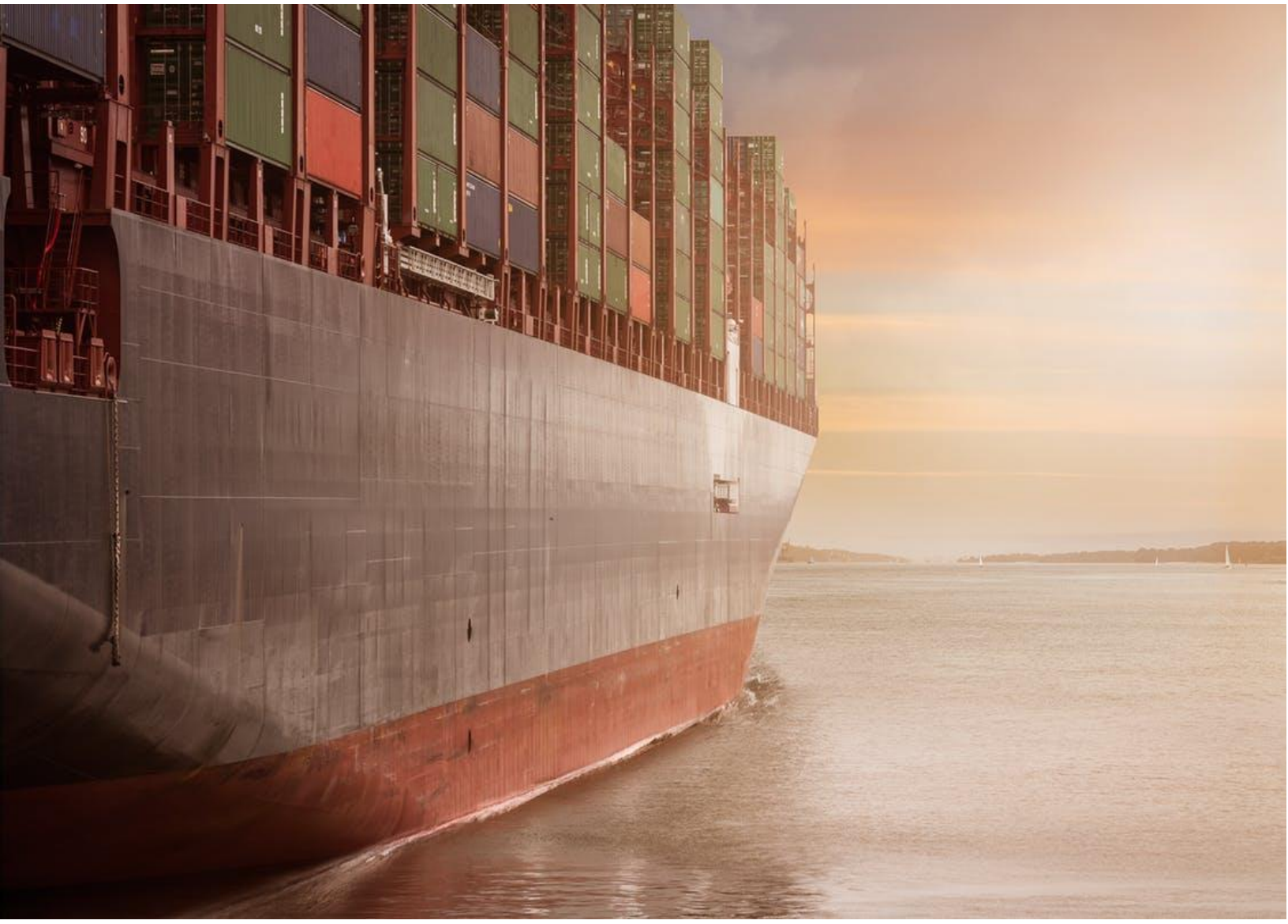
Crusade towards correct Dangerous Goods declarations:

A comprehensive overview of the current DG document flow



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ABSTRACT

The global transport of goods has only increased the last decades, that also goes for dangerous goods. Dangerous goods are serious business, an obvious risk is associated with the shipment of them, human errors are making it even more dangerous. If they are not declared completely and properly they can even become deadly. All stakeholders within the logistics and supply chain are aware of the risks. Recent incidents with dangerous goods on board of container vessels, or even the great explosion in Tianjin (2015) only increased the awareness. Yet this risky shipment is still subject to an archaic document flow.

The purpose of this paper is bifold: create a comprehensive overview of the document flow within the chain, and second to provide an explanation how human errors occur. To the best of our knowledge no study today has ever incorporated the document flow of dangerous goods into a single overview and subsequently provided an explanation for the undeclared dangerous goods. The key finding: mistakes are intrinsic to humans, the current document flow only increases the probability of mistakes.

LIST OF ABBREVIATIONS & DEFINITIONS

- ADN: European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways
- ADR: European Agreement concerning the International Carriage of Dangerous Goods by Road
- CFR: Code of Federal Regulations
- (Freight) Container: means an article of transport equipment that is of a permanent character and accordingly strong enough to be suitable for repeated use; specially designed to facilitate the transport of goods, by one or more modes of transport, without intermediate reloading; designed to be secured and/or readily handled, having fittings for these purposes, and approved in accordance with the International Convention for Safe Containers (CSC), 1972, as amended (IMO, 2018, p. 1.2.1).
- COTIF: The Convention concerning International Carriage by Rail
- CPC: Container Packing Certificate
- DG: Dangerous Goods
- DGD: Dangerous Goods Declaration (as shown in appendix A)
- DGSA: Dangerous Goods Safety Advisor(s)
- EDI: Electronic Data Interchange
- EU: European Union
- IMDG Code: The International Maritime Dangerous Goods (IMDG) Code adopted by the Maritime Safety Committee of the Organization by resolution MSC.122(75). (IMO, 2018)
- RID: Regulations concerning the International Carriage of Dangerous Goods by Rail
- SOLAS: International Convention for the Safety of Life at Sea
- VGM: Verified Gross Mass

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1. Introduction

Since 1956, with the introduction of the container by Malcolm McLean, the container shipping industry is omnipresent (Notteboom, 2004). Marine transport has become the backbone of economic growth and prosperity. Connecting countries and entire continents. Shipping can be described as the accelerator of globalization (Corbett & Winebrake, 2008). The increasing globalization, and therefore growth in container transport, is clearly visible in the ever-growing capacity of the container vessels. The UN Conference on Trade And Development (UNCTAD) forecast shows an annual growth of the seaborne trade with 3.2% between 2017 and 2022, with an increased expansion in the container segment (UNCTAD, 2017).

A significant part of all goods shipped consist of dangerous goods. Already in 2001 Roger Charlier found that 50% of all goods shipped, and 10% - 15% of the containerized shipments can be classified as dangerous goods. For most of us the concept of dangerous goods is something which does not concerns us, or even affects us. Wrong. We all encounter dangerous goods, even in our everyday life. Take for instance: deodorants (class 2.1), sparkling water out of a water dispenser (class 2.2), make-up remover or fuel for our cars (class 3), household cleaning materials (class 8), swimming pool disinfection or fertilizers (class 5.1), safety devices like airbags (class 9), Fireworks (class 1), batteries for our laptops, phones and electric bikes (class 9). As dangerous goods are the central theme in this paper a clear understanding is of the upmost importance. In order not to have any semantic discussion, dangerous goods are here defined as substances, materials and articles as described in the IMDG code (IMO, 2018). A list of the 9 dangerous goods classes as described by the IMDG code can be found in appendix B.

