Risk in Transporting Dangerous Goods via RoRo and RoPax Shipping

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1 Introduction

As the backbone of global and regional trade, the shipping industry processes roughly 75% of the world’s transport and adds tremendous value to society. Many of the goods moved at sea are dangerous, however, because they are liable to not only destroy water and coastline habitats but also cause a significant loss of health, life and property. At sea, moving *dangerous goods* (dg), defined as containing substances classified as dangerous in the applicable regulatory framework, is also a hazard for ships and their crews and passengers in particular since vessels are often far from land-based rescue services.

A large share of the dg shipped constitutes petroleum, in either crude or refined form and transported in tankers dedicated to the task, also referred to as *wet bulk shipping*. According to unctad,[[1]](#footnote-1) in 2019 fleets worldwide moved a total of 1.86 billion tonnes of crude oil and 1.31 billion tonnes of refined petroleum products, gas and chemicals. The supply chains that engage those tankers and thus connect wells, refineries and distribution depots in a network of ports are fully specialised in handling dg. Above and beyond that, the tanker shipping industry as a whole observes well-developed processes, including vetting procedures, to conduct the business of tanker shipping with a strict focus on safety.

Whereas moving hazardous fluids is the stuff of everyday life for personnel in wet bulk shipping, dry bulk shipping is far less associated with dg but can nevertheless involve transporting hazardous goods. According to unctad,[[2]](#footnote-2) 5.25 billion tonnes of dry bulk was shipped at sea in 2019 compared with 3.17 billion tonnes of wet bulk. Of such volumes, it is estimated[[3]](#footnote-3) that 100,000 tonnes of dry bulk could harm marine environments and that dg thus represent an overlooked threat in maritime transport. Although the contamination of water is the chief risk considered in both wet and dry bulk shipping, the loss of health and even life is also an apparent risk, as exemplified by the catastrophic explosions of large quantities of ammonium nitrate at the ports of Texas City in 1947, Tianjin in 2015 and Beirut in 2020.

dg are also transported in liner shipping—that is, shipping services with a fixed itinerary in the container, roll-on, roll-off (RoRo), roll-on, roll-off-passenger (RoPax) and cruiseferry segments for a broad spectrum of customers. RoRo vessels carry goods, typically loaded into trucks, semi-trailers or other load units, which are rolled on and off board via ramps. On short sea shipping (sss) routes,[[4]](#footnote-4) RoRo is dominated by semi-trailers and by containers on cassettes carrying various cargo. RoRo traffic also includes pure car and truck carriers (pctc s), which are primarily used for trans-continental shipping on behalf of the automotive and construction equipment industries. RoPax vessels, often dubbed *car ferries*, are adapted to transporting both freight and passengers. RoPax ferries are generally used on short routes, sometimes as so-called “bridge substitutes” with very high frequencies. When RoPax vessels transport both goods and passengers as well as provide significant leisure activities and shopping on board—they are also known as *cruiseferries*.

In either case, due to its wide variety of cargo, dg is less visible in liner shipping than in bulk shipping, and its risks pertain more to the loss of health, life and property than to water contamination. In 2019, the world’s rapidly growing container fleets transported 152 million Twenty-foot Equivalent Units (teu s)[[5]](#footnote-5) of containers,[[6]](#footnote-6) and from 5% to 10% of them declared dg.[[7]](#footnote-7) Consignments containing dg can range from, on the one hand, a carton of batteries on a pallet inside a trailer or an intermediate bulk container (ibc) with flammable chemicals consolidated with non-hazardous goods on a truck to, on the other hand, large specialised dg tank containers, semi-trailers, trucks and rail wagons. Any of those units can be consolidated with other cargo units on board liner vessels, some of which also carry passengers. In that light, liner shipping is not primarily designed to accommodate dg, which rarely constitutes more than a small fraction of the goods transported on a given vessel. For that reason, the crew members and other staff on such vessels are generally less experienced with safely handling dg than their colleagues in tanker shipping. The same goes for consignors, who are sometimes unaware of the myriad risks involved throughout the transport chain or even whether a consignment will be transported by sea after being retrieved by a truck.

