific methods that were focused on were explained to respondents. A structured questionnaire with close-ended ordinal-scale questions has been prepared as main data collecting form, where respondents were asked to decide where they fit along a scale continuum regarding the use of particular teaching method within ADR training classes.

3.2 Data Analysis

Implementing methodology of qualitative comparison analysis (QCA) combinations of suitable teaching methods are identified that are effective both in scope of operational risk management as well as from the perspective of learner's needs and expectations. QCA is a means of analysing the causal contribution of different conditions (*e.g.* aspects of an intervention and the wider context) to an outcome of interest [17]. QCA starts with the documentation of the different configurations of conditions associated with each case of an observed outcome [18]. These are then subject to a minimisation procedure that identifies the simplest set of conditions that can account all the observed outcomes, as well as their absence. Results are typically represented in statements expressed in ordinary language or as Boolean algebra. According to formula (1) expressed in Boolean notation combination of Condition A AND (*) condition B OR (+) a combination of condition C AND (*) condition D will lead to an OUTCOME (→) E [*Ibid.*].

$$A^{*}B + C^{*}D \rightarrow E \tag{1}$$

The paper presents a combined development research strategy based on studies regarding ADR regulations training courses in Estonia as well as on analysis of teaching methods applied in professional training of adults.

4 Results

The data collecting on learners' attitude and preferences concerning methodological format of courses was performed during the period from February 3–May 3, 2017. The online survey was prepared using *Google Forms* both in Estonian and in Russian. The distribution of the questionnaire was provided via email invitations (60 companies that work with DG on a daily basis) and social media channels addressed directly to speciality-focused groups (*e.g.* Estonian truck drivers with estimated number of 1800 ADR licenced drivers). Altogether 189 replies were gathered (CLUSTER 1–151 respondents, CLUSTER 2–38 respondents). On the basis of theory the sample must represent the population as well as possible. Current sub-samples are not statistically representative enough to draw accurate conclusions concerning population.[1] To ensure the representativeness, the sub-samplings were formatted in a non-probability sampling technique where the samples are gathered in a process that does not give all the individuals in the population equal chances of being selected [4]. In scope of this study samplings are also qualified as purposive samplings where subjects are chosen to be part of the sample with a specific purpose in mind that sufficient to draw objective conclusions concerning methodological approach of some subjects are more fit for the research compared to other individuals [*Ibid.*]. This is ARD regulations training courses, but is insufficient to give an accurate picture of attitudes and preferences of all DG transportation chain participants in details.

Within the structured questionnaire interactive teaching methods were firstly explained thoroughly and then proposed to be evaluated in contrast to main existing methodological approach today - classroom lecturing with the support of slideshow.

[1] According to the statistics during the period from 2012–2016 (*i.e.* currently valid certificates) the total number of issued ADR driver licenses in Estonia was 30 539 and the number of issued DGSA training certificates during the same period 118 [6, 24].

These methods were selected into the study mainly based on the practice of other countries (*i.e.* France, the Netherlands). See Tables 1 and 2 that present respondents' attitude and preferences by clusters concerning different methods that learners have experienced or are willing to undergo when taking ADR regulations training courses. Results are given in number of respondents and in percentage share of total cluster.

Table 1. Teaching methods evaluation (CLUSTER 1)

Teaching/learning method (Category)	Evaluation scale				
	1 (most inefficient)	2	3	4	5 (most efficient)
E-learning on a distance (A)	54 (36%)	57 (38%)	28 (18%)	6 (4%)	6 (4%)
Peer-learning (B)	29 (19%)	19 (13%)	73 (48%)	21 (14%)	9 (6%)
Practical tasks (C)	28 (19%)	17 (11%)	19 (13%)	40 (26%)	47 (31%)
Solving case studies in groups (D)	23 (15%)	27 (18%)	26 (17%)	35 (23%)	40 (27%)
Watching, analysing teaching videos (E)	28 (19%)	9 (6%)	20 (13%)	48 (32%)	46 (30%)
Reading individually materials (F)	29 (19%)	38 (25%)	34 (23%)	27 (18%)	23 (15%)
Listening to lectures with assistance of slide presentations (G)	19 (13%)	12 (8%)	34 (22%)	71 (47%)	15 (10%)

Source: Authors

Table 2. Teaching methods evaluation (CLUSTER 2)

Teaching/learning method (Category)	Evaluation scale				
	1 (most inefficient)	2	3	4	5 (most efficient)
E-learning on a distance (A)	5 (13%)	10 (26%)	15 (40%)	3 (8%)	5 (13%)
Peer-learning (B)	4 (11%)	7 (18%)	10 (26%)	12 (32%)	5 (13%)
Practical tasks (C)	5 (13%)	3 (8%)	12 (32%)	10 (26%)	8 (21%)
Solving case studies in groups (D)	3 (8%)	6 (16%)	7 (18%)	10 (26%)	12 (32%)
Watching, analysing teaching videos (E)	4 (11%)	6 (16%)	10 (26%)	8 (21%)	10 (26%)
Reading individually materials (F)	20 (52%)	7 (18%)	4 (11%)	4 (11%)	3 (8%)
Listening to lectures with assistance of slide presentations (G)	16 (42%)	5 (13%)	6 (16%)	8 (21%)	3 (8%)

Source: Authors

By implementing QCA methodology best suitable combinations of teaching methods were studied. As learners' operational risks within DG transportation chain differ, as well as expectations toward training courses, two separate truth tables were formed. According to methodological approach categorical variables (conditions) were defined as following: e-learning on a distance (A), peer-learning (B), practical tasks (C), solving case studies in groups (D), *etc.* As a result combinations of conditions A–G were combined that would lead to outcome. Effective methodological approach (outcome W) for ADR regulations training courses for drivers (W1 for CLUSTER 1) and DGSAs (W2 for CLUSTER 2) in Estonia are expressed in Boolean notation below in form of formulas (2) and (3).

$$(C^{*}D^{*}F + B^{*}E^{*}G) - A \rightarrow W1 \qquad (2)$$

$$E^{*}(D^{*}A + B^{*}C^{*}G) - F \rightarrow W2 \quad (3)$$

The results underline that methodological approach differs by learners' category. Empirical results indicates that classical lecturing with the support of slide presentation is still adequate and suitable teaching method concerning drivers training. Learner-centred interactive methods are expected to be implemented within a classroom lessons and individual theoretical learning is clearly outdated with regards to DGSAs training. Hence, interactive methods differ greatly on a national level. Well implemented blended learning methodological approach on example of Italy (TIP) is not suitable for Estonia's case according to results of this study. This leads to the standpoint that the attitude towards possible use of blended learning methodology at this point is clearly underestimated by trainees within ADR regulations training courses. In scope of further research the focus is to study what should be done in order to improve learners' attitude towards interactive teaching methods within ADR regulations training courses system in Estonia and to evaluate the impact of this methodological approach on operational risk management within the transportation chain of DG.

5 Conclusions

There are many prescriptions, which need to be followed by different parties within the transportation chain of DG in order to ensure safe transport and handling operations as well as to minimize operational risks related to human factors. The change in existing teaching practice today regarding ADR training courses is necessary due to many aspects. Due to continuously increasing number of the possible harm to the health of people and the environment in general, it is very important that all parties being involved are trained accordingly.

The implementation of interactive teaching methods focuses on learner during the process allowing training participant to acquire learning outcomes more efficiently. Moreover, it is important to highlight the fact that the first step when developing a new training course framework is to aware all parties involved regarding deficiency of a system. Next action is the model advancing phase which is finally followed by its partial or full implementation in practice. In scope of this paper finally developed ADR training course models propose learner-centred methodological approach with combinations of classical and interactive methods. Further research related to this issue has to consistently keep up with changes and consider new possible operational risks within the transportation chain of DG as well as with changing learner concept.

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Appendix 3

PUBLICATION III

Janno, J., Koppel, O. (2018). Operational risks in dangerous goods transportation chain on roads. LogForum. Scientific Journal of Logistics, 14 (1), pp. 33-41.

Drafts as conference proceedings:

- Janno, J. (2018). Transpordiettevõtete riskide hindamine ohtlike kaupade veoahelas. Tallinna Tehnikakõrgkooli Toimetised, 22, lk 36-46 (in Estonian).

LogForum
> Scientific Journal of Logistics <
2018, 14 (1), 33-41
http://dx.doi.org/10.17270/J.LOG.2018.261
http://www.logforum.net p-ISSN 1895-2038 e-ISSN 1734-459X
ORIGINAL PAPER

OPERATIONAL RISKS IN DANGEROUS GOODS TRANSPORTATION CHAIN ON ROADS

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ABSTRACT. **Background:** This paper focuses on operational risks of members of dangerous goods (DG) transportation chain. Due to the fact that there are multiple parties involved in handling and transportation procedures, plenty of different risks can occur during these activities with DG. According to European Commission statistics on dangerous goods transport (DGT) there are up to 80 percent of accidents that are caused by a human error, 8 percent of accidents are caused by technical failure [Eurostat 2016]. The importance of human factor in Estonia has been underestimated as parties of a DG transportation chain are not aware what operational risks are there in their daily activities with chemicals, nor the level of severity of these risks. This paper focuses on identifying and analyzing of operational risks within a dangerous goods transportation chain related to the specific participant. By identifying and evaluating risks, the most critical of them are identified and evaluated upon possible harm to the entire chain.

Methods: The paper presents a combined overview study based on theoretical aspects which are supported by results of previous studies regarding risk assessment of DG transport in practice. By implementing semi-quantitative risk assessment method, it finally allows differentiating operational risks according to their levels into acceptable, tolerable and unacceptable operational risks when transporting DG on roads.

Results: Main results of a research map and prioritize main operational risks regarding how involved parties in Estonia evaluate possible harms resulted from their activities while handling and transporting DG. Results also confirm the main finding that human factor is one of the crucial factors why accidents occur.

Conclusions: In the scope of further studies, the exact knowledge of operational risks in practice creates opportunities to manage these risks individually (from the perspective of each party separately) within the DG transportation chain. Hence, results of present study are milestones to focus on managing risks affected by human factor in road transport of DG.

Key words: transport of dangerous goods transport by road, operational risks, human factor, semi-quantitative risk assessment method.