The multimodal transportation of goods in general, and dangerous goods especially, have to rely on multiple stakeholders (Martinez Marin & Eguren, 2013), (Nyquist, 2015), (Wołejsza, Thombre, & Guiness, 2015). Each of them must pass the relevant information and transport documents to the next one in the chain. The complete and correct sharing of relevant information is imperative in shipping and of vital importance in containerized shipments (Güner-Özbek, 2008). By the very nature of the container, it is impossible to identify which goods were loaded in the container unit. Thus, all stakeholders must rely on the information in the transport document. Missing information could be calamitous. Undeclared or mis-declared cargo has been identified as a contributory factor in several maritime incidents (Ellis, 2010).

Recently some steps have been taken on an international level to tackle the problem of undeclared cargo. IMO's International Convention for the Safety of Life at Sea (SOLAS) has made it mandatory to have a certified document containing the verified gross mass (VGM) of a packed container (Maritime Safety Committee , 2014). This will provide the carrier an accurate overview of the weight, in order for them to plan the vessel and distribute the weight accordingly. However dangerous goods remain currently out of scoop. Even though research shows that undeclared dangerous goods are accountable for a significant part of the maritime incidents (Güner-Özbek, 2008), (Ellis, 2010), (CINS, 2019).

This paper will focus on the aspect of human error in the dangerous goods flow. A conceptual framework will be provided where the current legal requirements and previous research are connected in explaining how human error is imbedded in the current process of working.

2. Why is it relevant? Problem description

We must ask the question regarding the relevance of this topic and the paper. The answer can be found in the growing list of fires and incidents on board of ships carrying dangerous goods. An important comment, however, needs to be made. All existing research or documentation on these kinds of incidents can only be made when the information is available, in other words: if it is reported (Hassel, Asbjørnslett , & Hole, 2011). When a container catches fire on deck and the container is thrown overboard without any further damage to the ship or other containers, the incident is often widely unreported (in the media).

The list of recent (major) reported incidents onboard of container ships involving dangerous goods increases consecutively: MSC Flaminia (07/2012), Eugen Maersk (06/2013), Hansa Brandenburg (07/2013), Hyundai Fortune (03/2016), APL Austria (02/2017), MSC Daniela (04/2017), Maersk Honam (03/2018), APL Vancouver (01/2019), Yantian Express (01/2019), KMTC Hongkong (05/2019). Even a slight incident on board of a container ship, carrying dangerous goods can have devastating consequences. Crew members could be injured or killed (Zheng, Talley, Jin, & Ng, 2016), spillage can effect wildlife and the environment in general (Häkkinen & Posti, 2014), (Ceyhun, 2014). Loss of cargo or even general average. The ship repair costs quickly rise to millions of dollars.

2.1. Existing literature

The transportation of dangerous goods bares a certain risk. A large number of studies, evaluations and research projects have investigated the risk associated with shipping dangerous goods (Cova & Conger, 2003), (Forsman, et al., 2008), (Hamann, Papanikolaou, Eliopoulou, & Golyshev, 2013), (Chang, Xu, & Song, 2015), (Conca, Ridella, & Sapori, 2016), (Illiyas & Mohan, 2016), (Forigua & Lyons, 2016), (Janno & Koppel, 2017), (Banabakova & Minevski, 2017), (Batarlienė, 2018), (Janno & Koppel, 2018).

Forsman, et al. (2008) created a high-level risk model and made recommendations on how to reduce the accidents. Another study concluded that fire and explosions contribute to 25% of the accidents (Hamann, Papanikolaou, Eliopoulou, & Golyshev, 2013).

Table 3: Reported accidents of fully cellular container ships, 1993 – 2004 Accident category	Total number	Thereof Serious	Thereof Heavy weather
Collision	493	78	34
Contact	112	15	12
Grounding	210	64	17
Fire/Explosion	109	44	1
Machinery damage	395	108	5
Hull damage	39	6	13
Foundered	2	2	1
Miscellaneous	222	10	67
Total	1582	327	150

(Forsman, et al., 2008, p. 137)

We can safely say that fire and explosions have a significant share in all recent incidents. However most of the existing research fails to explain the cause of fire and explosions. In their recommendations Forsman et al. (2008) state that to reduce the fire and explosion risk one must reduce the amount of undeclared dangerous goods. This statement was later confirmed by Joanne Ellis (2011), who concluded that undeclared or not properly declared dangerous goods could be identified as the contributing factor in incidents. Question remains to the reason of mis – or undeclared dangerous goods. A closer look into the regulations and the dangerous goods document flow through the logistics chain will provide more insights.

3. Legal framework

All transport of dangerous goods by sea is managed and regulated by the IMDG code. Which is subject to amendment every two years in order to adapt the legislation and regulations to the rapidly evolving technological and economic developments in the shipping industry. The code consists of 7 chapters each of them meticulously describes which actions or rules need to be followed. Without going into detail over every single paragraph of the IMDG code, there are, however, some basic understandings you need to be aware of when shipping dangerous goods. First, the correct UN numbers must be picked, for which the appropriate packing material needs to be selected. Subsequently the packaging should bare the correct markings and labels. The philosophy is simple: it should always be possible to identify the danger inside without the risk of opening it. Same principle for the container. Once the goods are correctly loaded in the container, the unit will be affixed with marks and placards. Finally, a transport document needs to be completed.

In chapter 5.4 of the IMDG code we can find the dangerous goods transport document, containing dangerous goods information, commonly referred to as the DGD (Dangerous Goods Declaration). The importance of this document for the container shipping can't be emphasized enough. On the transport document we can identify 3 important parts:

1) The mandatory DG details on the dangerous goods transport document
2) The shipper's declaration
3) The container packing certificate

3.1. The mandatory DG details on the dangerous goods transport document

Due to the very nature of a container we are unaware of the content. The DGD should provide a clear description of the dangerous goods loaded in accordance with paragraph 5.4.1.4. of the IMDG code. It shall contain: (1) UN-number, (2) proper shipping name, (3) primary hazard, (4) subsidiary hazard and (5) packing group. Moreover, the sequence of the above description should be followed, for example (IMO, 2018, p. 5.4.1.4): *UN 2761, Organochlorine pesticide, solid, toxic, (Aldrin 19%), class 6.1, PG III, MARINE POLLUTANT*. In the field we see that a great deal of the DGD's are not following the mandatory sequence[1].

In addition, all relevant information must be supplemented (if applicable) (IMO, 2018, p. 5.4.1.5): Technical name, empty uncleaned, waste, elevated temperature substances, marine pollutants, flashpoint, limited quantities, …

Also, the total quantity of the dangerous goods should be added. Here we find already ambiguous description, the code states (IMO, 2018, p. 5.4.1.5.1):

> *Except for empty uncleaned packagings, the **total quantity** of dangerous goods covered by the description (by volume or mass as appropriate) of each item of dangerous goods bearing a different proper shipping name, UN number or packing group **shall be included**. For class 1 dangerous goods, the quantity shall be the net explosive mass. For dangerous goods transported in salvage packagings, an estimate of the quantity of dangerous goods shall be given. The number and kind (e.g. drum, box, etc.) of packages shall also be indicated. **UN packaging codes may only be used to supplement the description of the kind of package** (e.g. one box (4G)). Abbreviations may be used to specify the unit of measurement for the total quantity.*
>
> ***Note**: The number, type and capacity of each inner packaging within the outer packaging of a combination packaging is not required to be indicated.*

Some remarks should be made. First, the IMDG code does not clarify which weight needs to be mentioned: gross weight or net weight? Secondly, most carriers require the inner packing to be provided. This implicates the importance (otherwise the carrier wouldn't request this

[1] Based on empirical findings, however this paper can't include the details due to corporate sensitivity.

information). Then why isn't it mandatory information on the DG document? Thirdly, one may question the reason to why the UN packing code may only be supplemented. Almost all packings[2] require an UN packing code on the packaging. For instance, a steel drum non-removable head has the code 1A1, or fibreboard box has 4G. It is the opinion of this paper that the mandatory use of the UN packing code on the transport document could only improve the transparency of the document. Thus, making EDI or OCR technology easier and the latter more accurate.