Today’s society require dg to be transported while keeping such transport’s negative consequences at a minimum. For a vessel, the risk of a dg related incident correlates to the vessel’s size, because larger ships theoretically contain more dg consignments, each of which could, for example, start a fire. Beyond that, the potential consequence of any accident relates to the amount of cargo carried. Given that reality, the maximum size of tankers peaked already in the 1980’s, partly to mitigate the risk of large oil spills. However, dry bulk carriers and liner vessels have since been built in ever-larger dimensions. Far outgrowing tankers at present, the current generation of container vessels, at 400 m long and 60 m wide and carrying 24,000 teu s, now includes the biggest ships on the sea. Likewise, RoRo and RoPax vessels have also been built to bear considerably larger tonnages. For example, Cobelfret’s *mv Celine*, with 8000 lane metres[[8]](#footnote-8) and a gross tonnage of 74,000 delivered in 2017, can load more than 500 semi-trailers 13.6 m long. In fact, the sheer size of many liner vessels today implies that extinguishing a major fire on board would be extremely difficult, even if close to shore and with access to fireboats.

Because goods stuffed into load units, trucks and rail wagons in liner shipping remain visually invisible to load planners and stevedores, they require correct, timely information, as well as proper labelling if they contain dg,[[9]](#footnote-9) in order to be loaded safely and to avoid risky combinations of consignments in ports and on board,.[[10]](#footnote-10) [[11]](#footnote-11) The necessary information needs to be accurately collected already when the consignment is shipped from the consigner and be conveyed through the transport chain amid consolidation and modal shift. However, such is not always the case.[[12]](#footnote-12) After all, because transporting dg entails surcharges and restrictions, consignors and transport operators can be tempted not to properly declare dg.

As part of liner shipping, the container segment attracts most of the attention from not only researchers[[13]](#footnote-13) but also, news media outlets, most visibly in its routine depictions of foreign trade with images of containers’ being lifted onto ships. However, containers primarily move goods between continents, whereas most of the world’s trade, despite globalisation, remains regional. Although much of the intra-European trade is realised by trucks and trains, of the 3.35 billion tonnes loaded and discharged in EU ports in 2018, 1.16 billion tonnes, or 35%, was intra-EU trade.[[14]](#footnote-14) Whereas countries housing principal gateway ports, including Belgium and the Netherlands, report smaller shares of intra-EU goods, for ports in some peripheral countries—Denmark, Estonia, Finland, Latvia and Sweden—60% to 70% of goods, measured in tonnes, represent intra-EU trade. Even though much of that cargo comprises wet and dry bulk commodities, the latter countries are also especially extensive users of RoRo and RoPax services.

The empirical context addressed in this chapter is Northern Europe, particularly RoRo and RoPax shipping routes with one end in southern Swedish ports (*¡Error! No se encuentra el origen de la referencia*.). In that setting, RoRo and RoPax shipping are particularly prominent because the trade-intensive region’s geographical characteristics make RoRo and RoPax services pivotal for industry and citizens. In a comparison with bulk and container shipping, the RoRo and RoPax services are also far more adapted to particular routes than bulk and container shipping are, as well as more tightly embedded in the region’s transport chains. A special focus will be on RoPax services as regulations regarding dg are quite strict, because the presence of passengers on board significantly raises the potential consequences of accidents involving such goods.

Figure 9.1 Here

In the region, shipping involving dg is regulated by the International Maritime Dangerous Good (imdg) Code and the “Memorandum of Understanding for the Transport of Packaged Dangerous Goods on Ro-Ro Ships in the Baltic Sea”, nicknamed the “Baltic Agreement”. Both sets of rules cover the classification, packaging, marking, labelling, documentation, stowage and segregation of dg in packaged form for carriage by sea. In general, the imdg Code, drafted by the International Maritime Organization (imo), applies to the carriage of dg in packaged form on all ships.[[15]](#footnote-15) In the Code, “Dangerous goods” is divided into nine classes: 1. Explosives, 2. Gases, 3. Flammable liquids, 4. Flammable solids, 5. Oxidizing substances, 6. Toxic and infectious substances, 7. Radioactive material, 8. Corrosive substances, and 9. Miscellaneous. Containing more than a thousand pages, the imdg Code is extensive and details specific requirements for each type of substance, organised by class and UN number.[[16]](#footnote-16) The Swedish Transport Agency has incorporated the imdg Code into its regulations.