INTRODUCTION

When packaged dangerous goods are transported by road, it is critical to follow legal requirements and meet suggested safety regulations in order to prevent accidents during activities with chemicals that are harmful to man, assets, and environment. Dangerous goods transport (DGT) includes all goods - liquids, gasses, and solids - that include radioactive, flammable, explosive, corrosive, oxidizing, asphyxiating, biohazardous, toxic, pathogenic, or allergenic materials [Berman et al. 2007, ADR 2017]. Regulations are essential to prevent not only risk but also to reduce the hazard. In the transport of DG the key problem is how to optimize transport and distribution, minimizing the risk of an accident [Tomasoni 2010].

A transportation chain maps the whole route between the place of origin and the destination as well as describes the individual transportation for each route segment along the transport route. A typical transportation chain

Citation: Janno J., Koppel O., 2018. Operational risks in dangerous goods transportation chain on roads. LogForum 14 (1), 33-41, http://dx.doi.org/10.17270/J.LOG.2018.261
Received: 27.10.17, Accepted: 30.11.2017, on-line: 20.12.2017.

of DG may include many parties, from consignors and consignees, freight forwarders and transportation companies. From the perspective of the present paper, transportation chain starts at consignor's with loading and ends at consignee with unloading procedure. Considering possible risks in regards with DG, it is vital for transportation chain to operate efficiently and effectively by all the corresponding members function properly. In other words, if any member fails to perform, the system will easily collapse and fail to achieve its objectives [Choi et al. 2016]. The scope of this paper is to survey operational risks within the DGT system based on transportation chain where three different parties are involved – consignor/ consignee, transportation company and freight forwarder. The aim is to evaluate impacts of risks that are resulted by different operations within the transportation chain during the transport process of DG.

Based on conducted survey research and interviews with different parties of a DG transportation chain in Estonia, a comprehensive operational risk impact assessment framework is developed. Results are an important input for further researches to determine proper risk management tools in order to minimize the risks arising from transportation or maximize the level of security in DGT.

LITERATURE REVIEW

On a municipal and an international level, several kinds of research have been carried out on the issue of risk assessment on the DGT. The research on road transport of HazMat (Hazardous Materials) follows three topics. The first is related to methodologies aimed at improving emergency response based on road properties, weather conditions and traffic factors [Fabiano et al. 2005]. The second is based on methodologies for survey and accident risk analysis from historical data aimed at divulging accident characteristics such as frequency of occurrence, accident consequences, and identification of causal factors [Fabiano et al. 2002, Yang et al. 2010, and Shew et al. 2013 via Conca et al. 2016].

As a fact, the improvement of road traffic safety is one of the most important objectives for transport policy makers in contemporary society and represents a strategic issue for enhancing life quality. This is strongly supported by the fact that many studies regarding DGT risk assessment focus on technical aspects and quantitative methods rather than on risks related to human factor that is studied and analyzed by applying qualitative methods to formulate outcomes.

Table 1. Non-technical risk preventive means in DG transportation chain

Risk preventive means concerning procedures:	Risk preventive means concerning staff and parties involved:
loading procedures at loading areas according to safety requirements	ADR training for drivers
labeling of packaging (clear and easily identifiable labeling of cartons to reduce the risk of picking errors)	DG related training for safety advisers (freight forwarders and logisticians)
loading order and placement of dangerous load in the transport unit	
restricted parking authorization	work safety and ergonomics trainings for personnel
fixed traffic routes with the necessity to get the confirmation from institutions in control	
additional road permissions system for third countries	
higher prices for ferry tickets and tunnel passes	economic driving training for drivers
daily temporal and seasonal driving bans	
special procedures when an accident occurs	
compulsory transport documentation and remarks on documents	performance appraisals with personnel
DG shipment tracking system	
marking and labeling the shipment and vehicle	

Source: own work based on previous results [Erceg and Trauzettel, 2016; Krasjukova, 2010; Vikulov and Butrin 2014]

According to the qualitative studies of managing risks in DGT [Krasjukova 2010], there are three main decision criteria in the sphere of DG road transportation, which can be accepted assets of preventive means derived out of technical, procedural or staff factors. Particular risk preventive means related to human factor i.e. non-technical in road transport of DG that consequently refer to possibly related operational risks are structured as presented in following Table 1.

In relation to the main topic of this paper specific human-related risk preventive means are defined above. Preventive means pointed out, are currently widely in use in road transport sector and have become as binding requirements and compulsory procedures in the overall process of DGT. In following parts of this paper operational risks of different parties within the DG transportation chain are identified, the semi-quantitative method to evaluate impacts of operations within the DG transportation chain is applied and results are presented. Despite the limited study group, adequate data is collected and operational risk assessment is performed on the example of DG transportation chain parties of Estonia.

BACKGROUND

With regards to transportation of DG on roads, there are traditionally same parties involved when transporting general goods. The main difference is noted related to responsibilities of participants in the carriage of DG and obligations on those that ADR considers the main participants. According to ADR there are main parties (consignors; transportation companies; consignees) and so-called other parties (loaders of packages; packers; fillers; tank-container/ portable tank operators; unloaders of packages or of tanks/ bulk vehicles) mentioned.

On a national scale, it is shown that DGT accidents on the roads make up no more than 0.1 percent of total accidents [Eurostat 2016]. But, even though this probability is minimal, the consequences are important when dangerous substances are involved. Regulations are essential to prevent not only risk but also to reduce the hazard. Firstly, the risk attached to the transport of DG by road is a risk that is hard to understand as it is connected to all the road network and depends on multiple factors such as traffic density, weather conditions, the necessities of undesired events (road accidents, natural phenomenon etc.). Secondly, this risk is also strongly linked to the nature of the transported goods and to the presence of exposed humans and materials in proximity to the place of incident. For example, the transport of fuel such as petrol or GPL (a.k.a. liquefied petroleum gas, liquid propane gas, LPG, LP Gas) can provoke considerable fire or the explosion of the tankers in which it is transported, with heat, excess pressure and missile effects [Tomasoni 2010]. Thirdly, the risk of DGT is strongly related to a human factor as all decisions, processes, and procedures within a transportation chain are made by different parties involved.

According to the classical definition of a risk, it is a measure of frequency and severity of harm due to a hazard. The hazard in this context is the presence of DG having toxic, explosive, and/ or flammable characteristics with the potential to cause harm to humans (and property or the environment if a broader context is considered). In the context of public safety, the risk is commonly characterized by fatalities (and injury) to members of the public [Risk Assessment – Recommended Practices for Municipalities and Industry 2010].

PROBLEM DESCRIPTION

DGT is a worldwide problem of growing interest, mainly because of the increasing transported volumes of materials that can be classified as DG, and because of a global challenge in the goods transportation performance [Tomasoni 2010]. Based on statistics the transport of DG in the EU-28 slightly increased from 74 billion tkm in 2013 to 75 billion tkm in 2014 (+1.5 percent). The largest specific product group was flammable liquids, taking over more than half of the total. Two other groups, gases (compressed, liquefied or dissolved under pressure) and corrosives, accounted for 14 percent and 10 percent respectively. This represents very little change compared with previous years showing a very similar distribution between product groups [Eurostat 2016].

There is a substantial difference between incident and accident. The accident begins with an incident [Crowl et al. 2007]. An incident is defined as an event involving the transportation of DG that results in an unanticipated cost to the shipper, transportation company or any other party [Tomasoni 2010]. In the scope of this paper, the incident is considered as an operation or a procedure involved in the transportation chain of DG. It has been reported that human error is, in fact, the most common individual cause of DG related accidents.

Risks facing different parties and their operations within the transportation chain of DG can result from factors both external (culture, regulations, board composition) and internal (accounting controls, information system, requirement, supply chain) the organization [A Risk Management Standard 2012]. Operational risks in logistics as well as in DGT have both external and internal key divers. Operational risk can be summarized as a human risk; it is the risk of business operations failing due to human error. In the DGT, most operations are run in contribution of a personnel involved, apparently operational risks are higher. Despite the fact that the probability of operational risk emerging in DGT is minimal, consequences can be crucial. The problem lies in the fact that the importance of human factor has been clearly underestimated - it is unknown what are exact operational risks within the transportation chain of DG and how severe they are. For effective DG risk management it is important to pay attention to operational risks within complete transportation chain of DG from the perspective of all parties – consignor/ consignee; freight forwarder; transportation company. The aim of present paper is to identify and commit detailed analysis of operational risks of different parties that allows to understand clearly the contrasts of risks of participants as well as assess them.

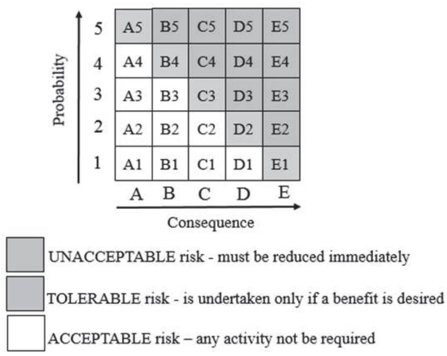
METHODOLOGY

In the risk assessment definition, many concepts are involved. The risk is most commonly defined as the combination of the probability (frequency; likelihood) of occurrence of a defined hazard and the magnitude of the consequences of the occurrence as it is described by formula (1) below [Royal Society 1992].

*DG Risk = Consequence * Probability* (1)

To assess the risk, then analyze and estimate the level of risk of accidents three different methods: qualitative, semi-quantitative and quantitative are defined [Dziubinski et al. 2006]. The semi-quantitative methods are applied to identify hazards and to select the so-called incidental events reasonably foreseeable (credible failure events) [Tomasoni 2010].

Considering the specifics of operational risks in DGT, semi-quantitative risk assessment methodological approach, as presented Figure 1. These can be adjusted in order to identify incidents leading to accidents (i.e. risks) and to estimate the level of risk. Based on this methodology risk probability is scaled in range of 1-5 (1 - rare; 2 – unlikely; 3 – likely; 4 – certain; 5 – imminent) and severity of risk that may arise from the possible event or outcome is scaled in range of A-E (A – minor; B – medium; C – major; D – catastrophic; E – catastrophic external) [Dangerous Goods Safety Guidance Note 2013].



Source: own work based on semi-quantitative risk assessment model [Dziubinski et al. 2006]

Fig. 1. Semi-quantitative DG risk assessment.