3.2. The shipper's declaration

The second feature on the DGD is the shipper's declaration. This fixed declaration has important legal consequences. Here the shipper (or consignor) states that all information on the document is complete and accurate and is in compliance with all relevant regulations. The statement shall be signed and dated by the consignor (IMO, 2018, p. 5.4.1.6.1). Hence the shipper has an undeniable responsibility and liability (Tomotaka, 2011).

SHIPPER'S DECLARATION

I hereby declare that the contents of this consignment are fully and accurately described below by the proper shipping name, and are classified, packaged, marked and labelled/placarded and are in all respects in proper condition for transport according to the applicable international and national governmental regulations.

3.3. The container packing certificate

When dangerous goods are packed and loaded in a (freight) container[3], a Container Packing Certificate (CPC) shall be supplemented. This may be included in the DGD form or consisting of a separate document. For the purpose of this paper we consider the DGD and CPC to be one document and will refer to it as the DGD. In analogy with the shipper declaration the CPC is signed and dated, and consequently implicates certain responsibilities. Here the person in charge of packing the goods in the container (stuffer) makes a declaration specifying that all operations have been carried out in accordance with the conditions described by the IMDG code, and the container number is specified (IMO, 2018, p. 5.4.2.1):

- *The container/vehicle was clean, dry and apparently fit to receive the goods*
- *Packages which need to be segregated in accordance with applicable segregation requirements have not been packed together onto or in the container/vehicle (unless approved by the competent authority concerned in accordance with 7.3.4.1);*

[2] Some exceptions exist. The packings of packing instruction P200, or crates for example do not require an UN packing code.
[3] When Tanks are used a Tank Certificate is mandatory.

- *All packages have been externally inspected for damage, and only sound packages have been loaded;*
- *Drums have been stowed in an upright position, unless otherwise authorized by the competent authority, and all goods have been properly loaded and, where necessary, adequately braced with securing material to suit the mode(s)* of transport for the intended journey;*
- *Goods loaded in bulk have been evenly distributed within the container/vehicle;*
- *For consignments including goods of class 1 other than division 1.4, the container/vehicle is structurally serviceable in accordance with 7.1.2;*
- *The container/vehicle and packages are properly marked, labelled and placarded, as appropriate;*
- *When substances presenting a risk of asphyxiation are used for cooling or conditioning purposes (such as dry ice (UN 1845) or nitrogen, refrigerated liquid (UN 1977) or argon, refrigerated liquid (UN 1951)), the container/vehicle is externally marked in accordance with 5.5.3.6; and*
- *A dangerous goods transport document, as indicated in 5.4.1, has been received for each dangerous goods consignment loaded in the container/vehicle.*

CONTAINER/VEHICLE PACKING CERTIFICATE

I hereby declare that the goods described above have been packed/loaded into the container/vehicle identified above in accordance with the applicable provisions.

In paragraph 5.4.5 of the IMDG code we can find an example of the Multimodal Dangerous Goods Form (IMO, 2018). However, the layout of the form presented in this paragraph is not mandatory. As also stated by paragraph 5.4.1.2.1: "*A dangerous goods transport document may be in any form, provided it contains all of the information required by the provisions of this Code*" (IMO, 2018, p. 5.4.1.2.1). As a result, many different DGD forms (PDF, images, Excel, Word, handwritten, …) are present in the industry making interpretation only more challenging. This only increases the probability of mistakes, in an already labor-intensive process, which will be discussed later on. Some examples of these various forms are provided in appendix A.

4. Different stakeholders

We are fully aware of the complex logistical chain, however for the purpose of this paper we will be only mentioning the most relevant ones. The absence of the other stakeholders in this paper has no influence on the discussion and/or the conclusion.

4.1. Shipper

The shipper is defined by the IMDG code as any person, organization or government which prepares a consignment for transport (IMO, 2018, p. 1.2.1). In some cases, the shipper is acting on behalf of the original client (Martinez Marin & Eguren, 2013). To have a comprehensible understanding, this paper will start from the premise that the shipper is the first stakeholder in the chain. Camilla Nyquist (2015) correctly states that the shipper is the initial source of

information. The importance of this can't be emphasized enough, as the dangerous goods document -which is created by the shipper- is passed subsequently to each stakeholder in the chain.

4.2. Freight forwarder

The international transport is characterized by complex tangle of transport companies, customs clearances, additional documentation, certificates and licenses, insurances and so on. A freight forwarder is an intermediary agent who provides a custom-tailored solution and arranges all of the latter for the shipper (Özsomer, Mitri, & Cavusgil, 1993), (Burkovskis, 2008) , (Popovych, Shyriaieva, & Selivanova, 2016), (Ochoa-Zezzatti, Sánchez, Cedillo-Campos, & de Lourdes, 2016). Moreover, freight forwarders might get better freight rates.

4.3. Freight consolidator

The cargo to be shipped could be relatively small, making a container for exclusive use far too expensive. In those cases, a freight consolidator is contacted (Cheong, Graves, & Bhatnagar, 2007), (Boysen & Fliedner, 2010). In contrast to a freight forwarder a freight consolidator will take the cargo (too small for exclusive container use) from all kinds of different shippers and load it in a container, thus taking the role of container stuffer (i.e. the one who is signing the container packing certificate).

4.4. Ship agent/Carrier

The shipping and maritime industry is a highly competitive sector due to a very demanding customer base, huge volumes, high demand and many players in the field. The increasing capacity of the new build vessels only intensifies this competition. In order to strengthen their position in the market shipping companies often acquire strategic parts of the logistical chain, as for example terminals, warehouses and shipping agencies (Artuso, et al., 2015). For the purpose of this paper we will define the ship agent as local representative of the carrier or ship owner.

4.5. Authorities

The international movement of goods requires declarations and licenses of authorities, especially in the case of dangerous goods, declarations to the local competent authorities are mandatory. Shipments require declaration to multiple governmental agencies, as for example customs, port authorities, waste regulating agencies and so on. Multiple stakeholders have an obligation to declare cargo to, sometimes different/the same, governmental agencies. Camilla Nyquist (2015) investigated the information sharing between stakeholders in Sweden, regarding the transport of dangerous goods, and concluded that information sharing among governmental agencies is little to nonexistent.

5. Document flow

Now the (most prominent) stakeholders are known, it's important to see where they are situated in the chain and which role they play. To the best of our knowledge no study today has ever investigated the dangerous goods document flow between the different stakeholders in the chain. The paper will present three scenarios. The chain presented here is a simplified version of the reality but does in no way effect or influence the conclusion of this paper. The overview integrates the previous research into the logistical supply chain (Meersman, Van De Voorde, & Vanelslander, 2010), (Martinez Marin & Eguren, 2013), (Wołejsza, Thombre, & Guiness, 2015).

As already discussed, the shipper can either directly contact a carrier, via the ship agent, or rely on the services provided by a freight forwarder (figure 2) or even a freight consolidator. The latter is shown in figure 3, whereas the direct contact between shipper and ship agent is provided in figure 1.

Since every stakeholder is working with a specific IT system for their specific needs, Electronic Data Interchange (EDI) is imperative and proven to be the preferred platform for business-to-business or business-to-government information sharing (Narayanan, Maruchec, & Handfield, 2009). The thick line represents a copy of the original Danger Goods Document (DGD) which is sent from one stakeholder to the other. The dashed line stands for the information flow of reproduced data from the DGD.

The paper document (DGD) remains persistent in the shipping industry since international and local legislation require the document or a copy of the document to follow the cargo (IMO, 2018):

> 5.4.6 Retention of dangerous goods transport information
>
> 5.4.6.1 The consignor and the carrier shall retain a copy of the dangerous goods transport document and additional information and documentation as specified in this Code, for a minimum period of three months.
>
> 5.4.6.2 When the documents are kept electronically or in a computer system, the consignor and the carrier shall be able to reproduce them in a printed form.