The multilateral Baltic Agreement between Denmark, Germany, Poland, Finland, Estonia, Latvia, Lithuania and Sweden regulates the transport of dg in packaged form. Under certain circumstances when operating in the Baltic Sea and parts of Kattegat on Sweden’s western coast, RoRo and RoPax vessels can opt to follow the Baltic Agreement instead of the imdg Code.[[17]](#footnote-17) That allowance intends to not only facilitate the transport of dg on RoRo ships by departing from the rules that normally apply under the imdg Code but also better align requirements with regulations for transport via road (“European Agreement Concerning the International Carriage of Dangerous Goods by Road”, or adr) and rail (“Regulations Concerning the International Carriage of Dangerous Goods by Rail”, or rid). Similar to the imdg Code, the adr and rid are also extensive sets of regulations, each totals approximately 1300 pages. The adr and rid regulations apply for all of Europe. To a large extent, the adr and rid regulations can also apply to sea transport under the Baltic Agreement, which reduces the need to modify documentation, labels and markings etc. It moreover simplifies and expedites the transfer of cargo between modes on the fairly short sea voyages in the region. The simplifications are warranted by shorter distances and lower wave heights, where the greatest simplifications are offered to ships operating in low wave heights areas.[[18]](#footnote-18)

Against that background, the purpose of this chapter is to examine how regulations for dg applicable to RoRo and RoPax shipping in Northern Europe affect transport chain operations and the overall risk of transport. It also explains the general structure and operations of RoRo and RoPax shipping for readers familiar with law but not necessarily with logistics or shipping.

The chapter is structured as follows. This introductory section has set the scene and scope of the chapter, as well as briefly introduced dg-related regulations for RoRo and RoPax shipping in Northern Europe. Next, Section 2 elaborates upon RoRo and RoPax shipping with a focus on the consolidation of freight and passengers, followed by an overview of dg flows in the region in Section 3, supported by statistics on the amount of dg processed in Swedish ports. After that, Section 4 provides an overview of approaches to handling dg in transport chains, followed by a discussion and conclusions in Section 5 concerning some regulatory issues with implications for logistics.

2 RoRo and RoPax Shipping

When geographical and trade conditions are favourable for sss, a great deal of cargo tends to be rolled onto quays instead of lifted over them. Because the RoRo principle accommodates highly efficient handling at ports, albeit at the expense of less densely loaded ships, it has become widely adopted at ports worldwide. Japan registered 35,000 port calls with RoRo ships in 2019, the United Kingdom registered 16,500, the Netherlands 12,500, Spain 11,500 and Italy 9500, for 191,000 port calls altogether, or 4.4% of all calls that year.[[19]](#footnote-19) RoRo accounted for fewer port calls than container ships (10.9%), tankers (13.6%) and dry bulk carriers (6.4%), and global RoRo statistics represent not only RoRo with sss but also pctc shipping. Even so, RoRo shipping is widely used in the Nordic countries, in the United Kingdom and Ireland[[20]](#footnote-20) and in Sub-Saharan Africa.[[21]](#footnote-21) Ports in the EU-27—that is, excluding the United Kingdom—handled 377 million tonnes of rolling cargo in 2018, mostly at Calais (18.4 million tonnes), Dublin (13.8), Zeebrügge (13.4), Lübeck (12.8), Rotterdam (11.9), Trelleborg (11.2) and Gothenburg (9.5).[[22]](#footnote-22) Because RoRo and RoPax vessels used in sss are typically deployed on direct routes between two ports, dividing those statistics in half reveals that some 188 million tonnes of goods were carried in RoRo units in the EU-27 in 2018. Because several of the largest RoRo flows pertain to the United Kingdom, however, figures for the EU-28 before Brexit were larger than today’s.

For various reasons, freight-only RoRo shipping is used more in Europe than in East Asia, which relies far more on containers for intra-Asian trade, complemented with RoPax ferries. These are used on shorter routes as bridge substitutes with high frequency. As a result, passenger ships accounted for as much as 55% of all port calls worldwide in 2019, with Norway leading the pack, followed by the United States and Italy. unctad[[23]](#footnote-23) has also reported intense passenger traffic in the Baltic and East Mediterranean Seas and in South East Asia’s extensive archipelagos. All told, of the world’s 915 RoRo cargo ships and 2394 passenger and RoPax ships in 2019, 279 (30%) and 691 (29%) vessels, respectively, belonged to the EU-27.[[24]](#footnote-24) Measured in deadweight, 52% of the world’s RoRo vessels (3.80 of 7.30 million tonnes) and 34% of its passenger or RoPax vessels (2.27 of 6.61 million tonnes) belonged to the EU-27 and those statistics only include vessels with gross tonnage exceeding 1000. Counting all ships exceeding 300 gross tonnes but limited to passenger, cargo and RoPax ships in the EU-27 plus the United Kingdom, the EU-28 accounted for 27% of vessels and 49% of deadweight tonnage in 2018.[[25]](#footnote-25)