This paper presents identifying and evaluating operational risks of different parties within the transportation chain. In order to map risks within a transportation chain of DG, risks were evaluated among different parties in Estonia affected to identify what they mean to them. Data collection was performed during a comprehensive survey research with the focus to evaluate frequency (probability) and possible harms resulted (consequences) by their activities while handling and transporting DG. The survey covered companies related to DGT by road – consignors and consignees, freight forwarders and transportation companies. Due to the fact that the majority of transportation and freight forwarding companies in today's market situation have somehow been related to the transportation of DG - all of these companies turned out to be in the selection. Consignor and consignee companies as a single party were selected according to their primary activity. Most of them represent companies that produce different chemicals, building materials or use hazardous materials on a daily basis in their activity. By implementing semi-quantitative risk assessment method, it finally allows for differentiating operational risks according to their levels into acceptable, tolerable and unacceptable operational risks when transporting DG on roads as according to semi-quantitative risk assessment methodology.

RESULTS

This chapter describes results of DG risk assessment based on conducted survey research and detailed interviews among different parties of a DG transportation chain in Estonia. As the first step of risk assessment, operational risks of different parties were defined on a basis of Estonian companies that represent different roles within the DG transportation chain.

The data collecting was performed in forms of the non-anonymous online survey (transportation companies, freight forwarders) and structured interviews (consignors/ consignees). To ensure the representativeness, the sub-samplings were formatted in a non-probability sampling technique where the samples are gathered in a process that does not give all individuals in the population equal chances of being selected [Babbie 2010]. Within this study, samplings are also qualified as purposive samplings where subjects are chosen to be part of the sample with a specific purpose in mind that sufficient to draw objective conclusions concerning the methodological approach of some subjects are fit for the research compared to other individuals [Ibid.]. The distribution of the online questionnaire was provided via email invitations (136 companies that work with DG on a daily basis). Altogether 74 replies were gathered: 17 responses from freight forwarders; 57 responses from transportation companies. Interviews with representatives of consignor/ consignee companies (11) selected for the sampling were performed in a semi-structural form.

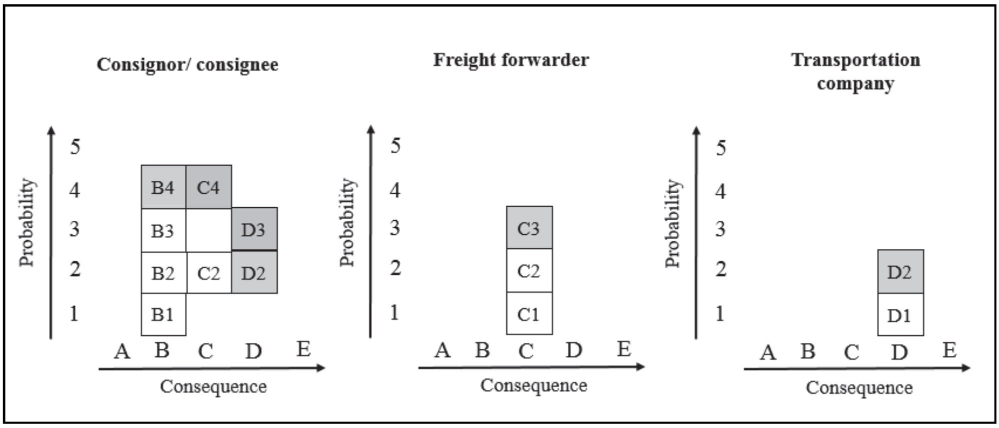
Table 2. Evaluation of DG operational risks

DG operational risk	Consignor/ consignee (n=11)	Freight forwarder (n=17)	Transportation company (n=57)
Inaccurate customer communication	B4	C3	D2
Incomplete transport documentation	C4	C2	D2
Improper transport documentation	D3	C2	D2
Missing transport permits and licenses	B2	C2	D1
Not safe load securing	C2	C2	D2
Inadequate packaging	D2	C1	D2
Insecure loading/ unloading	B1	C1	D2
Wrong classification of DG	B1	C2	D1
Inadequate load securing	B3	C1	D1
The use of incorrect load restraints	B3	C1	D1
Driver's caused error/ accident	B3	C1	D1
Improper packing material	B2	C2	D1
Wrong/ missing marks and labels on the package	B1	C2	D1
Wrong route planning /choice	B1	C2	D1
Wrong /missing vehicle placards	B1	C1	D1

Source: own work

In the first part of the survey, parties were asked to name independently operational risks that they experience at their daily work. By defining operational risks within the DG transportation chain makes it possible to evaluate both consequence and probability of these risks. According to structured questions in the questionnaire, in the second part of the survey respondents evaluated these indicators in the range of A-E (consequence) and 1-5 (probability). Following Table 2 presents an overall rating to DG operational risks from the perspective of different parties. The rating represents a combination of letter and number – the letter stands for risk consequence value and the number describes its probability. According to rating, each risk can be positioned in a DG operational risk matrix for final specification as the acceptable, tolerable or unacceptable risk.

By implementing semi-quantitative DG risk assessment methodology operational risks are differentiated according to their levels into acceptable, tolerable and unacceptable. Detailed results of participants' operational risk matrixes are presented below (Figure 2).



Source: own work

Fig. 2. DG operational risk matrixes

Figure 2 shows existing operational risk matrixes of consignor/ consignee; freight forwarder and transportation company separately in a combination of the consequence of an incident and its probability within the DG transportation chain. The results underline how different operational risks influence participants' activity within DG transportation chain. The empirical result indicates consignor's/ consignee's and transportation company's risks as most severe when handling and transporting DG by roads. Based on results of risk assessment, unacceptable risks are related to incomplete or improper transportation documents and exist clearly outstanding only from the perspective of consignor/ consignee, i.e. in the beginning or at the end of the transportation chain. Inaccurate customer communication is a great concern for all parties and is defined as a tolerable risk. This may indicate the deficiency of information flow. Even the smallest loss of information between the parties of DG transportation chain may lead to additional costs. Hence, freight forwarder's risks do not need any additional activity and the activity of this party can be considered as the most risk-free within the DG transportation chain. Mainly half of transportation company's operational risks are classified as tolerable risks with major consequences and with a slight possibility to take place. Identifying operational risks of different parties in Estonia within the DG transportation chain increases the awareness of the role of human factor when handling and transporting DG.

CONCLUSION

Risk management is one of the key issues in planning safe handling and transportation of DG. Identifying and examining risks by means of semi-quantitative risk assessment method allows focusing strictly on operational risks that are resulted by activities of different parties within DG transportation chain. There are plenty of activities when handling and transporting DG that are considered as incidents but do not necessarily lead to accidents. In order to identify which of human factor activities are closer to the emergence of the accident in practice, it is necessary to identify operational risks from the perspective of main parties involved on a national level and next assess risks in the combination of risk consequence and its probability.

The human factor has a considerable impact on ensuring safety in DGT. Accidents within the DG transportation chain are caused mainly due to the number of members involved, repetitive nature of operational risks at parties involved and the possible consequence of an event. Probability is a secondary aspect when assessing DG operational risks. Results of the study highlight, in particular, the important role of consignor/ consignee as the number of different operational risks is the largest and their levels the highest. In the scope of further studies, the exact knowledge of operational risks in practice creates opportunities to manage these risks individually (from the perspective of each party separately) within the DG transportation chain.

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RYZYKO OPERACYJNE W ŁAŃCUCHACH TRANSPORTU DROGOWEGO TOWARÓW NIEBEZPIECZNYCH

STRESZCZENIE. **Wstęp:** Ryzyko operacyjne członków łańcucha transportowego towarów niebezpiecznym jest tematem prezentowanej pracy. Ze względu na dużą ilość podmiotów będących uczestnikiem tego łańcucha, występuje również wiele różnych ryzyk związanych z transportem wyrobów niebezpiecznych. Według statystyk Komisji Europejskiej dotyczących transportu wyrobów niebezpiecznych, 80% wypadków jest spowodowanych czynnikiem ludzkim, natomiast 8% jest spowodowane przez awarie techniczne [Eurostat 2016]. Istotność czynnika ludzkiego jest niedoszacowania w Estonii, gdyż podmioty będące uczestnikami łańcucha transportowego towarów niebezpiecznych nie są świadome, jakie ryzyka operacyjne istnieją w trakcie ich obchodzenia się z takimi towarami. Najważniejsze z tych ryzyk zostały zidentyfikowane i oszacowane wraz z możliwych ich wpływem na cały łańcuch.

Metody: Prezentowana praca zawiera analizę teoretycznych aspektów wraz praktycznymi przykładami dotyczącymi oceny ryzyk w transporcie wyrobów niebezpiecznych. Poprzez zastosowanie metody półilościowej oceny ryzyka, zróżnicowano ryzyka operacyjne odpowiednio do ich poziomu na akceptowalne, tolerowane i nieakceptowane.

Wyniki: Główne wyniki naniesione na mapę oraz ustalenie kryteriów ryzyk operacyjnych w odniesieniu do udziału poszczególnych podmiotów w Estonii umożliwiło oszacowanie poszczególnych szkód wynikających z działań w obrębie transportu wyrobów niebezpiecznych. Potwierdzono, że czynnik ludzki jest jednym z kluczowym czynników powodujących wypadki.

Wnioski: Dokładna wiedza dotycząca ryzyk operacyjnych w praktyce stwarza możliwość zarządzania tymi ryzykami w sposób indywidualny (z punktu widzenia każdego uczestnika) w obrębie łańcucha transportowego towarów niebezpiecznych. Otrzymane wyniki istotnie przyczyniają się do skutecznego zarządzania ryzykiem związanym z czynnikiem ludzkim w transporcie wyrobów niebezpiecznych.

Słowa kluczowe: transport drogowy towarów niebezpiecznych, ryzyka operacyjne, czynnik ludzki, półilościowa metoda oceny ryzyka.