The same obligation can be found in the regional regulations around the world:

Regulation	**Region**	**Part**
ADR	EU(*)	Chapter 5.4
ADN	EU(*)	Chapter 5.4
RID	EU(*)	Chapter 5.4
CFR 49	USA	CFR 49 - Subpart C—Shipping Papers

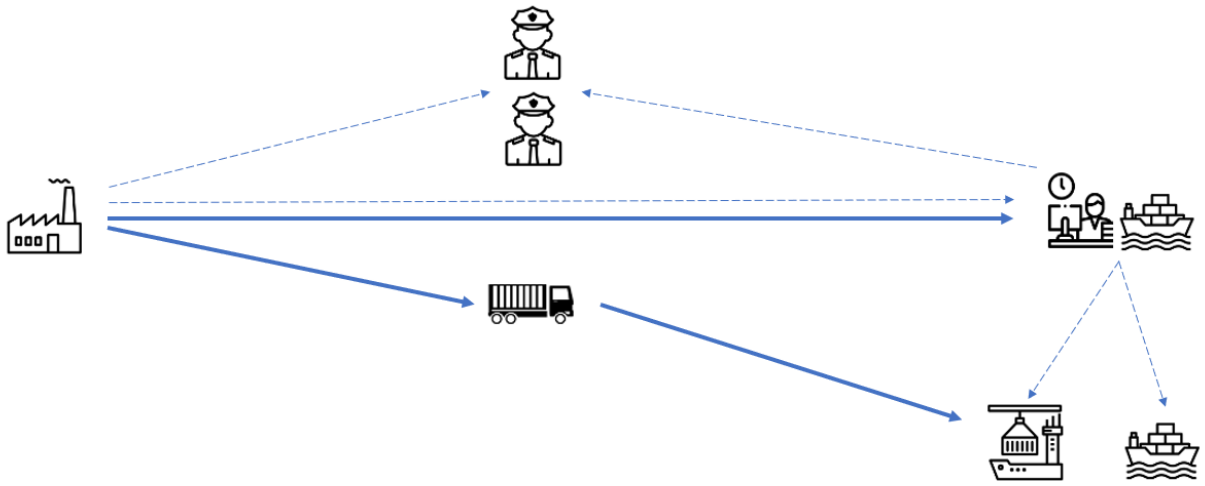
(*) EU in this case is not equal to the European Union. For instance, the Russian Federation, Tunisia and others are member states of these agreements.

5.1. Scenario 1

The shipper sends EDI messages and a copy of the DGD to multiple stakeholders. Let us begin with the declaration to the proper authorities: they expect a full and correct declarations of the goods to be shipped. The shipper can either have an EDI connection to the systems of the authorities or enter the relevant data on their website or in an application. Camilla Nyquist (2015) found that information is often not (or not fully) shared among government agencies (in the same country). The same findings about lack of information sharing between government agencies can be found in different studies (Liu & Chetal, 2005), (Fan, Yen, & Zhang, 2013), (Praditya & Janssen, 2015), (Keeley, Bullen, Bates, Katz, & Choi, 2015). Due to the lack of information sharing, the shipper must enter the same data multiple times, this manual reentry of data only increases the probability of mistakes.

The ship agent receives the information, in order to create a booking, from the shipper, who sends both an EDI message and a copy of the DGD. In most cases the information (in the EDI message) concerning the dangerous goods is insufficient or missing the necessary information or is not fully compatible with the ship agent's system[4]. Therefore, the ship agent must rely on the DGD in order to manually add the missing DG info to the booking. Yet another problem arises: as already discussed the DGD has no standard (mandatory) form or layout, making the recognizability and readability of the details only more difficult, this significantly increases the chance of misinterpretations. Additional communication between ship agent and shipper happen when not all required information can be found in de EDI or the DGD (this will be discussed later on). Once the booking is confirmed by the ship agent, the shipper will arrange transport to move the container from his company to the terminal[5]. As legally required the transporter must carry a copy of the DGD, which will be handed over to the terminal. Meanwhile the DG details from the booking are used by the ship agent for planning (taking into account the segregation rules of the DG cargo) of the vessel, and sending load instructions to the terminal[6]. Finally, the ship agent and shipper send the necessary and required declarations to the proper authorities. Again, the information used for planning, load instructions and declarations all derive from the initial information from the shipper, which is often manually reentered throughout the chain.

[4] Based on empirical findings, however this paper can't include the details due to corporate sensitivity.
[5] Transport depends on the agreement made with the ship agent: carrier haulage, intermodal or merchant haulage.
[6] For the purpose of this paper we assume that the ship agent and carrier are one entity.

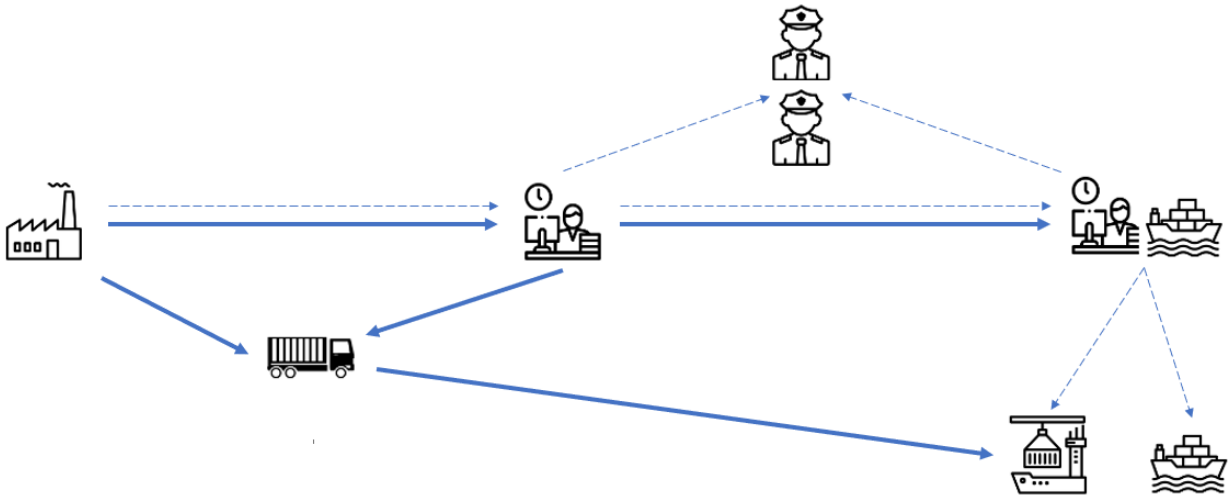


5.2. Scenario 2

The same logic as in figure 1 applies in figure 2. The only difference here is the presence of an additional stakeholder: the freight forwarder. In this case the shipper does not directly contact the ship agent, as already mentioned the freight forwarder will act as a transport engineer: taking care of the documentation, prospecting the lowest rates with carriers and so on. An additional stakeholder in the chain means additional communication channels. In the best-case scenario, the shipper sends EDI message to freight forwarder containing the relevant information about the cargo to be shipped, the DGD is sent separately.