RoRo and RoPax shipping are typically links in intermodal transport chains, which involve using different traffic modes for goods from consignors to consignees. By definition, *intermodal transport* is “the movement of goods in one and the same loading unit or road vehicle, which uses successively two or more traffic modes without handling the goods themselves in changing modes”.[[26]](#footnote-26) In such transport, goods are packed into a load unit—for instance, a maritime container or semi-trailer—to facilitate efficient trans-shipment between modes. In RoPax shipping, however, trucks also act as load units. From the perspective of shipping lines, load units constitute consignment for the shipping lines, although each unit also may contain smaller sub-consignments where freight forwarders consolidate numerous shipments from different shippers in the same load unit for transport efficiency.[[27]](#footnote-27) From the shipping lines perspective, a consignment is thus largely synonymous with what many shipping lines refers to as an *article of transport*: “any vehicle, train, carriage, container, flat, pallet, trailer, transportable tank and similar items used for the consolidation of Goods as well as timber packages”.[[28]](#footnote-28)

2.1 RoRo

To gain the inherent benefits of low-cost, high-capacity, energy-efficient shipping, medium-distance sss routes primarily use RoRo cargo vessels designed to move rolling cargo.[[29]](#footnote-29) In Northern Europe, such routes connect industrial regions in the British Isles, Benelux and Scandinavia, where they target large shippers in the forest, steel and automotive industries. Although not as frequent as RoPax services, the transport frequency offered by RoRo vessels generally exceeds what each shipper could achieve by using bulk or specialised shipping. Each route typically has a dominant shipper that offers long-term base volumes and can thus stipulate departure times and frequencies, where the high frequency is supported by other shippers that help fill up the vessels. For example, in a case study, Christodoulou[[30]](#footnote-30) found that cost-sharing and high-frequency in commercially “open” services were greatly appreciated by the forest product firm Stora Enso, the chief shipper on the Gothenburg–Zeebrügge route.

In RoRo shipping, the primary units of transport are semi-trailers, which are transported to and from ports by road by semi-trailer trucks. At ports, semi-trailers are disconnected from trucks and loaded onto ships with a small terminal tractor called a *tugmaster*. Because the truck drivers do not travel with the ships, the semi-trailers are *unaccompanied*. RoRo vessels also transport goods packed into maritime containers that are loaded onto rolling platforms called *cassettes* or *roll trailers* (e.g. mafi trailers) and thus towed aboard ships. Cars, trucks, construction equipment and over-sized cargo that is driven or towed aboard are other commonly transported items. A few RoRo ships are even equipped with a rail track and can thus carry rail wagons. In any case, each transport or terminal service in the transport chain is retailed directly to large shippers and forwarders, one type of which specialises in RoRo shipping and offers full or part load transport in a certain trade lane, for instance between Benelux and Scandinavia. Consignments in RoRo shipping are rather large and dominated by semi-trailers filled with a single commodity and part loads, although some semi-trailers are packed with general cargo and parcels that are consolidated in a terminal. To shipping lines, however, all semi-trailers containing dg,[[31]](#footnote-31) hence also those with embedded dg sub-consignments, have to be treated as dg consignments. To rescue services and in terms of risk, any vessel carrying dg consignments is regarded as a dg super-consignment.

Figure 9.2 shows a characteristic transport chain involving RoRo shipping. One semi-trailer is fully loaded with dg, while another is loaded with a mix of general cargo and dg, thus with dg transported as a part load together with non-dg. The shipping line’s stowage planners thus need information in advance to organise the placement of dg on board and identify what loads need to be separated for safety.

Figure 9.2. Here

2.2 RoPax

RoPax ferries, by contrast, catering to both freight and passengers at once, are often used on short routes with a significant demand for passenger transport. Typically seeking the shortest possible crossings, hence the nickname “bridge substitutes”, RoPax ferries offer their services to a truly wide set of customers and, as Woxenius[[32]](#footnote-32) has stated, “virtually anything allowed on the road is accepted, perhaps excluding lorries with hazardous cargo on ships with passengers, and passengers without a vehicle can walk on board” (p. 252). RoPax ports are often located in city centres for passengers’ convenience, whereas RoRo ports are generally part of pure freight ports located outside such densely populated areas. As a consequence, the risk of handling dg in port operations is a greater concern for RoPax ports than for their RoRo counterparts.

In RoPax shipping, consignments can be either towed semi-trailers or trucks that are loaded aboard ships by drivers accompanying them on board. Some RoPax ferries accept rail cars and are equipped with tracks. On RoPax vessels, shipping acts a sub-contractor to land-based traffic modes and ferry crossings are bundled with road or rail haulage and wholesaled as a door-to-door transport service to shippers and forwarders. Somewhat longer RoPax services, in line with the all-freight RoRo services, also accept unaccompanied semi-trailers, maritime containers and over-sized cargo.