OPERATIVES RISIKO IN DER KETTE DES STRASSEN-TRANSPORTES VON GEFAHRGUT

ZUSAMMENFASSUNG. Einleitung: Das operative Risiko der Teilnehmer an der Transportkette bei der Beförderung von Gefahrgut wurde zum Thema der vorliegenden Arbeit. Wegen der hohen Anzahl der daran beteiligten Subjekte treten auf diesem Gebiete viele unterschiedliche, mit dem Transport von Gefahrgut verbundenen Risiken auf. Laut den betreffenden Statistiken der Europäischen Union 80% der Verkehrsunfälle werden von Menschenfaktor, dagegen nur 8% durch technische Havarien verursacht [Eurostat 2016]. Die Relevanz des Menschenfaktors bleibt in Estland nicht genügend beachtet, da die an der Beförderung der Gefahrgüter beteiligten Subjekte sich dessen nicht bewusst sind, welche operative Risiken während der Handhabung solcher Güter bestehen. Die wichtigsten davon wurden identifiziert und die möglichen Beeinflussungen der ganzen Transportkette auch ermittelt.
Methoden: Die vorliegende Arbeit beinhaltet die Analyse theoretischer Aspekte samt den praktischen Beispielen, die die Einschätzung der Risiken im Gefahrgut-Transport anbetreffen. Unter Anwendung der halbmengenmäßigen Methode zur Einschätzung des Risikos werden die operativen Risikofälle entsprechend ihrem Niveau als akzeptable, tolerierte und unakzeptable angesehen.
Ergebnisse: Die grundlegenden, auf die Landkarte gezeichnete Ergebnisse und die Festlegung von Kriterien für operative Risiken in Bezug auf die Teilnahme daran der einzelnen Subjekte in Estland ermöglichten die Einschätzung einzelner Schäden, die auf die konkreten Tätigkeiten innerhalb des Gefahrgut-Transportes zurückzuführen sind. Es wurde bestätigt, dass der Menschenfaktor einer der Schlüsselfaktoren, die die Verkehrsunfälle verursachen, ist.
Fazit: Ein grundlegendes, die operativen Risiken anbetreffendes Wissen schafft in der Praxis eine Möglichkeit für ein gängiges Management dieser Risiken auf eine individuelle Art und Weise (aus dem Gesichtspunkt eines jeden Teilnehmers) innerhalb der Gefahrgut-Transportkette. Die gewonnenen Ergebnisse tragen wesentlich zum effektiven Risiko-Management bezüglich der mit dem Menschenfaktor verbundenen Gefahren im Straßentransport bei.

Codewörter: Straßentransport von Gefahrgut, operative Risiken, Menschenfaktor, halbmengenmäßige Methode zur Risiko-Einschätzung

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Appendix 4

PUBLICATION IV

Janno, J.; Koppel, O. (2018). Managing Human Factors Related Risks. The Advanced Training Model in Dangerous Goods Transport on Roads. International Journal of Engineering Pedagogy, 8 (4), pp. 70-88.

Drafts as conference proceedings:

- Janno, J.; Koppel, O. (2017). Integrating Interactive Teaching Methods into ADR Training Courses System in Estonia. In: Kabashkin, I. V.; Yatskiv, I. V. (Ed.). Abstracts of the 17th International Multi-Conference Reliability and Statistics in Transportation and Communication (RelStat'17), 18-21 October 2017, Riga, Latvia. (120-121). Riga: Transport and Telecommunication Institute.
- Janno, J.; Koppel, O. (2017). Managing Dangerous Goods Risks on Roads during Transportation under Normal Conditions. In: B. Katalinic (Ed.). DAAAM International Scientific Book 2017 (pp. 333-344). Vienna: DAAAM International Vienna.

Managing Human Factors Related Risks

The Advanced Training Model in Dangerous Goods Transport on Roads

https://doi.org/10.3991/ijep.v8i4.8150

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Abstract—This paper studies the methodological essence of dangerous goods (DG) training courses for drivers and dangerous goods safety advisers (DGSA). The research aims to advance existing teacher-centered course model in Estonia with learner-centered methods that best suit specific objectives and meet expected learning outcomes, as well as to improve DG training model with the integrated use of interactive teaching methods.

The paper presents a qualitative development research strategy based on studies regarding ADR regulations training courses in Estonia as well as on the analysis of teaching methods applied in the professional training of adults. The data is collected in two steps: firstly by implementing questionnaires for consignors/ consignees, freight forwarders carrier companies and drivers, secondly during in-depth interviews/ focus group meeting with DG regulations training companies' providers. Implementing methodology of qualitative comparison analysis (QCA) combination of best suitable teaching methods is identified. After following in-depth interviews and performing a focus group, these combinations are further used as input for developing existing course model with integrated use of blended learning alternatives, where digital media meets with traditional classroom methods. Results of this research contribute coming up with interactive methodological approach within ADR regulations training courses that meet the best trainees' expectations and fulfills the risk management aim.

Keywords—DG training courses, teaching methods, qualitative comparison analysis, blended learning

1 Introduction

The transportation of DG on the road always involves risks. If substances are mishandled, injury and property damage risks are increased. From the perspective of road transport, this concerns primarily main parties of a transportation chain, *i.e.*, consignors/ consignees and carrier companies (including drivers), but also freight forwarders, and third parties. A transport containing DG can have an impact on the environment if an accident occurs and these often incur a higher cost for the society than non-dangerous goods accidents. This is one reason why it is essential to focus on improving the efficiency and security of DG transport and avoid potential accidents [41].

Training courses for drivers and DGSA involved into dangerous goods transport (DGT) are based accordingly to the European Agreement concerning the International Carriage of Dangerous Goods by Road (*i.e.* ADR, Chapter 8.2) and the European Commission Directive (96/35/EC) on the appointment and qualification of Safety Advisers for the transport of dangerous goods by road, rail and inland waterways [43, 45]. In addition to these documents, there is the Adult Education Act that sets additional requirements for adult education in Estonia on a national level [31]. The role of DG training courses has an essential impact on the human factors aspect that reveals during DG handling and transportation processes as the human factors are crucial why accidents occur within a transportation chain.

The role of educational technology in teaching today has importance due to combining the amount of information and communication technologies [41]. What comes to in-service training with the focus on practice, it is complicated to implement suitable interactive teaching methods and techniques effectively. In the scope DGT by roads, there is no doubt that adequate training of drivers and DGSA may affect the safety aspects in peculiar transportations, such as the one of DG. Training may not only include regulations, technical and procedural elements, but also important psychophysical aspects such as how to manage fatigue [3, 33].

The provider of training may be different according to national legislation. It can be the role of the employer (in the US and Canada) to ensure appropriate truck-driver training for the transportation of DG. In Sweden and the Netherlands, as well as in Estonia, a competent national authority must accredit training institutions or trainers and monitor the examination of truck drivers [20]. However, all training system approaches to pursue the same goal: to ensure appropriate training and prevent the accidental release of DG during transportation. By implementing specific interactive teaching methods, remarkable improvement of course participants' learning can be achieved. Moreover, operational risks related to human factors' issues can be reduced within entire transportation chain of DG.

When considering an approach to instruction, teachers are aspired to use methods that are most beneficial for all of their students. Using both approaches, teacher-centered as well as student-centered together, learners can sense the positives of both types of education. By implementing interactive teaching methods to support existing teacher-centered ADR training course model in Estonia remarkable improvement of course participants' learning can be achieved. To implement the procedural approach, a designer has to understand the contents of the whole system, its structure, the principle of operation and behaviour [21] fully. It becomes very difficult to describe complex systems using only procedural techniques. The reason lies in the nature of a modeled object because any procedural model implies a one-sided, incomplete, and prejudiced glance on the original [27]. In the scope of this paper relation between concepts of a training system, training model, training process and training requirements is visualized as shown in Figure 1.

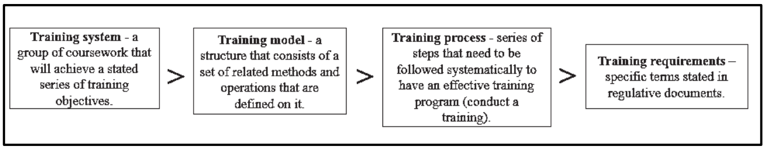

Fig. 1. Conceptual relation. Source: Authors.

In Estonia, ADR regulations training courses are formed based on teacher-centered course design mainly. This methodological approach is outdated as the concept of the learner is changing rapidly. The problem discussed in the scope of this paper is a part of a broader study and refers to an outdated methodological approach in carrying out DG training in Estonia, both for drivers and safety advisers. Based on conducted survey research among representatives of different parties of a DG transportation chain in Estonia, best suitable interactive teaching methods are studied. From developed combinations of techniques, advanced training course models are created with the implementation of blended learning elements. As this methodological approach is in the scope for discussion of a focus group with DG training provider companies and the representative of Estonian Road Administration, it finally represents a comprehensive training model that considers human factor risk managing elements of all parties. Results present readily handled ADR regulations training course model that could be implemented by DG training provider companies of Estonia in the coming years. All this will contribute to improved human risk management of DGT by road.

2 Background

2.1 Literature review

The global trend of increasing traffic due to globalisation leads to a higher number of DGT [11]. Several studies have focused primarily on the critical analysis of ADR implementation concepts in European countries [*Ibid.*]. What comes to performance indicators supplemented regarding the transport and handling of dangerous goods, the number of DGSA as well as the number of ADR training certificates, are critical controlling the performance of handling dangerous goods in green transport corridor [36]. Chances and challenges coming along with the ADR ratification were illustrated, and the concept / recommended procedures of how to train involved people in the framework of DG was developed from in-depth analysis and critics of current training methods.

The broader approach with regards to blended learning issues within in-service training, in general, has been studied a lot. These studies focus mainly on training school teachers with implementing different types of blended (mixed) learning scenarios of information and communication technology (ICT) related subjects. When modeling practical scenarios based on a combination of different face-to-face interactive approaches (such as problem-based learning, collaborative and project-based approaches, and diversity of e-learning activities and resources within), it is fundamental to take into account learner's previous experience and ICT skills. Better results in acquiring the content of the course are in a healthy relationship with learner's previous experience in ICT [22].

Specific models, methods, and technologies have also been studied in the scope of support the training of drivers involved in the transport of DG [5]. Italian developed online training environment (TIP – Transport Integrated Platform) is addressed to operators in the transport sector and combines classroom-based training with online self-learning possibilities on a distance. The platform has been continuously upgraded with innovative tools and presents a component of blended learning model where online digital media meets with traditional classroom methods [5, 39, 40]. Implementing blended learning methodology within classes keeps students active not allowing them to disconnect from the subject. This leads to a better attitude to improve learners' thinking and writing, motivating them for further study and development of new thinking skills [13, 22].