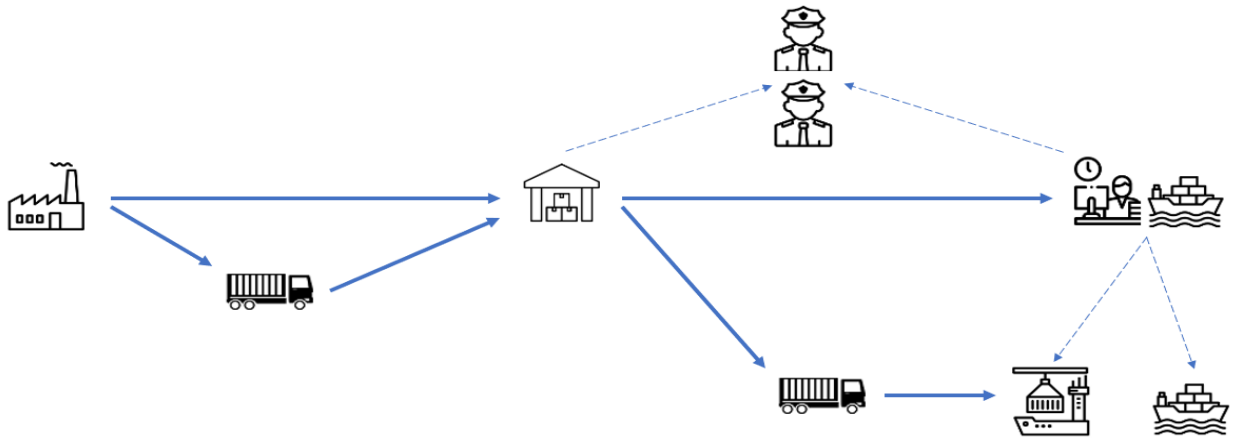
One must understand that in order for two systems to communicate, a comprehensive interface needs to be set up, often using an EDI provider. However, it's an expensive investment to make a system compatible with the EDI provider. So, you may conclude that in most cases the large companies make this investment. Which means that smaller shippers still must rely on manual data entry, and consequently also the receiving freight forwarder. EDI shows potential, yet it's not fully integrated in the chain, and moreover not between all stakeholders (Osnin, 2003) (Handfield, Narayanan, & Marucheck, 2009).

Once the freight forwarder found the best carrier, he will send and EDI message and DGD to the ship agent. In all further communication the freight forwarder is only passing the information back and forth between shipper and ship agent. The freight forwarder will take no responsibility regarding the correctness for the DGD, he is merely passing on the information. In the other scenario all the information from the shipper must be manually entered by the freight forwarder, hence higher probability of mistakes. Based on the original information of the shipper, the freight forwarder and ship agent declare the goods to the authorities. The transport of the container to the terminal can be arranged by either the shipper or the freight forwarder.



5.3. Scenario 3

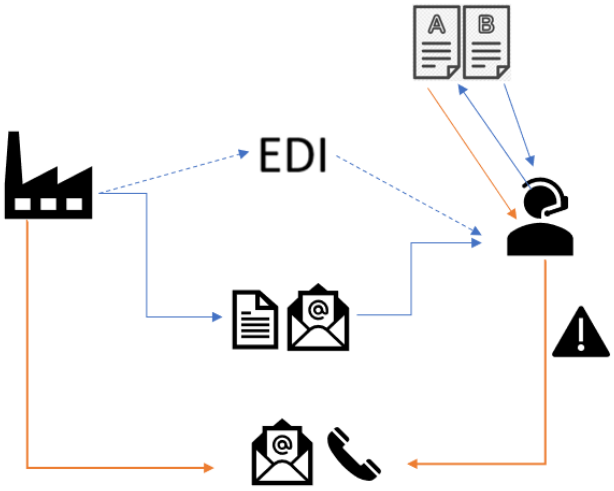
The third, possible scenario is the one involving a freight consolidator. There is less literature about the freight consolidator, although some significant research has been done, none of them fully integrated the concept of dangerous goods (Cheung, Slack, & Tong, 2003), (van Heeswijk, Mes, Schutten, & Zijm, 2016), (Hanbazazah, Abril, Erkoc, & Shaikh, 2018). In this case the goods shipped by the shipper are not yet containerized. This will be done by the consolidator, who will take up the role and associated responsibilities of the stuffer (cfr. signs the CPC). In this case the shipper will only provide the paper documents to the freight consolidator: DGD, packing list, … The goods are brought to the warehouse of the freight consolidator. The transport of the DG goods must be accompanied by the DGD from the shipper. The freight consolidator will load the cargo in the container, together with the cargo of other shippers, mark and placard the container accordingly and signs the CPC. The DGD's from the X number of shippers and the CPC are then sent to the ship agent. Who will manually enter the DG details from the shipment in his booking system. Both freight consolidator and ship agent declare the goods to the appropriate authorities.



5.4. Additional communication

As described above in some cases additional communication is required between the stakeholders to identify for instance the missing or illegible dangerous goods details. This paper has provided an illustration of this additional communication flow, which needs to be considered. If all information is clearly found in the EDI and the original DGD, which is sent via email, the blue line is followed. However, when additional information is required or missing, the ship agent (or freight forwarder/freight consolidator) will email or call the shipper in order to have all information (orange line). Needless to explain the risk of errors in phone calls. As will be discussed later on, EDI connection is not ubiquitous meaning manual entry is often the only solution, as EDI setup requires an investment. Hence we can safely assume that EDI connections are in place in the industrialized parts of the world and even there only with the bigger companies, who are able to make this investment. Even when an EDI connection is in place between the stakeholders, it often does not contain all required DG info. Consequently manual entry of the info on the DGD is needed.

Figure I



5.4.1. Provisional vs. Final DGD

One important additional comment needs to be made. To the best of our knowledge the existing literature has never mentioned the existence of a provisional and final DGD in the shipping industry (visualized in figure I with document A and B). Which is however a widespread phenomenon in the field. To make a booking with a ship agent the shipper must provide the DG details: weight, class, PSN, UN number, number of packages, and so on. In order for the ship agent to perform all kinds of checks: is the commodity allowed as per carriers' house rules? Is the commodity allowed onboard of the vessel? Which restrictions are applicable? Is the shipment in

compliance with the IMDG code? Is the vessel's allowed capacity exceeded? And many others. The shipper in many cases will provide, what is called, a provisional DGD. Why a provisional and not final? And what is the difference? First, the 'final' DGD is the one in full compliance with the IMDG code, which means all required information is filled in, the document is signed by the shipper, the CPC is signed by the stuffer and the container number is specified on the DGD. However, the release for empty container pick-up will only be provided by the ship agent once the booking has been confirmed[7].

Hence our first problem, the container number is not yet known when making a booking. Thus, the shipper will provide a provisional DGD. Only after the container has been loaded all required information is filled in and signed, the final DGD will be sent to the ship agent. In some cases, especially in the scenario with freight consolidators, a few packages where not loaded in the container for all sorts of reasons (example late delivery of some goods). Consequently, the weight and number of packages or even loaded UN numbers could differ from the original DGD, which has been used by the ship agent to complete the booking bearing all DG details. Discrepancies between the provisional and final DGD are currently only found by performing a visual inspection of both documents. Needless to say, that this human interaction is subject to mistakes.

In addition, Barchard & Pace (2011) conducted an experiment where 195 undergraduates were randomly assigned to three data entry methods: double entry, visual checking, and single entry. They came to the staggering finding that visual checking resulted in 2958% more errors than double entry, and was not significantly better than single entry. A later study of Barchard & Verenikina (2013) confirmed the previous findings.

6. Human factor

First of all, a clear distinction needs to be made in regard to the human factor, undeclared cargo due to human interaction can be caused by two things: (1) Deliberate act not to declare dangerous goods. (2) An honest mistake leading to undeclared or mis-declared DG goods.

The first one will not be discussed in this paper because it's a fraudulent and deliberate violation of the law. We will focus exclusively on the 'honest mistake', meaning an innocent human mistake without the intention of making the mistake or falsifying information. In his report Mullai (2006) found that human action can be the cause or a contributing factor to an incident. The U.S. Coast Guard Research & Development Center concluded that human error is the cause (or at least a major contributor) in 75-96% of marine incidents (Rothblum, 2000). Recently more studies identify human error as a significant factor in the transport in general and specifically transport of dangerous goods (Galieriková, Sosedová, Dávid, & Bariak, 2018), (Al-Shammari & Oh, 2018).

[7] Not the case when shipper owned containers are used.