In general, the number of transport customers are greater in RoPax than in RoRo. As an example, Figure 9.3 shows a transport chain with general cargo being retrieved by drivers with vans or smaller trucks and cross-docked in a consolidation terminal. Another driver uses a larger long-distance truck to transport the goods to the port, drives it onto and subsequently off the RoPax ferry and, in turn, to the receiving consolidation terminal. After another cross-docking operation, a new set of drivers uses vans and small trucks to deliver the sub-consignments to the consignees. Forwarders offer that transport service to a multitude of shippers, although a few large shippers (e.g. retail chains and e-commerce firms) organise it themselves. Although the figure depicts a rather complex way of transporting small sub-consignments, many trucks on board RoPax ferries constitute full and part loads similar to all-freight RoRo.

Figure 9.3 Here

In both RoRo and RoPax shipping, ports and shipping lines need to assess the risk and require that drivers notify them in advance of hazardous substances and the amount of all dg consignments.[[33]](#footnote-33) From an operational standpoint, dg are placed on the weather deck, if available, and are sometimes restricted to certain departures with fewer or no passengers on board.

3 Dangerous Goods in RoRo and RoPax Shipping

Having described the transport system involving RoRo and RoPax shipping, the chapter now narrows its empirical focus to dg and Northern Europe, with statistics and estimates of shares of dg limited to shipping services using ports in West and South Sweden.

The intensive use of RoRo and RoPax shipping for trade in Northern Europe implies the potentially intensive transport of dg. Zachcial[[34]](#footnote-34) has identified dg as particularly suitable to unitisation, implying that RoRo shipping indeed captures flows from dg bulk shipping. At the same time, he found that RoRo shipping could benefit from “growth by constraint” (p. 43); because road transport had become increasingly restrictive and liable to impose particularly stiff constraints on dg, RoRo shipping was likely to benefit as a result. Nevertheless, regulations regarding dg were also identified as hindering the development of sss.

In a study based on interviews with 2500 truck drivers in Sweden’s southern and western ports completed in 2016 and 2017, the Swedish Transport Administration[[35]](#footnote-35) found that, on average, some 4.3% of road vehicles displayed dg signage, as required by regulations for vehicles carrying dg. However, this does not show how much of each vehicle load that was dg. Because the interview study in the ports provides a snapshot from 2016–2017 only, it remains difficult to estimate the current share of dg transported by RoRo and RoPax. As a comparison, for domestic all-road transport in Sweden, Transport Analysis and Statistics Sweden[[36]](#footnote-36) reported that 2.0% (i.e. 9 of 449 million tonnes) of all goods moved by heavy trucks (>3.5 tonnes) in 2019 was dg. For Swedish domestic rail transport, 4.9% (i.e. 3.6 of 73 million tonnes) was dg.[[37]](#footnote-37) Trafikanalys and Statistics Sweden, also reported that the transport of dg in tonnes from 2014 to 2019 had decreased by 40% for road[[38]](#footnote-38) but increased by 10% for rail, even though total tonnekm dropped by 10% for rail.[[39]](#footnote-39) Transport Analysis and Statistics Sweden[[40]](#footnote-40) have not reported the share of dg in maritime traffic exclusively, although a gross share would be largely irrelevant for studying RoRo and RoPax shipping anyway, because most dg are moved by wet bulk shipping. For shipping in general, crude oil and petroleum products accounted for 53 of 170 million tonnes (31%) of turnover in Sweden’s ports in 2019.

The Swedish Transport Administration[[41]](#footnote-41) also shows that flows of dg through Sweden’s western and southern ports were somewhat unbalanced in 2016–2017, for 4.7% of inbound but only 4.1% of outbound vehicles were marked with dg signage. Significant differences from port to port arose as well, as detailed in Table 9.1. Drivers using ports for RoPax shipping as bridge substitutes reported a smaller share of dg: 3.0% for outbound flows, 3.7% for inbound flows and 3.2% overall. The imbalance between some ports was remarkably large, notably for Stena Line’s Gothenburg–Kiel route with 16% of dg reported for outbound flows but none for inbound ones. By comparison, the share of dg was far higher in freight-only RoRo to or from Gothenburg, at 13% in both inbound and outbound flows. As an alternative, using the Øresund Bridge, the fixed connection between Malmö and Copenhagen, attracts more dg than nearby RoPax options: 9% for Danish trucks, 7% for Swedish ones and 7.5% overall.