Training of safety and DG topics is essential for a risk and accident minimisation in the handling of DG and their transports. According to previous research studies on DGT the awareness of different parties of transportation chain in Estonia, there is a lack of professional knowledge among personnel on the national level [17]. According to a comparative analysis of teaching methods of ADR driver training courses of France, the Netherlands, and Estonia, remarkable differences were identified [18]. In Estonia, a significant lack of learning tools and no ARD based activities to endorse training courses and to increase the proportion of practice are so far in use [*Ibid.*].

Human-related risk preventive mean lies in efficient staff training. In following parts of this paper, the methodology of QCA is implemented in to analyse specific methods as cases due a set of relations and assess of their consistency. Existing teacher-centered DG training model will be completed with blended learning approach and evaluated within focus group meeting to define its' relevance toward risk management of human factors related risks when transporting DG by roads.

2.2 Dangerous goods regulations training courses

As DG and their transport need special handling and attention due to their risk for the environment and health of people, the training of any persons having to deal with those goods is essential for safe processing [15]. Common legal requirements (ADR) states in details that drivers when transporting DG (with small exceptions) shall undergo training in the form of a course approved by the competent authority. Concerning chapter 1.3 of the ADR, every employee, which has to commit the duties of DG regulations, needs to be specially trained [1]. Other parties involved within operations with DG can be: manufacturer or owner of DG, owner of tank containers, persons carrying out forwarder duties, persons writing and preparing transport documents, persons working for the DG receiving, persons committing packaging procedures, filling personnel of tanks, vehicle drivers, who do not need an ADR certificate, persons carrying out carrier and vehicle owner duties [2, 23].

Persons mentioned above often carry obligations of DGSA as they are involved in operations with DG in road transportation. A DGSA is a consultant or an owner or employee of an organisation appointed by a company that transports, loads or unloads DG in the European Union and other countries [38]. There is no specific classification regarding DGSA courses. However, ADR driver training courses can be classified according to two aspects. Figure 2 visualises the content of training programs and training courses, highlighting common and distinctive elements of ADR driver training courses.

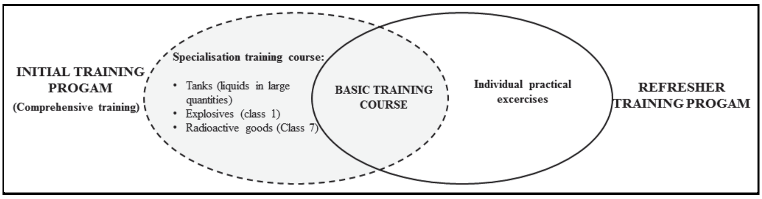

Fig. 2. The content of ADR driver training programs. Source: [18]; adapted by authors.

Firstly, training programs are identified by the level of the training program (initial or refresher training program), and secondly, training courses within programs are divided according to specificity (basic or specialisation training course). The minimum duration of the theoretical element of each initial training course or part of the comprehensive training course is set according to common legal requirements. The overall length of the comprehensive training course may be determined by the competent authority, which shall maintain the duration of the basic training course and the specialisation training course for tanks, but may supplement it with shortened specialisation training courses for Class 1 (explosives) and Class 7 (radioactive materials) [25]. Refresher training has to be undertaken by drivers (as well as by DGSAs) at regular intervals in every five years. As the form of a training program is defined by compulsory topics and minimum learning hours only (according to ADR), it is free to choose the methodological approach to conduct the training itself [18].

2.3 Interactive teaching in adult training

Today classrooms challenge traditional, teacher-centered curriculum to meet the increasingly diverse needs of students and make the required increases in achievement gains [7]. The fact that the adult teaching method is to a great extent different from the system in which students of various ages are schooled is felt in the assimilation of knowledge, in the means which they put into practice and understanding at a conceptual level of the theories and models proposed in the course program. Moreover, what comes to in-service training with a focus on practice, it is much more complicated to implement suitable interactive teaching methods and techniques efficiently.

Today, adult learning theories have series of characteristics that differentiate adult learners. These determine the teaching methods that will most successfully promote learning in an older population of students[1] [37]. According to theories and practices on adult learning these characteristics are as follows:

1. Selective learning - adults determine what is meaningful to them.
2. Self-directed learning - adults take responsibility for their education.
3. Previous knowledge and experience of adult learners.
4. Problem-centered approach – adults are interested in content that has a direct application to their lives.
5. Anxiety and low self-esteem due to possible negative previous experiences with school [14, 16, 32].

The impact of these characteristics on adult learning is not limited to the face-to-face classroom as they also affect the way that adult learners will approach learning in the online environment as well [24]. Named characteristics have to be considered when training personnel within ADR regulations training. From the perspective of a diversity of methods in use and resulting approach to adult learner's peculiarity within ADR training courses, the United Kingdom can be highlighted as a best-practice. The existing models of ADR related training in the UK apparently differentiate learners by their category – drivers and DGSA. When registering for the training course the learner can select among different approaches how to study. Due to the preferences traditional classroom learning, full or partial e-learning, as well as webinar-based learning options, are possible. The training model of existing ADR training provider companies of Estonia is alike and methodologically outdated as it doesn't take into account learners' unique features nor their preferences.

Rapid development of ICT has facilitated an approach to traditional face-to-face and technology-mediated learning environments, which is called "blended/hybrid learning." In the scope of this paper blended learning methodological approach, where digital media meets with traditional classroom methods is brought into focus as appropriate for Estonia's case to start with the methodological development of an existing model of ADR regulations training courses. In following parts of this paper alternative, learner-centered training model is proposed for efficient ADR regulations training courses with the integrated use of interactive teaching methods.

3 Methodology

3.1 Problem description

The primary purpose of teaching at any level of education is to bring a fundamental change in the learner [42]. Due to the high risk of DG, there is a must to learn be-fore doing in the content of ensuring safety. The ADR implementation and the knowledge transfer concerning DG are complex.

Existing learning model of DG training courses in Estonia today is standard for all learners without differentiating them into categories: drivers and DGSA. Moreover,

[1] According to the statistics during the period from 2012-2016 (*i.e.,* currently valid certificates) the total number of issued ADR driver licenses in Estonia was 30 539 and the number of issued DGSA training certificates during the same period 118 [8, 44].

ADR regulations training courses are formed based on teacher-centered course design mainly, i.e., learning activity is performed during classroom lectures supported by the slideshow presentation. ADR regulations training courses are mostly in-class and theoretical proceedings, even in cases, where a practical example would be considered necessary, as in the case of fire confronting and first aid issues. In most cases, in-class training is followed by the use of books, issued by the training companies, slide presentations and internal tests [18].

Today this methodological approach is outdated as the concept of a learner with its needs is changing rapidly. Moreover, existing learning form does not meet efficient risk management within the transportation chain that is evolving more complex due to the number of parties involved as well as due to additional risks concerned new DG and their danger characteristics. The methodological approach of professional training should be student-centered and focused on developing learner autonomy and independence by putting responsibility for the learning path in the hands of learners [12]. This approach ensures the fact that after completing the training course a trainee can handle problems in practice independently. This is essential in the scope of DGT. The present paper aims to perform the analysis and identification of teaching methods suitable to be integrated into existing ADR professional training courses in Estonia with the scope to increase the proportion of practice and thereby to minimise operational risks related to human factors in further studies.

3.2 Data collection and analysis

A research design is the set of methods and procedures used in collecting and analysing measures of the variables specified in the research problem research study [10]. The research problem defines the research design of this study according to which the methodological approach of ADR regulations training courses in Estonia is outdated as the concept of a learner is changing rapidly. In the scope of this paper primary data collecting on learners' attitude regarding the current format of courses is collected from all main parties who operate with DG on a daily basis, i.e. consignor/ consignee, freight forwarder and carrier company. Respondents were divided into clusters according to the type of ADR regulation training course type which is aimed at them. Clustering was performed as follows:

1. CLUSTER 1 (truck drivers; ADR driver training course),
2. CLUSTER 2 (consignors/ consignees, freight forwarders, carrier companies, other participants; ADR DGSA training course).

Truck drivers have been separated from carrier role to identify their preferences individually. The primary objective is to understand attitudes and preferences by clusters toward specific teaching methods respectively. The essence of specific methods that were focused on was explained to respondents. A structured questionnaire with close-ended ordinal-scale questions has been prepared as main data collecting form, where respondents were asked to decide where they fit along a scale continuum regarding the use of particular teaching method within ADR training classes.

Implementing methodology of qualitative comparison analysis (QCA) combinations of suitable teaching methods are identified that are effective both in the scope of operational risk management as well as from the perspective of learner's needs and expectations. QCA is a means of analysing the causal contribution of different conditions (*e.g.*, aspects of an intervention and the broader context) to an outcome of interest [28]. QCA starts with the documentation of the different configurations of conditions associated with each case of an observed outcome [29, 34]. These are then subject to a minimisation procedure that identifies the simplest set of conditions that can account all the observed outcomes, as well as their absence. Results are typically represented in statements expressed in ordinary language or as Boolean algebra. According to formula (1) expressed in Boolean notation combination of Condition A AND (*) condition B OR (+) a combination of condition C AND (*) condition D will lead to an OUTCOME (→) E [*Ibid.*].

$$A * B + C * D \rightarrow E \quad (1)$$

The paper presents a qualitative development research strategy based on studies regarding ADR regulations training courses in Estonia as well as on the analysis of teaching methods applied in the professional training of adults with the implementation of ICT possibilities to contribute to effective human factor risk management. Upon the results of QCA analysis and in-depth interviews with DG training companies' representatives, preliminary models of training courses are developed for further validation during the focus group with selected experts from DG training activity. Focus group research involves an organised discussion with a selected group of individuals to gain information about their views and experiences on a topic [19]. Within this research stage, the initially developed training model for drivers and DGSA are in focus. The participants of a focus group influence each other through their answers to the ideas and contributions during the discussion by assessing advanced training model with regards to human risk management.

3.3 Research design

Within the process of developing research, the study can be broken down into 3-4 distinct stages. Firstly it is establishing a research type, secondly naming research strategy and finally determining a research design by defining specific methods and research procedures [10]. The research design refers to the overall strategy that is chosen to integrate different components of the study in a coherent and logical way, thereby, ensuring the effective address to the research problem [*Ibid.*].