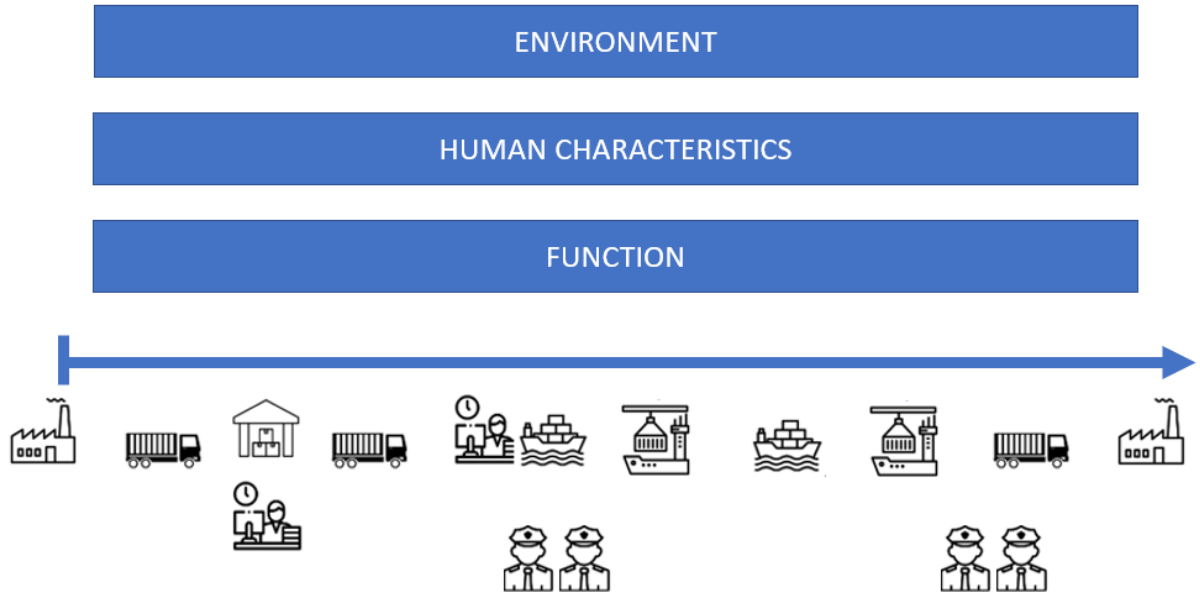
6.1. Reasons of the mistake

The concept of the human factor is becoming the research topic in many studies, even beyond the field of psychology, yet a clear classification of the types of human error is not present. Suominen & Suhonen (2007), for instance, allocated poor training, carelessness or indifference as the cause of human error. Other resaerch found multiple potentiale causes of human errors such as fatigue, inattention, lack of communication, inadequacies in the organization, inappropriate repair, operator error, non-compliance with work procedures, non-compliance with occupational safety rules, etc. (Galieriková, Sosedová, Dávid, & Bariak, 2018).

As you can see, while human errors are all too often blamed on "inattention" or "mistakes" on the part of the operator, more often than not they are symptomatic of deeper and more complicated problems in the total maritime system (Rothblum, 2000, p. 5) .

It is clear that the concept of human error covers many causes .This paper will integrate the classifications of existing research into an overall human-error-overview (see figure II) (Rasmussen, 1982), (Rothblum, 2000), (Reason & Hobbs, 2003), (Wenwen, Fuchuan, Qiang, & Jingjing, 2011), (Butlewski, Jasiulewicz-Kaczmarek, Misztal, & Sławińska, 2014), (Morag, Chemweno, Pintelon, & Sheikhalishahi, 2018).

Figure II



Errors can happen everywhere along the logistic chain: from shipper to consignee (receiver). An incident can be the result of one error by one stakeholder, however it could also be the result of a chain of human error events (Grabowski, Merrick, Harrald, Mazzuchi, & van Dorp, 2000). Further we have concluded, through the investigation of previous research, that human error is caused by a complex interaction between – what we describe as- environment, human characteristics and function.

The error is strongly depended on the function of the stakeholders. For instance, a driver of a fork lift could accidently penetrate a steel drum filled with a highly corrosives substance. Or a ship agent who is not able to clearly recognize the UN number on the DG document, or even mistypes the digits on his computer keyboard can result in incorrect segregation (the segregation table can be found in appendix C) on board of the vessel[8]. This analogy applies to all stakeholders in the chain.

A second, is the human characteristics. Which means certain aspects attributed to the simple fact that we are human, such as:

- Concentration constraints: as a human being we are unable to keep the same level of focus during the day (Miller & Mackie, 1980), (Nobre & Coull, 2013), (Mori, Naghsh, & Tezuka, 2014).

- Physical condition: for example, fatigue, sickness. Fatigue is considered one of the most important causes of human mistakes (Wenwen, Fuchuan, Qiang, & Jingjing, 2011).

- Psychological factors: Slovic, Tversky and Nobel prize winner Daniel Kahneman (1982) found, in their groundbreaking studies, that in cases of uncertainty (stress), people tend to be guided by heuristics (Kahneman, 2011). In regard to this paper the concept of availability heuristics is very much applicable. Let's take for example a shipper who previously made a booking of 3 different UN numbers (UN1202, UN1263, UN1993). One day a DGD is received by the ship agent with one of the 3 UN numbers illegible (with UN1202 and UN1993 readable). The ship agent in a moment of time pressure could rely on his availability heuristic and manually add UN1263 to the booking. However, it may be the case that the shipper did not ship UN1263, but a totally different UN number, which could result in different segregation.

- Skills and knowledge, as it also influences the human performance (Rothblum, 2000), (Butlewski, Jasiulewicz-Kaczmarek, Misztal, & Sławińska, 2014). A multiple case study performed by Suominen et al. (2007) suggested that the human factor can be positively influenced by high-quality education, training and knowledge of the use of modern equipment.

[8] Some DGD's are shown in appendix A, there you can see the information is sometimes illegible.

The third one we call the environment. Meaning all other external factors which contribute or have an effect on the performance of the stakeholder (Rothblum, 2000), (Ganguly, 2011), (Butlewski, Jasiulewicz-Kaczmarek, Misztal, & Sławińska, 2014), (Janno & Koppel, 2017), (Galieriková, Sosedová, Dávid, & Bariak, 2018). Such as:

- Time constraints: pressure and stress
- Legal complexity: various local and international regulations
- Meteorological conditions
- Distracting factors: for instance, noise in the office
- Economy
- Multiple stakeholders: reproduction of data (lack of overall EDI connection)

7. IT solutions

We have seen that there is a level of EDI communication between the stakeholders, yet a lot of manual data entry needs to be additionally made. Technological innovations are finding their way in the shipping industry: for example smart containers. Yet dangerous cargo documentation remains a blind spot. Why? This paper and many others have shown the risks associated with dangerous goods shipment. Yet the majority of the stakeholders in the shipping industry still operate with manual handling and reentry of paper documents, and many of them are still working with mainframe systems dating back to the 1960s (Loklindt, Moeller, & Kinra, 2018). So why? An answer can be found in three factors (Harris, Wang, & Wang, 2014).

1) User-related

Imeri, Khadraoui, & Khadraoui start their study by stating that "*the transportation of dangerous goods (TDG) remains one of the main challenges to manage for the stakeholders*" (Imeri, Khadraoui, & Khadraoui, 2017, p. 708). One of the major problems lies in the fact that multiple stakeholders are involved, and all information needs to pass to each and every one of them (Janno & Koppel, 2017). Another study found different levels of IT penetration, meaning every stakeholder has adopted his own IT solutions in a different scale. Which leads to low compatibility between the systems of the stakeholders (Antoniou, Gagatsi, & Tyrinopoulos, 2007). Moreover, not all stakeholders are of equal size, hence adopting compatible IT infrastructure is a big investment (Pokharel, 2005).