Table 9.1 Here

The data supporting the estimates in Table 9.1 represent vehicles with dg signage and thus include trucks only partly transporting dg. Of course, trucks and semi-trailers may carry dg without carrying the correct signage, in violation of regulations.[[42]](#footnote-42) The various RoPax routes offered at the ports examined in the interview study are also used by a significant number of passengers, with passengers travelling to and from Sweden in 2019 totalling 10.2 million for Denmark, 2.17 million for Germany, 1.61 million for Norway and 0.96 million for Poland.[[43]](#footnote-43)

4 Approaches to Moving dg in Transport Chains

For further analysis, we used a framework developed by Woxenius and others[[44]](#footnote-44) for the handling of goods requiring special attention in transport chains. The framework can be applied to not only dg but also theft-prone, oversized, temperature-controlled and/or fragile goods as cargo requiring special attention. Following the framework, transport planners need to determine whether any links of the transport chain restrict the conveyance of dg (e.g. tunnels and ferries) and choose an appropriate approach from the six principally different approaches outlined. Planners should also recognise that the lack of proper handling equipment or authorised personnel can also restrict the transport of dg.

When dg are presented in any transport setting, the first approach—to *deny transport*—implies that the dg are simply not accepted for transport. By contrast, to *apply brute force* means that the forwarder or the transport chain’s first link has allowed the dg to enter the chain without regard for potential problems at subsequent links. If a link is only temporally restricted, then the transport planner has the option to *postpone goods* and dispatch them to arrive at the particular link when no physical, capacity-related or regulatory restrictions limit their transport. If the restriction is not only temporal, then the planner can opt to *divert goods* to follow a non-restricted path. Another alternative to divert goods, to *use an* *alternate link*,involves substituting the problematic link and later allowing the dg to return to their original route. Last, to *transform goods* implies altering the properties of dg to permit their reclassification as non-dg. The framework’s six approaches are illustrated in Figure 9.4.

Figure 9.4 Here

4.1 Deny Transport

From the perspective of shipping lines, the easiest way to manage the risks associated with dg is to simply prohibit their transport. However, such restrictions would negatively impact the market, because the RoRo–RoPax segment of the shipping industry is typically part of intermodal transport chains. Although the share of dg may be relatively low, the same customers not only often transport both dg and non-dg but also rarely separate them in their planning and operations of their transport system. In short, denying dg risks entirely losing certain customers. Transporting dg is seldom regarded as a particularly profitable segment of RoRo and RoPax shipping but offered as a service to retain customers. In parallel, ferry services that substitute for bridges play an infrastructural role that benefits society and often enjoy subsidies, or at least reduced taxation, and thus cannot discriminate goods based solely on an individual segment’s profitability. Nevertheless, to recover additional costs, ports and shipping lines typically impose surcharges for dg and state in their conditions of carriage that the imdg Code or, if applicable, the Baltic Agreement should be followed. However, restrictions can apply to specific classes of cargo. For instance, a significant difference exists between, on the one hand, RoRo ships that carry highly limited numbers of passengers and, on the other, RoPax and cruiseferries that can carry thousands of them.[[45]](#footnote-45) RoPax ferries also face stricter regulations that prohibit the transport of several classes of dg, particularly if stored under deck. Whereas many RoPax ferries today are built with limited storage capacity on their weather decks, normally far aft, it is common for older cruiseferries to have under-deck storage only, which restricts the transport of dg. The design and type of ships used on a given route may therefore cause two seemingly similar routes to allow different types of dg.

dg may also be denied transport for practical reasons, including limits on the volume of dg that may be carried on a particular departure without violating regulations, for example, concerning the stowage and separation of dg. In that case, the consignment would not be entirely denied but referred to another departure. The transport of dg therefore typically needs to be booked well in advance to allow the shipping line to prepare stowage plans and thereby guarantee transport. Added to that, transport can be denied due to regulations against certain classes of dg in RoPax ports located in city centres. Conditions of carriage also often stipulate that dg should be removed from the port of discharge as soon as practicable, see for instance the General terms of Stena Line.[[46]](#footnote-46) This practice decreases risk of accumulating dg in the port but may also relate to limited capacity of the port’s dg storage area, as space is often limited in city terminals.

