

## 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 logistics 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 system 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).

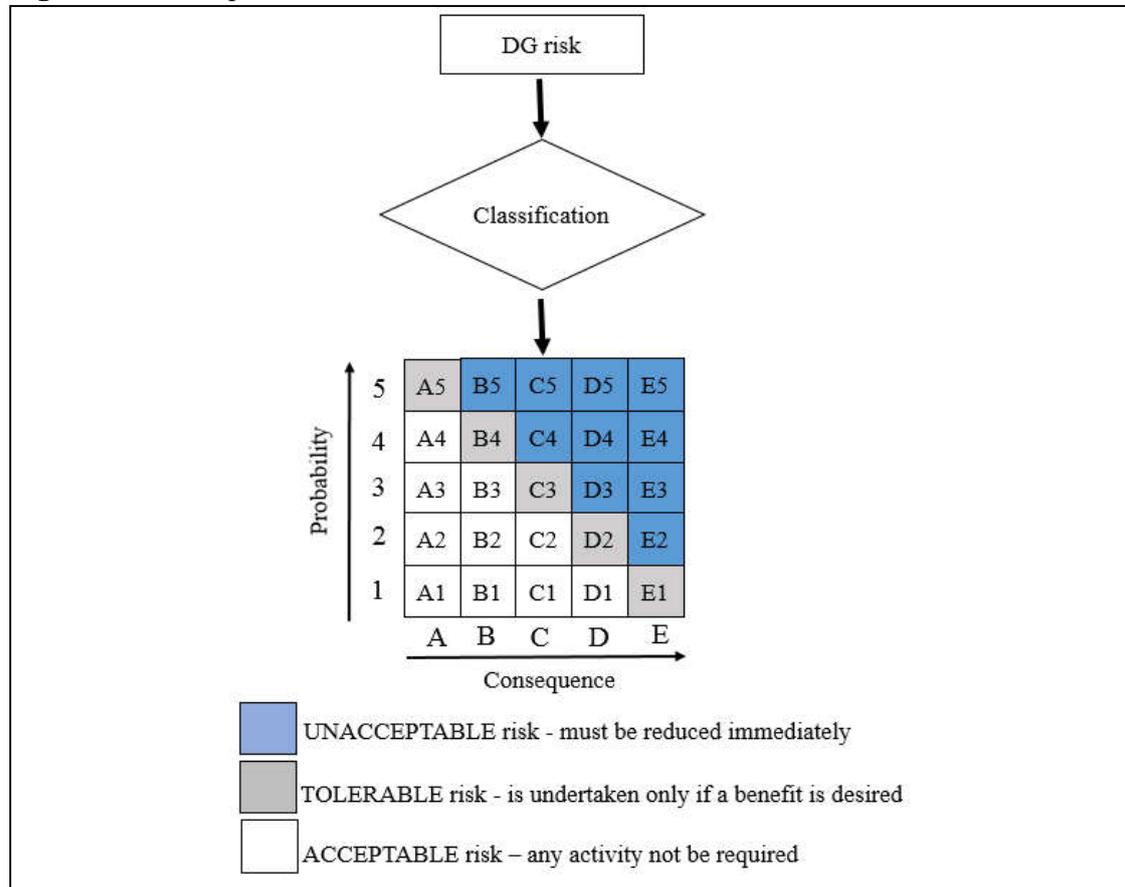
Risks facing different parties and their operations within the transportation chain of DG can result from factors both external (culture, regulations, board composition) and internal (accounting controls, information system, requirement, supply chain) the organisation (A Risk Management Standard, 2012). Operational risks in logistics as well as in DGT have both external and internal key drivers. 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

<b>Experience in DG road transport in years</b>	<b>&lt; 1</b>	<b>1-2</b>	<b>2-5</b>	<b>5-10</b>	<b>&gt; 10</b>
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

<b>Average number of DG shipments per month</b>	<b>1-2</b>	<b>3-5</b>	<b>6-10</b>	<b>&gt; 10</b>
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 into 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

<b>Consignor/Consignee</b> <i>(11 companies; max score 55 of points)</i>	<b>Freight forwarder</b> <i>(17 companies; max score of 85 points)</i>	<b>Carrier company</b> <i>(57 companies; max score of 285 points)</i>
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.

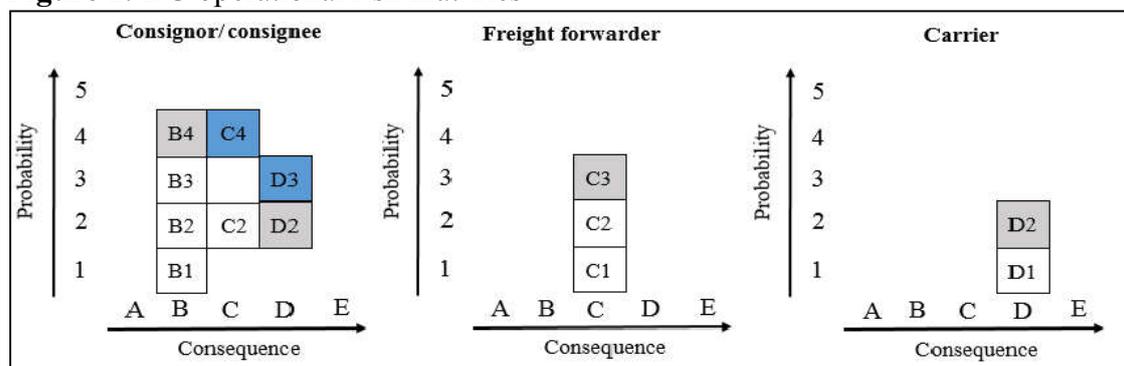
**Table 4.** Ratings of DG operational risks

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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