2) Policy Related

Some studies attributed local and international regulations as the cause of the complexity and barrier for IT applications and development (Suominen, et al., 2007), (Imeri, Khadraoui, & Khadraoui, 2017). International shipping is associated with multimodal transportation, which means local, regional and international regulations need to be followed. Furthermore, the regulations are subject to the type of transport. For instance, in the European Union (EU) the

transport via the road is managed by the ADR regulations, train via RID and inland waterways via ADN. A shipment from the EU to the United States could in worse case be subject to at least 6 regulations (ADR, RID, ADN, IMDG, CFR, national laws of the member state of the EU).

3) Technology-related

The lack of a homogenous standard in multimodal transport is clearly an important feature in the EDI process, among others as lack of data exchange interoperability and the lack of system integration (Antoniou, Gagatsi, & Tyrinopoulos, 2007). With every stakeholder adopting his IT applications independently from the others in the chain, they may have different separate ICT applications, provided by various technology service providers thus making communication even more difficult (incompatible) (Harris, Wang, & Wang, 2014). The unilateral adoption of IT applications is contradictory to the high interdependency between the stakeholders.

A recent study investigated 15 digital innovations in Northwest Europe, they concluded that close collaboration between the stakeholders is required and a clear responsibility for the public sector to create an environment where the private sector can engage in this collaboration (Carlan, Sys, Calatayud, & Vanelslander, 2018). Maybe their biggest finding is the fact that there is a tremendous need for digitization in the industry. Most of the investigated digital innovation projects are only handling a specific part of the logistical chain.

8. Conclusion and recommendations

8.1. Conclusion

This paper addresses an important topic in today's shipping industry and supply chain in general. The increasing number of fires and explosions onboard of container vessels are only confirming this. An obvious risk is associated with the shipment of dangerous goods, human errors are making it even more dangerous or even deadly. The purpose of this paper is bifold: create a compressive overview of the document flow within the chain, and second to provide an explanation how human errors occur. To the best of our knowledge no study today as every incorporated the document flow of dangerous goods into a single overview and subsequently provided an explanation for the undeclared dangerous goods.

By analyzing the key stakeholders in the logistics and supply chain together with the current legal framework a comprehensive overview of the relevant document flow is provided for three scenarios: shipper – ship agent, shipper – freight forwarder – ship agent, and shipper – freight consolidator – ship agent. The key finding here: errors are imbedded in the current manual data entry process (Reason, 1997). Due to the labor-intensive process of data reentry from the original document (DGD) there is a high probability for human error (Barchard & Pace, 2011). Based on

the existing studies of human error classification this paper provided a new overview which factors (environment, human characteristics and function) influence the chance of human error.

Unfortunately, some significant barriers (user-related, policy related, technology-related) are still present causing a limited digitization of a paper-dominated industry. By inserting the previous research concerning the IT applications into this paper a clear examination is provided. The overall conclusion of this paper is for all stakeholders to significantly intensify their collaboration to digitize the dangerous goods shipments. Human error can only be diminished when human interaction is taken out of the equation, thus through digitization.

8.2. Recommendations

The impact of national or local initiatives are neglectable in the international shipping industry. It's the author's opinion that unilateral top-down enforcement is counterproductive. The only way human handling can be taken out of the process is through a very close sustainable cooperation between all private and public stakeholders on an international level. All shipbrokers and ship agents should, free of competitive interests, take a responsibility by using their global position to initiate standardization and harmonization. The safe shipment of dangerous goods is beneficial for all stakeholders and the world in general. We recently see some initiatives are being taken by some carriers, in for instance the formation of a Digital Container Shipping Association. These initiatives should be openly supported and encouraged by the public stakeholders.

All shore-side personnel already receives a training in accordance with paragraph 1.3.1 of the IMDG code. It's, to the opinion of this paper, deficient. All stakeholders should, in analogy with ADR/ADN/RID regulations, appoint a dangerous goods safety advisor(s) (DGSA). Who's duties are to facilitate the activities of the stakeholder in accordance with the requirements applicable and in the safest possible way (ADR/ADN/RID, paragraph 1.8.3.3). The DGSA must follow a mandatory training and examination every five years in order to proof their knowledge, thus ensuring all updates are taken into account.

8.3. Limitations

This paper is transparent in acknowledging the limitations of the work. The paper provides a literature and experience-based overview. It should be considered as the basic structure for future research. More and detailed research is required in the standard operating procedures of every stakeholder and possibilities of IT solutions.

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10. Appendix

10.1. Appendix A: Various forms of the DGD9

10.1.1. Excel

	Dangerous Goods Declaration / Dock Receipt			
		ELECTRONICALLY PREPARED		
Shipper / Exporter:		**Exporter / Shippers Ref:**		
		Additional Information:		
Consignee				
		Trucker / Carrier:		
	Booking Ref:	**SHIPPERS DECLARATION**		
		I hereby declare that the contents of this consignment		
Shipping Line:	**Port / Place of Loading:**	are fully and accurately described below by the proper		
MSC	TALLINN	shipping name, and are classified, packaged, marked		
VESSEL	**DESTINATION**	and labeled / placarded and in all respects in proper		
	ABIDJAN	condition for transport according to applicable		
		international and national governmental regulations.		
Marks / Numbers:	**Description of Packages and Goods**			**Tare Weight Kg**
	6 METRE ISO TANK T11	100L		3550
	SHIPPING NAME			**Net Weight Kg**
	GASOLINE			
	TECHNICAL DESCRIPTION			17000
	FUEL FOR AIRCRAFT PISTON ENGINES			
	CLASS 3			**Gross Weight Kg**
	UN 1203	condition for transport according to applicable		
	PACKING GROUP 2			20550
	MARINE POLLUTANT – YES			
	FLASH POINT - (-43C)			
I hereby declare that the goods described above		Received the above described goods or packages subject to all the		
have been packed / loaded into the container / vehicle		Terms of the undersigned's regular form of dock receipt and Bill of		
identified above in accordance with the applicable		Lading which shall constitute the contract under which the goods are		
provisions. MUST BE COMPLETE AND SIGNED FOR		Recieved. Copies of which are available from the carrier on request		
ALL CONTAINER VEHICLE LOADS BY PERSON		And may be inspected at any of its offices.		
RESPONSIBLE FOR PACKING / LOADING				
Load point / Company:			**Company preparing this note:**	
			Name of person preparing note:	
		Electronic Signature:	**Date / Status of declarant:**	

[9] All commercial or corporate sensitive information has been removed from these documents.

10.1.2. PDF (scan)

MULTIMODAL DANGEROUS GOODS FORM

This form meets the requirements of SOLAS 1974, chapter VII, regulation 5
Marpol 73/78. Annex III, regulation 4

1. SHIPPER	2. TRANSPORT DOCUMENT NUMBER
	3. Page 1 of 1 pages
	4. Shipper's reference KT
	5. Freight Forwarder's reference
CONSIGNEE	7. CARRIER
	SHIPPERS DECLARATION I HEREBY DECLARE THAT THE CONTENTS OF THIS CONSIGNMENT ARE FULLY AND ACCURATELY DESCRIBED ABOVE BY THE PROPER SHIPPING NAME(S) AND ARE CLASSIFIED, PACKAGED,MARKED AN LABELLED/PLACARDED, AND ARE IN ALL RESPECTS IN PROPER CONDITION FOR TRANSPORT ACCORDING TO THE APPLICABLE INTERNATIONAL AN NATIONAL GOVERMENTAL REGULATIONS.
8. This shipment is within the limitations prescribed for: PASSENGER AND CARGO AIRCRAFT CARGO AIRCRAFT ONLY	9. Additional handling information **PAINTS & PAINT RELATED MATERIAL** **Emergency phone number:**
10. Vessel 1 E	11. Port of loading ANTWERP
12. Port of discharge SHUWAIKH	13. Destination KUWAIT