Most often, the approach of denying transport does not halt transport in its tracks but redirects it to one of the other five approaches for handling dg in transport chains outlined in Figure 9.4. Although the adaptations required to accommodate another approach usually increase transport costs, the need for such modifications can also in a long-term perspective prompt structural changes, for heightened costs may incentivise transport customers to redesign their supply chains by, for instance, replacing suppliers, stop serving customers, relocating facilities or discontinuing products classified as dg that require complicated transport.

4.2 Apply Brute Force

For transport customers, shipping dg via Northern European RoRo or RoPax comes with surcharges of approximately 100 eur per load unit, as well as added administration and operational restrictions. Beyond that, road and rail transport operators typically add surcharges for transporting dg over land. As a consequence, such disincentives can tempt customers to ship dg in a transport chain without regard for regulations. For customers, misdeclaring the consignment is a simple way of applying brute force. After all, simply not informing the forwarder, road haulier, port and/or shipping line that a consignment contains dg can lower costs and increase the flexibility of transport. However, not declaring dg also presents increased risks in transport,[[47]](#footnote-47) as evident by several recent fires on container ships, some of which were caused by misdeclared dg.[[48]](#footnote-48) Most notably, the 2018 fire on the *Maersk Honam* claimed the lives of five crew members and caused damages worth 500 million usd, including 30 million usd for vessel repairs.[[49]](#footnote-49) Although the accident report[[50]](#footnote-50) did not conclusively determine the cause of the fire, the accident has since been unofficially attributed to a shipment of sodium dichloroisocyanurate dihydrate.[[51]](#footnote-51) The Maritime Executive[[52]](#footnote-52) has identified a particular risk in that the imdg Code relies on chemical manufacturers to self-certify the characteristics of their products and, citing a salvor, has called for “accurate testing, and not just 50 gram samples in a laboratory setting”. Taking action to mitigate casualties and damages in light of recent container fires at sea, shipping lines such as Evergreen have begun levying fines as high as 35,000 usd per misdeclared container.[[53]](#footnote-53) Several RoRo/RoPax shipping lines also apply strict terms, including about the compensation of costs related to misdeclared goods, such as rules issued by tt-Line[[54]](#footnote-54) for the Trelleborg–Travemünde RoPax route and the clarification by dfds[[55]](#footnote-55) that passengers are responsible for indemnifying dfds for costs “whether or not the passenger was aware of the nature of the goods” (p. 8).[[56]](#footnote-56)

Although no major accident related to misdeclared dg has occurred on RoRo or RoPax ferries in Northern Europe, the consequences of a cargo fire on any RoPax ferry with 2000 passengers could be disastrous. Although not caused by dg but by arson, the 1990 fire on the cruiseferry Scandinavian Star operating between Norway and Denmark, which killed 158 passengers and crew members—out of 383 and 99 respectively—illustrates the danger related to fire on board RoPax vessels.[[57]](#footnote-57) In addition to this, the risk of being caught misdeclaring goods is quite low. Goods inside a unit load, (e.g. semi-trailers and containers) cannot be seen from the outside, and the number of inspections by authorities is limited. According to Carlsson,[[58]](#footnote-58) the manager of marketing and sales at the Port of Karlshamn, the port cannot search for un- or misdeclared goods inside semi-trailers, which makes consignors’ faithful declarations of cargo a critical component in minimising risks. In most cases, cargo accepted at a port is also accepted on board ships, even if the shipping line’s terms and conditions[[59]](#footnote-59) afford the rights to conduct inspections.

Although the extent of misdeclared goods remains unknown, it continues to be regarded as a significant problem in the shipping industry.[[60]](#footnote-60) Of course, shipping lines maintain the right to inspect the contents of containers; however, the investigation team in the case of the *Maersk Honam* fire[[61]](#footnote-61) noted that “the current cargo screening process in the industry is not able to ensure declarations by shippers, which are based on trust, match the description of the cargo in the container, as such a process could be too onerous and labour-intensive if carried out manually” (p. 91). Making matters worse, transport companies face commercial constraints in transporting dg and have incentives to “bend the rules” in order to accommodate customers and maintain their businesses.