The research problem defines the research design of this study according to which the existing course model in Estonia is teacher-centered and the role of using interactive teaching methods within ADR regulations training courses are underestimated by trainees. In the scope of this paper, the research object is the existing model of ADR regulations training courses in Estonia, methodologically the same both for drivers and for DGSA. The research design for this study is built upon the principle of qualitative development research as it is seen in Figure 3.

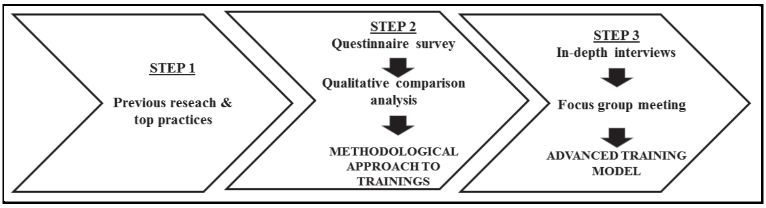

Fig. 3. Research design. Source: Authors.

The first step in a complete research design of this study involves identifying top previous research on a topic related and reviewing the published empirical articles to diversify possible methods. At this stage, the best practice is identified (the training models of the UK) and results of previous studies on the example of Estonia [18] are brought together.

The second step presents a combined questionnaire survey on learners' attitude and preferences concerning the methodological format of courses. QCA analyses collected data. Hence, the methodological approach to training is developed respectively for ADR course training for drivers and DGSA separately.

Individual in-depth interviews with ADR training provider companies within the third stage of the research is a data-collecting phase mainly. According to the information from Estonian Road Administration, there are altogether five trainer companies that have a license to train drivers and one that prepares DGSA [25]. Based on some trainees per trainers in 2016 four interviewee trainer companies that provide ADR training for drivers is chosen. Regarding training DGSA interview with the single representative business was carried out (share of 100%). The results of interviews are structured with the implementation of comparative analysis methodology and commented by contrasting them with the best practice on an example of the UK training course models. Focus group with DG training provider companies and the representative of Estonian Road Administration gives an objective assessment to the advanced ADR regulations training model that considers human factor risk managing elements of all parties.

4 Results

4.1 Learners' methodological approach

The data collecting on learners' attitude and preferences concerning the methodological format of courses was performed during the period from February 3 – May 3, 2017. The online survey was prepared using Google Forms both in Estonian and in Russian. The distribution of the questionnaire was provided via email invitations (60 companies that work with DG on a daily basis) and social media channels addressed directly to specialty-focused groups (e.g., Estonian truck drivers with an estimated number of 1800 ADR licensed drivers). Altogether 189 replies were gathered

(CLUSTER 1 – 151 respondents, CLUSTER 2 – 38 respondents). By theory, the sample must represent the population as well as possible. Current sub-samples are not statistically representative enough to draw accurate conclusions concerning population. To ensure the representativeness, the sub-samplings were formatted in a non-probability sampling technique where the samples are gathered in a process that does not give all the individuals in the population equal chances of being selected [4]. In the scope of this study, samplings are also qualified as purposive samplings where sub-jects are chosen to be part of the sample with a specific purpose in mind that sufficient to draw objective conclusions concerning the methodological approach of some subjects are fit for the research compared to other individuals [*Ibid*.]. This is ARD regulations training courses but is insufficient to give an accurate picture of attitudes and preferences of all DG transportation chain participants in details.

Within the structured questionnaire, interactive teaching methods were firstly explained thoroughly and then proposed to be evaluated in contrast to leading existing methodological approach today - classroom lecturing with the support of slideshow. These methods were selected into the study mainly based on the practice of other countries (i.e., France, the Netherlands). See Table 1 and Table 2 that present respondents' attitude and preferences by clusters concerning different methods that learners have experienced or are willing to undergo when taking ADR regulations training courses. Results are given in some respondents and percentage share of the total cluster.

Table 1. Teaching methods evaluation (CLUSTER 1)

Evaluation scale / **Teaching/ learning method (Category)**	**1 (most inefficient)**	**2**	**3**	**4**	**5 (most efficient)**
E-learning on a distance (A)	54 (36%)	57 (38%)	28 (18%)	6 (4%)	6 (4%)
Peer-learning (B)	29 (19%)	19 (13%)	73 (48%)	21 (14%)	9 (6%)
Practical tasks (C)	28 (19%)	17 (11%)	19 (13%)	40 (26%)	47 (31%)
Solving case studies in groups (D)	23 (15%)	27 (18%)	26 (17%)	35 (23%)	40 (27%)
Watching, analysing teaching videos (E)	28 (19%)	9 (6%)	20 (13%)	48 (32%)	46 (30%)
Reading individually materials (F)	29 (19%)	38 (25%)	34 (23%)	27 (18%)	23 (15%)
Listening to lectures with assistance of slide presentations (G)	19 (13%)	12 (8%)	34 (22%)	71 (47%)	15 (10%)

Source: Authors

Table 2. Teaching methods evaluation (CLUSTER 2)

Evaluation scale / Teaching/learning method (Category)	1 (most inefficient)	2	3	4	5 (most efficient)
E-learning on a distance (A)	5 (13%)	10 (26%)	15 (40%)	3 (8%)	5 (13%)
Peer-learning (B)	4 (11%)	7 (18%)	10 (26%)	12 (32%)	5 (13%)
Practical tasks (C)	5 (13%)	3 (8%)	12 (32%)	10 (26%)	8 (21%)
Solving case studies in groups (D)	3 (8%)	6 (16%)	7 (18%)	10 (26%)	12 (32%)
Watching, analysing teaching videos (E)	4 (11%)	6 (16%)	10 (26%)	8 (21%)	10 (26%)
Reading individually materials (F)	20 (52%)	7 (18%)	4 (11%)	4 (11%)	3 (8%)
Listening to lectures with assistance of slide presentations (G)	16 (42%)	5 (13%)	6 (16%)	8 (21%)	3 (8%)

Source: Authors

By implementing QCA methodology best, suitable combinations of teaching methods were studied. As learners' operational risks within DG transportation chain differ, as well as expectations toward training courses, two separate truth tables were formed. According to methodological approach, categorical variables (conditions) were defined as following: e-learning on a distance (A), peer-learning (B), practical tasks (C), solving case studies in groups (D), *etc.* As a result combinations of conditions A-G were combined that would lead to the outcome. Effective methodological approach (outcome W) for ADR regulations training courses for drivers (W1 for CLUSTER 1) and DGSAs (W2 for CLUSTER 2) in Estonia are expressed in Boolean notation below in the form of formulas (2) and (3).

$$(C * D * F + B * E * G) - A \rightarrow W1 \quad (2)$$

$$E * (D * A + B * C * G) - F \rightarrow W2 \quad (3)$$

The results underline that methodological approach differs by learners' category. Empirical results indicate that traditional lecturing with the support of slide presentation is still adequate and suitable teaching method concerning drivers training. Learner-centered interactive methods are expected to be implemented within classroom lessons, and individual theoretical learning is clearly outdated with regards to DGSAs training. Hence, interactive methods differ greatly on a national level. Well-implemented blended learning methodological approach on the example of Italy (TIP) is not suitable for Estonia's case according to results of this study. This leads to the stand-point that trainees clearly underestimate the attitude towards the possible use of blended learning methodology at this point within ADR regulations training courses.

4.2 Advanced methodological approach

This chapter gives an overview of results of analysed data collected during in-depth interviews with four ADR training provider companies for drivers and one training company which is responsible for training DGSA in Estonia.

Table 3. Main findings of in-depth interviews.

Researched aspects	Trainer A	Trainer B	Trainer C	Trainer D	Trainer E
Design of existing training course	Teacher-centered/ student-centered	Teacher-centered	Teacher-centered	Teacher-centered/ student-centered	Teacher-centered/ student-centered
Active-learning methods in use	Discussions	Discussions	Discussions	Discussions	Discussions / Q&A
Current use of ICT	No	No	No	No	Not significant use
Comments on results of previous studies	A great contribution of a trainer are expected	More practical aspects should be included; active-learning methods can be implemented without ICT usage	Existing approach supports learners' expectations	DG related information has to be introduced within occupational training of drivers	Important information in scope of further developments
Changes in existing training	Partial e-learning	Improving handout materials	Improving handout materials	Provide additional voluntary DG related training to companies	Involvement of more expert lecturers
Comments on further developments of training system	Focus on knowledge; license issued to trainers individually (not to a training providing company)	Ask for systematic feedback on training course	Changes in supervision of an ADR regulations training system	Greater emphasis on DGSA training	Audio lecturing possibilities should be studied; slow transition onto blended learning

Source: Authors

As in-depth interviews are useful when the focus is on getting detailed information about a person's thoughts and behaviors or the aim is to explore new issues in depth on the particular matter [6], this method was chosen suitable for collecting data within the third stage of the research. Table 3 gives a summary of essential findings of interviews that are relevant input for improving training models with the integrated use of interactive teaching methods and implementing blended learning. Results are presented summarised in the form of table where training provider companies' names are left hidden (named as Trainer A, B, C, D for driver training companies, Trainer E for DGSA training company), as the intention of comparability analysis is not to compare companies or their services, but to identify opinions and views regarding integration of ICT opportunities and interactive teaching methods into existing ADR regulations training course system in Estonia.

The result of individual interviews confirms the aspect that ADR regulations training courses in Estonia are primarily teacher-centered since the only mainly used learners-centered method is a discussion according to main findings presented in Table 3. However, some points indicate on the fact that training providers are interested in implementing new approaches to carry out training courses, including with support of ICT possibilities. At the moment none of the interviewed trainers in Estonia are taking advantage of ICT opportunities with-in ADR training course for drivers. On the other hand, implementing partial e-learning is considered as further development within the existing course model. Such topics as first aid, basic knowledge of the use of protective equipment, *etc.* can be presented in the form of e-learning already soon.

Considering results of QCA of this study and results of in-depth interviews, preliminary training model for ADR regulations training courses for drivers and DGSA with the implementation of interactive and e-teaching methods were developed. This was presented as an interim result of research during a focus group meeting with ADR training provider companies and a representative of Estonian Road Administration to collect opinions on the relevance of the methodological approach in the scope of applicability in training and the possible effect on managing human-related risks. Considering remarks made by focus group participants the advanced training model for the model for ADR regulations training courses for drivers and DGSA was developed as it is presented in Figure 4.