14. shipping marks	Number and kind of packages, description of the goods (proper shipping name, hazard class, UN N°, packaging group)	NET (kg)	GROSS (kg)	Cube (m³)
	1) PAINT NAIL POLISH: 1 PG II 500 METAL TINS, 44 CARTONS UN 1263, PAINT, CLASS 3, FLASH PT - 4°	520 KG	580 KG	
	2) PAINT EASY COLOR GOLD PAINT(125ML, 250ML, 560ML AND 750ML PG III 4720 METAL TINS, 138 CARTONS UN 1263, PAINT, CLASS 3, FLASH PT 23°	1512 KG	1665 KG	
	3) PAINT RELATED MATERIAL: NAIL PLASTIC BOTTLE [illegible] PG II 5600 METAL TINS, [illegible] CARTONS UN 1263, PAINT RELATED MATERIAL, CLASS 3, FLASH PT -10°	2100 KG	2310 KG	

15. Container/vehicle identification	16. seal number(s)	17. Container size/type	Tare (kg)	Total gross (incl.tare) (kg)
579 873-0		20'	2220 kg	6.775,00 kg

CONTAINER/VEHICLE PACKING CERTIFICATE I hreby declare that the goods described above have been packed/loaded into the container/vehicle identified above in accordance with the applicable provisions.	21. Recieving organization receipt Received the above number of packages/containers/ trailers in apperent good order and condition, unless stated hereon:
20. Name of Company (Packer)	Haulier's name Vehicle Reg. No. Date Driver's Signature
	20. Name of Company (Shipper)

10.1.2. Image (handwritten + scan)

This form may be used as a dangerous goods declaration as it meets the requirements of SOLAS 74, chapter VII, regulation 5; MARPOL 73/78, Annex III, regulation 4.

1 Shipper/Consignor/Sender		2 Transport document number		
		3 Page 1 of 1 pages	4 Shipper's reference	
			5 Freight forwarder's reference	
6 Consignee		7 Carrier (to be completed by the carrier)		
		SHIPPER'S DECLARATION I hereby declare that the contents of this consignment are fully and accurately described below by the Proper Shipping Name, and are classified, packaged, marked and labeled/placarded and are in all respects in proper condition for transport according to the applicable international and national government regulations.		
8 This shipment is within the limitations prescribed for: (Delete non-applicable)		9 Additional handling information		
PASSENGER AND CARGO AIRCRAFT	CARGO AIRCRAFT ONLY			
10 Vessel/flight No. and date	11 Port/place of loading ANTWERP			
12 Port/place of discharge WALVIS BAY	13 Destination LUSAKA			

14 Shipping marks	Number and kind of packages; description of goods	Gross mass (kg)	Net mass (kg)	Cube (m^3)
UN1950	1x Steel Box containing 12x AEROSOLES (600ML) class 2.1	11,1	5,8	0,05152 m³

15 Container identification No./vehicle registration. No.	16 Seal number(s)	17 Container/vehicle & type	18 Tare mass (kg)	19 Total gross mass (including tare) (kg)
6003204		40' OT	3900	

CONTAINER/VEHICLE PACKING CERTIFICATE I hereby declare that the goods described above have been packed/loaded into the container/vehicle identified above in accordance with the applicable provisions.+ MUST BE COMPLETED AND SIGNED FOR ALL CONTAINER/VEHICLE LOADS BY PERSON RESPONSIBLE FOR PACKING/LOADING	21 RECEIVING ORGANIZATION RECEIPT Received the above number of packages/containers/trailers in apparent good order and condition, unless stated hereon: RECEIVING ORGANIZATION REMARKS:	
20 Name of company	Haulier's name Vehicle reg. no. Signature and date	22 Name of company (OF SHIPPER PREPARING THIS
	DRIVER'S SIGNATURE	

10.2. Appendix B: List of the dangerous goods classes

Classes	Definitions
Class 1- Division 1.1	Substances and articles which have a mass explosion hazard
Class 1- Division 1.2	Substances and articles which have a projection hazard but not a mass explosion hazard
Class 1- Division 1.3	Substances and articles which have a fire hazard and either a minor blast hazard or a minor projection hazard or both, but not a mass explosion hazard. This division comprises substances and articles: .1which give rise to considerable radiant heat; or .2which burn one after another, producing minor blast or projection effects or both.
Class 1- Division 1.4	Substances and articles which present no significant hazard This division comprises substances and articles which present only a small hazard in the event of ignition or initiation during transport. The effects are largely confined to the package and no projection of fragments of appreciable size or range is to be expected. An external fire must not cause virtually instantaneous explosion of almost the entire contents of the package.
Class 1- Division 1.5	Very insensitive substances which have a mass explosion hazard This division comprises substances which have a mass explosion hazard but are so insensitive that there is very little probability of initiation or of transition from burning to detonation under normal conditions of transport.
Class 1- Division 1.6	Extremely insensitive articles which do not have a mass explosion hazard This division comprises articles which predominantly contain extremely insensitive substances and which demonstrate a negligible probability of accidental initiation or propagation.
Class 2.1	Flammable gases
Class 2.2	Non-flammable, non-toxic gases
Class 2.3	Toxic gases
Class 4.1	Flammable solids, self-reactive substances, solid desensitized explosives and polymerizing substances
Class 4.2	Substances liable to spontaneous combustion
Class 4.3	Substances which, in contact with water, emit flammable gases
Class 5.1	Oxidizing substances
Class 5.2	Organic peroxides
Class 6.1	Toxic substances
Class 6.2	Infectious substances
Class 7	Radioactive material
Class 8	Corrosive substances
Class 9	Miscellaneous dangerous substances and articles (class 9) and environmentally hazardous substances

(IMO, 2018, p. part 2)

10.3. Appendix C: The segregation table

CLASS	1.1/1.2/1.5	1.3/1.6	1.4	2.1	2.2	2.3	3	4.1	4.2	4.3	5.1	5.2	6.1	6.2	7	8	9
1.1, 1.2, 1.5	*	*	*	4	2	2	4	4	4	4	4	4	2	4	2	4	X
1.3, 1.6	*	*	*	4	2	2	4	3	3	4	4	4	2	4	2	2	X
1.4	*	*	*	2	1	1	2	2	2	2	2	2	X	4	2	2	X
2.1	4	4	2	X	X	X	2	1	2	2	2	2	X	4	2	1	X
2.2	2	2	1	X	X	X	1	X	1	X	X	1	X	2	1	X	X
2.3	2	2	1	X	X	X	2	X	2	X	X	2	X	2	1	X	X
3	4	4	2	2	1	2	X	X	2	2	2	2	X	3	2	X	X
4.1	4	3	2	1	X	X	X	X	1	X	1	2	X	3	2	1	X
4.2	4	3	2	2	1	2	2	1	X	1	2	2	1	3	2	1	X
4.3	4	4	2	2	X	X	2	X	1	X	2	2	X	2	2	1	X
5.1	4	4	2	2	X	X	2	1	2	2	X	2	1	3	1	2	X
5.2	4	4	2	2	1	2	2	2	2	2	2	X	1	3	2	2	X
6.1	2	2	X	X	X	X	X	X	1	X	1	1	X	1	X	X	X
6.2	4	4	4	4	2	2	3	3	3	2	3	3	1	X	3	3	X
7	2	2	2	2	1	1	2	2	2	2	1	2	X	3	X	2	X
8	4	2	2	1	X	X	X	1	1	1	2	2	X	3	2	X	X
9	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

The numbers and symbols in the table have the following meanings:

1 - “away from”

2 - “separated from”

3 - “separated by a complete compartment or hold from”

4 - “separated longitudinally by an intervening complete compartment or hold from”

X - the Dangerous Goods List has to be consulted to verify whether there are specific segregation provisions

* - see 7.2.7.1 of this chapter for the segregation provisions between class 1 substances or articles

(IMO, 2018, p. 7.2.4)