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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

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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.

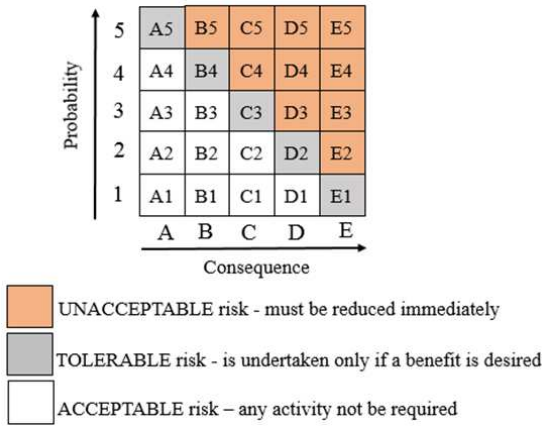
METHODOLOGY

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.

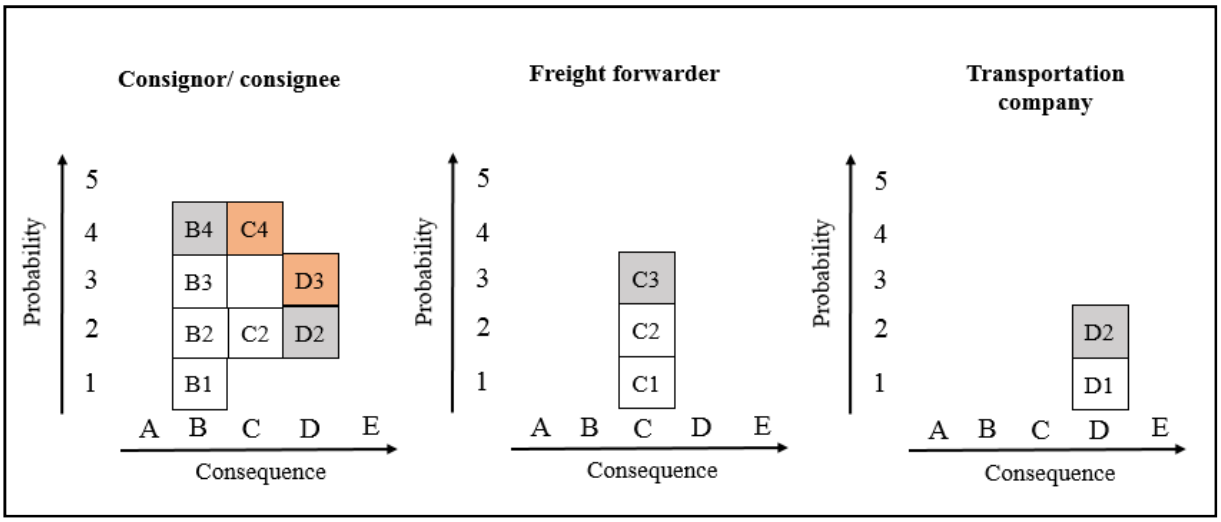
Table 2. Evaluation of DG operational risks

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.

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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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