When developing models for ADR related training courses in Estonia following principles and additional remarks made by focus group participants were taken into account:

1. Teaching methods make a difference with regards to human-related risk management.
2. Transition to blended learning course model has to be slow and step-by-step to take into account both trainers' possibilities as well as learners' readiness for a renewed approach to learning.
3. The DGSA trainee is more independent learner than the trainee who is undergoing ADR training course for drivers. Therefore methods that support independent

learning (e-learning opportunities) are included in training model for DGSA (seen in Figure 4).
4. Due to personal learning habits and preferences, learner needs for different learning options.
5. Learners' ICT skills have to be considered.
6. During self-assessment as well as final-assessment the use of materials (Internet) should be allowed. The assessment has to be more integrated in the learning process and, learners will also take responsibility in it [35].
7. Implementation of the advanced methodological approach of ADR related training courses in Estonia should begin with DGSA training.
8. Further development of training course model with the implementation of virtual reality solutions with the variety of specialised simulations for education and training purposes. [2]

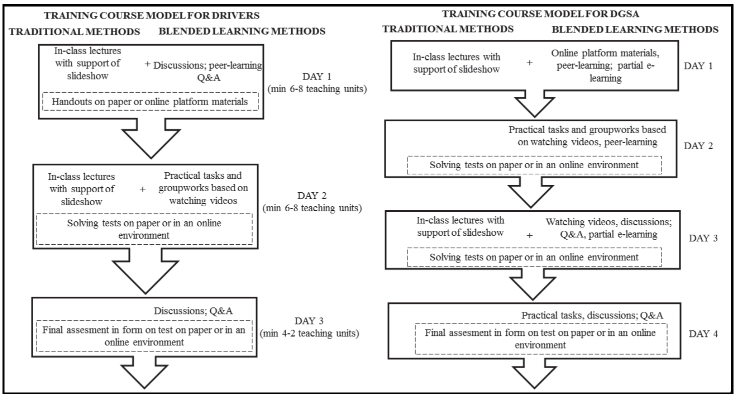

Fig. 4. Blended learning training course models. Source: Authors

Within this research finally developed training course model is final and considered ready to be implemented in practice for piloting. Herein opinions of all parties have been viewed with regards to applying blended learning techniques into ADR regulations training courses. Developed blended learning training course model is considered to be a good starting point for piloting and for establishing specific conditions and metrics on its' effect with regards to managing human-related risks when transporting DG by roads.

[2] Simulating complex incidents and accidents with DG on roads may have a positive effect on managing risks, as drivers/ DGSA may never face similar situations in practice unlike the awareness of a danger that is acquired through simulation. Similar simulations are in use for training of fire and medical emergency situations on example of German Chemical Industry. Firefighters can train their behavior on complex transport accidents with dangerous goods on motorways, rails, and country roads. Most of the firefighters have not been called very often to those accidents in their daily business. Within virtual training spaces, it is possible to train staff's behavior and to cope with complex operations [31].

5 Conclusions

There are many prescriptions, which need to be followed by different parties within the transportation chain of DG to ensure safe transport and handling operations as well as to minimise operational risks related to human factors. The change in existing teaching practice today regarding ADR training courses is necessary due to many aspects. Due to the continuously increasing number of the possible harm to the health of people and the environment in general, it is essential that all parties being involved are trained accordingly.

Educated and competent personnel is the critical factor that defines the competitiveness and efficiency of a system. What comes to competitive and efficient transportation chain of DG this all refers to a minimised level of risks; hence it is essential that personnel involved is capable of managing these risks properly when arranging or performing DGT. Due to possible risks with high consequence and the fact that trainees are adults, the training of employees of transportation chain of DG has to be detailed and practical giving a learner the opportunity to acquire the knowledge using different methods. Integration of ICT and implementing blended learning methodology within existing ADR regulations training courses were studied within this research.

According to collected and analysed data as well as to results in the form of developed training courses model conclusions have didactical and regulative nature. Didactical findings are directly related to principles on which improved training models are developed. Regulative conclusions refer to an overall ADR regulations training course system in Estonia. These are as following:

1. The trainer's qualification requirements are questionable – review and, if necessary, change conditions.
2. The trainer's knowledge of the methods used is insufficient
3. The control system of trainees has to be improved.

Conclusions presented above on regulative issues of ADR regulations training courses system rises next questions that need attention on a national level. Further researches related to this issue will focus on testing improved ADR regulations training course models in practice.

6 Acknowledgment

Authors of this paper would like to thank DG training provider companies of Estonia and the Estonian Road Administration for their contribution and participation in present research.

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This article is a revised version of a paper presented at the International Conference on Interactive Collaborative Learning (ICL2017), held September 2017, in Budapest, Hungary. Article submitted 20 December 2017. Resubmitted 20 January 2018. Final acceptance 21 January 2018. Final version published as submitted by the authors.

Appendix 5

The classification of DG into classes

UN Class	DG	Division(s)	Classification
1	Explosives	1.1 - 1.6	Explosive
2	Gases	2.1	Flammable gas
		2.2	Non-flammable, non-toxic gas
		2.3	Toxic gas
3	Flammable liquid		Flammable liquid
4	Flammable solids	4.1	Flammable solid
		4.2	Spontaneously combustible substance
		4.3	Substance which in contact with water emits a flammable gas
5	Oxidising substances	5.1	Oxidising substance
		5.2	Organic peroxide
6	Toxic substances	6.1	Toxic substance
		6.2	Infectious substance
7	Radioactive material	-	Radioactive material
8	Corrosive substances	-	Corrosive substance
9	Miscellaneous DG	-	Miscellaneous DG

Source: (ADR, 2017); (Health and Safety Executive); (adapted by the author)

Appendix 6

Supervised DGT related students' works:

1) Kivi, K., Rehepapp, A., Tuisk, M.-L., Veanes, K. Coursework in Project Management, 2011, (sup) Jelizaveta Janno. The Study of Transport of Dangerous Goods in Estonia; TTK University of Applied Sciences, Faculty of Transportation, Chair of Logistics.
2) Matsar, R. Applied Higher Education Diploma, 2013, (sup) Jelizaveta Janno. Dangerous Goods Transport Regulations, Modes and Shippers Awareness. TTK University of Applied Sciences, Faculty of Transportation, Chair of Logistics.
3) Põrk, M. Applied Higher Education Diploma, 2014, (sup) Jelizaveta Janno. Gaining Overall Safety in the Field of Dangerous Goods Road and Rail Transport by Improving the Competence of Safety Advisers. TTK University of Applied Sciences, Faculty of Transportation, Chair of Logistics.
4) Kirjušetškina, M. Master's Diploma, 2014, (sup) Jelizaveta Janno, Ott Koppel. Safe Road Transport of Dangerous Goods by Example of Eskaro, Ltd. Tallinn University of Technology, Faculty of Civil Engineering, Department of Logistics and Transport, Chair of Transportational Logistics.
5) Kase, M. Bachelor's Diploma, 2015, (sup) Jelizaveta Janno. Dangerous Goods Driver Training in Estonia. Tallinn University of Technology, Faculty of Civil Engineering, Department of Logistics and Transport, Chair of Transportational Logistics.
6) Zolina, S. Applied Higher Education Diploma, 2015, (sup) Jelizaveta Janno. Problems Concerning the Handling of Flammable Liquids in Estonian Road Transport Sector. TTK University of Applied Sciences, Faculty of Transportation, Chair of Logistics.
7) Vigla, L. Bachelor's Diploma, 2015, (sup) Jelizaveta Janno. Mapping the Methodology of Dangerous Goods Training Courses in Estonia. Tallinn University of Technology, Faculty of Civil Engineering, Department of Logistics and Transport, Chair of Transportational Logistics.
8) Kotševa, A. Bachelor's Diploma, 2017, (sup) Jelizaveta Janno. Risk Assessment for Transport Companies Within the Transport Chain of Dangerous Goods. Tallinn University of Technology, School of Business and Governance, Department of Business Administration.
9) Kuhi, J. Bachelor's Diploma, 2017, (sup) Jelizaveta Janno. Consignors' Awareness of Shipping Dangerous Goods. Tallinn University of Technology, School of Business and Governance, Department of Business Administration.
10) Lilišentsev, A. Bachelor's Diploma, 2017, (sup) Jelizaveta Janno. Interactive Methods for ADR Training Courses in Estonia. Tallinn University of Technology, School of Business and Governance, Department of Business Administration.
11) Muravjova, E. Bachelor's Diploma, 2017, (sup) Jelizaveta Janno. The Analysis of Time Expenditure within the Transportation Chain of Dangerous Goods. Tallinn University of Technology, School of Business and Governance, Department of Business Administration.

12) Poršneva, J. Bachelor's Diploma, 2017, (sup) Jelizaveta Janno. Consignor's Risks Within the Transportation Chain of Dangerous Goods on Example of Krimelte Ltd. Tallinn University of Technology, School of Business and Governance, Department of Business Administration.
13) Raudsalu, K. Bachelor's Diploma, 2017, (sup) Jelizaveta Janno. The Effectiveness of ADR Training Courses. Tallinn University of Technology, School of Business and Governance, Department of Business Administration.
14) Treial, A. Bachelor's Diploma, 2017, (sup) Jelizaveta Janno. The Effect of the Human Factor on Transporting Dangerous Goods by Road. Tallinn University of Technology, School of Business and Governance, Department of Business Administration.

Curriculum vitae

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3. Education

2008 –	Tallinn University of Technology, School of Engineering, Department of Mechanical and Industrial Engineering, Doctoral studies
2005 – 2007	Tallinn University of Technology, Faculty of Civil Engineering, Department of Road Engineering, MSc in logistics, *cum laude*
2002 – 2005	Tallinn University of Technology, Faculty of Civil Engineering, Department of Road Engineering, BSc in logistics, *cum laude*
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4. Language competence

Russian	Mother language
Estonian	Native speaker level
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2018 – …	Tallinn University of Technology, School of Engineering, Department of Mechanical and Industrial Engineering; programme director (logistics), lecturer.
2009 – …	TTK University of Applied Sciences, Institute of Logistics, lecturer, Head of the Research Group on research on logistics Main courses: transportation economics, supply chain management, research methods, supervising students' project Students' Logistics Seminar. Supervisor of 67 BSc theses.
2008 – 2011	Tallinn University of Technology, guest-lecturer of a course on the carriage of goods. Supervisor of 17 BSc and 4 MSc theses.
2004 – …	Ergo Transport Grupp, Ltd., logistician (international transportation, carriage of dangerous goods)
2003 – 2004	Tallink, LLC; Tallink Cargo, LLC, cargo operator, part-time

6. Scientific Work

The main area of scientific work:

4. Natural Sciences and Engineering; 4.15. Construction and Municipal Engineering; CERCS SPECIALTY: T280 Road transport technology; SPECIALITY: Risk management of dangerous goods by human factor.

1. Biosciences and Environment; 1.8. Research relating to the State of the Environment and to Environmental Protection; CERCS SPECIALTY: T270 Environmental technology, pollution control; SPECIALITY: Dangerous goods transport by roads.

Other publications:

1. Janno, J. (2016). Logistika kui süsteem. J. Suursoo (Toim.). Ekspedeerija käsiraamat (119−133). Tallinn: Tallinna Tehnikakõrgkool.
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6. Krasjukova, J. (2010). Dangerous Goods Transport by Roads - Should have be Extra Charged for Road Usage? Young European Arena of Research, Transport Research Arena YEAR2010.

7. Defended Theses

Krasjukova, J. Finding Optimal Solution for Transportation Liquids in Tank-Container. J. Laving (Sup.): MSc thesis. Tallinn University of Technology, Faculty of Civil Engineering, Department of Road Engineering (2007).

Supervised dissertations:

1. Deanna Vainoja, Master's Degree, 2018, (sup) Jelizaveta Janno, Improving the Supply Chain of Temperature Sensitive Pharmaceuticals Shipped by Air, Tallinn University of Technology School of Engineering, Department of Mechanical and Industrial Engineering.
2. Anton Larin, Master's Diploma, 2017, (sup) Jelizaveta Janno, Oversized Cargo Transportation based on TallShip LLC Practice, Tallinn University of Technology School of Engineering, Department of Mechanical and Industrial Engineering.
3. Sander Vanaisak, Master's Degree, 2016, (sup) Jelizaveta Janno; Ott Koppel, Distribution logistics of large shipments, Tallinn University of Technology, Faculty of Mechanical Engineering, Department of Mechanical and Industrial Engineering Chair of Logistics.
4. Marija Kirjušetškina, Master's Degree, 2014, (sup) Jelizaveta Janno; Ott Koppel, Safe road transport of dangerous goods by example of Eskaro, Ltd, Tallinn University of Technology, Faculty of Civil Engineering, Department of Logistics and Transport, Chair of Transportational Logistics.
5. Oliver Kivinuk, Master's Degree, 2013, (sup) Jelizaveta Janno, Logistical, economic and legal aspects of the establishment of waste oil refinery in Estonia, University of Technology, , Faculty of Civil Engineering, Department of Logistics and Transport, Chair of Transportational Logistics.

8. Projects

1. Estonian Road Administration. The Study on a Traffic Behavioural Impact of a Warning Lamp Equipped Pedestrian Crosswalk, 02.11.2017 – 31.10.2018 (in progress), R&D research, senior research staff.
2. E-NOBANET. E-business Models for International SMEs, 15.06.2017−1.10.2018 (in progress), education development project, senior research staff.
3. World Energy Council Estonia. Options for Reducing Greenhouse Gas Emissions from Carriage of Goods (road, rail and marine transport), 02.06 – 19.10.2017, senior research staff.
4. Curriculum Alignment and Cross-Border Cooperation with SMEs, 1.09.2015−28.02.2017, E&D project, other research staff.
5. Improved Logistics Processes of Havi Logistics Ltd.,1.03.2012−30.09.2012, R&D project, principal investigator.

9. Membership

2017 – ... Member of the DAAAM International network

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2002 – 2005	Tallinna Tehnikaülikool, ehitusteaduskond, teedeinstituut tehnikateaduse bakalaureus (logistika), *cum laude*
– 2002	Tallinna 49. Keskkool, keskharidus

4. Keelteoskus

Vene keel	emakeel
Eesti keel	vabalt valdamine
Inglise keel	edasijõudnud (C1)
Saksa keel	kesktase (B1)

5. Teenistuskäik

2018 – ...	Tallinna Tehnikaülikool, inseneriteaduskond, mehaanika ja tööstustehnika instituut; logistika programmijuht, lektor.
2009 – 2018	Tallinna Tehnikakõrgkool, logistikainstituut, lektor, logistika ja veonduse alaste uuringute uurimistööde rühma juht. Peamised ainekursused: transpordiökonoomika, Tarneahela juhtimine, uurimistöö meetodid, üliõpilasprojekti Logistikaseminar vastutav õppejõud. 67 diplomitöö juhendaja.
2008 – 2011	Tallinna Tehnikaülikool, õppeaine "Kaubavedu" külalislektor. 17 bakalaureuse ja 4 magistritöö juhendaja.
2004 – ...	Ergo Transport Grupp OÜ, logistik (rahvusvaheline kaubavedu, ohtlike kaupade maanteetransport)
2003 – 2004	Tallink AS, Tallink Cargo AS, kaubaveo operaator osakoormusega

6. Teadustöö tulemused

Teadustöö valdkond:

4. Loodusteadused ja tehnika; 4.15. Ehitus- ja kommunaaltehnika; CERCS ERIALA: T280 Maanteetransporditehnoloogia; PÕHISUUND: Ohtlike kaupade riskide maandamine inimfaktori mõjul.

1. Bio- ja keskkonnateadused; 1.8. Keskkonnaseisundit ja keskkonnakaitset hõlmavad uuringud; CERCS ERIALA: T270 Keskkonnatehnoloogia, reostuskontroll; PÕHISUUND: Ohtlike kaupade maanteetransport.

Muud publikatsioonid:

1. Janno, J. (2016). Logistika kui süsteem. J. Suursoo (Toim.). Ekspedeerija käsiraamat (119−133). Tallinn: Tallinna Tehnikakõrgkool.
2. Krasjukova, J. (2011). Sensation of Dangerous Goods in Business Activity. Journal of International Scientific Publications: Economy and Business, 5 (2), 234-257.
3. Ossipova, J.; Krasjukova, J. (2011). The use of interactive teaching methods in logistics. Journal of International Scientific Publications: Educational Alternatives, 9 (1), 219−248.
4. Krasjukova, J.; Ossipova, J. (2010). Практический маркетинг в сфере транспортно-логистических услуг в условиях кризиса. Journal of International Scientific Publications: Economy and Business, 4, 101-115.
5. Krasjukova, J. (2010). Possibilities to Manage Effectively Risks in Transport of Dangerous Goods. Journal of International Scientific Publications: Economy and Business, 4 (2), 27-36.
6. Krasjukova, J. (2010). Dangerous Goods Transport by Roads - Should have be Extra Charged for Road Usage? Young European Arena of Research, Transport Research Arena YEAR2010.

7. Kaitstud lõputööd

Krasjukova, J. Optimaalse lahenduse leidmine vedelike transportimisel tank-konteineriga. J. Laving (juh.): magistritöö. Tallinn: Tallinna Tehnikaülikooli ehitusteaduskond, teedeinstituut, 2007.

Juhendatud väitekirjad:

1. Deanna Vainoja, magistrikraad, 2018, (juh) Jelizaveta Janno, Termolabiilsete ravimite lennutarneahela täiustamine, Tallinna Tehnikaülikool, inseneriteaduskond, mehaanika ja tööstustehnika instituut.
2. Anton Larin, magistrikraad, 2017, (juh) Jelizaveta Janno, Ülegabariidiliste kaupade vedu Tallship OÜ näitel, Tallinna Tehnikaülikool, inseneriteaduskond, mehaanika ja tööstustehnika instituut.
3. Sander Vanaisak, magistrikraad, 2016, (juh) Jelizaveta Janno; Ott Koppel, Suuremõõtmeliste saadetiste jaotuslogistika, Tallinna Tehnikaülikool, mehaanikateaduskond, mehaanika ja tööstustehnika instituut, logistika õppetool.
4. Marija Kirjušetškina, magistrikraad, 2014, (juh) Jelizaveta Janno; Ott Koppel, Ohtlike ainete säästlik maanteevedu Eskaro AS näitel, Tallinna Tehnikaülikool, ehitusteaduskond, logistika instituut, veonduslogistika õppetool.
5. Oliver Kivinuk, magistrikraad, 2013, (juh) Jelizaveta Janno, Vanaõli rafineerimistehase Eestisse loomise logistilised, majanduslikud ja õiguslikud aspektid, Tallinna Tehnikaülikool, ehitusteaduskond, logistika instituut, veonduslogistika õppetool.

8. Projektid

1. Maanteeamet. Hoiatuslampide süsteemiga varustatud ülekäiguraja liikluskäitumusliku mõju uuringu läbiviimine, 02.11.2017 – 31.10.2018 (pooleli), teadus- ja arendusprojekt, põhitäitja.
2. E-NOBANET. E-äri mudelid väike- ja keskmise suurusega ettevõtetele (VKE), 15.06.2017−1.10.2018 (pooleli), õppearendusprojekt, põhitäitja.

3. Maailma Energeetikanõukogu Eesti Rahvuskomitee MTÜ. Kaubaveoga seotud kasvuhoonegaaside vähendamise võimalused (maantee- ja raudteetransport ning laevandus), 02.06 – 19.10.2017, teadus- ja arendusprojekt, põhitäitja.
4. Õppekavade ühtlustamine ja piiriülene koostöö väike- ja keskmise suurusega ettevõtetega (VKE), 1.09.2015−28.02.2017, õppearendusprojekt, täitja.
5. Havi Logistics OÜ logistiliste protsesside parendamine, 1.03.2012−30.09.2012, teadus- ja arendusprojekt, vastutav täitja.

9. Kuulumine erialaorganisatsioonidesse

2017 – ... DAAAM International võrgustiku liige

2005 – ... Eesti Ostu- ja Tarneahelate Juhtimise Ühingu (ProLog) põhiliige

Jelizaveta Janno /allkiri/
03.01.2019