4.3 Postpone Goods

The regulations limiting dg on RoPax ferries have caused some shipping lines to divide their departures into two types—namely, passenger departures and freight departures—the latter of which limit the number of passengers on board to make room for particularly dangerous classes of dg onboard. In that case, the affected dg are often delayed to freight departures occurring late at night when passenger demand is low. Similarly, shipping lines can operate RoRo and RoPax ships in parallel on the same route and simply refer dg to RoRo vessels. The decisions are usually made for commercial reasons to maximise each departure’s revenue, and for example tt-Line[[62]](#footnote-62) reserves the right to reclassify departures between freight and passenger services on short notice and acknowledges that doing so can activate restrictions regarding dg. As a related example, dfds began diverting truck drivers using the Karlshamn–Klaipeda RoRo departure to the parallel RoPax departure as a means to mitigate a shortage of cabin capacity when the covid-19 pandemic required limiting the number of drivers allowed to share a cabin on the RoRo vessel from four to two.[[63]](#footnote-63)

The division into freight and passenger departures can also be imposed for the public welfare, as in the case of domestic ferries to the Swedish island of Gotland, whose population of 60,000 has no bridge connecting their communities to the mainland. Traffic for such ferries is publicly procured by the Government of Sweden and receives subsidies to, among other things, offer departures that accept dg.[[64]](#footnote-64) Last, postponement can also occur when a departing ship has reached its maximum capacity for dg, which can further incentivise consignors to use brute force to avoid waiting for the next dg-friendly departure.

4.4 Divert Goods

With different route options affecting driving and resting times, as well as costs and risks, planning long-distance road transport is rather complex.[[65]](#footnote-65) If a shipping link does not accept dg and postponement is undesirable, then the forwarder, haulier or consignor may choose a different route to the consignee. Often, such a route is by road. RoRo and RoPax shipping in Northern Europe is particularly sensitive to a direct modal competition, because an alternative land route or combination of land and sea routes is often available. For example, from Sweden’s western coast to Belgium or from southern Sweden to Germany and Poland, shippers have land-based options via the Øresund Bridge and Denmark, and modal competition is likely to stiffen once the Fehmarn Belt connection is opened.

Diverting goods thus often includes a modal shift from shipping to road or rail that also diverts the risks of transporting dg for shipping lines. However, ranked among sss’s strengths, Paixão Casaca and Marlow[[66]](#footnote-66) identified shipping’s high levels of safety in transporting dg and its removal of dg from roads. In that light, diverting dg from shipping to another more dangerous traffic mode may well increase the aggregated risk in the transport chain. On top of that, that sort of modal shift undermines political initiatives of transferring freight from road to sea for environmental reasons and to reduce congestion.

Diversion to other shipping routes with fewer constraints can also occur—for example, across the Baltic Sea—if land-based options for transport are limited. Another reason for diverting dg consignments is to better utilise the allowed driving times under the driving time regulations for road transport. It might be preferable to continue driving to another RoPax port with a suitable departure allowing dg instead of waiting at the current port for such a departure. In that scenario, regulations concerning driving times for truck drivers are significant factors, for certain routes or departures may better accommodate required periods for rest. Road transport driving times are regulated where drivers are required to take breaks and overnight rest after driving a certain time. It is desirable that a ferry departure match with when the driver is required to take a break.

4.5 Use an Alternate Link

Similar to diverting goods, using an alternative link allows bypassing a restrictive shipping link, after which the transport can return to the original route. A notable example of such a link is the Øresund Bridge between Sweden and Denmark, which offers both road and rail connections alongside several RoPax services running more or less in parallel. When it comes to dg, The Øresund Bridge[[67]](#footnote-67) imposes no additional charge and, in following adr regulations, imposes only some dg restrictions due to the fixed link’s tunnel.[[68]](#footnote-68) The Swedish Transport Administration[[69]](#footnote-69) has asserted that the high proportion of dg (i.e. 7–9%) via that fixed connection stems from more dg-restricted departures for RoPax shipping.

Another alternate link could be a shipping service operating with other types of ships—for instance, using a RoRo vessel instead of its more heavily restricted RoPax counterpart. It might be due to larger overall demand for dg transport on the particular trade lane rather than rerouting from RoPax routes, but the Swedish Transport Administration[[70]](#footnote-70) also found a much higher proportion of dg—13% in both directions—for the terminal Gothenburg roro handling unaccompanied RoRo between Sweden, UK and Belgium. In a notable example of redesigning a link, in 1993 a RoPax route between Turkey and Italy was replaced with a RoRo route along with a dedicated flight for truck drivers operating between airports close to the ports. The reasons for the switch included not only lower operational costs and convenience for drivers but also relaxed regulations regarding dg.[[71]](#footnote-71)

4.6 Transform Goods

Regulations stipulating in detail how dg should be transported impact which classes of dg can be loaded and transported together. However, regulations are less stringent for limited and excepted quantities of dg. By adapting to these and other regulations, transport customers can transform their consignments to enjoy less restrictive regulations, including by sending cargo in small quantities (i.e. dividing each consignment into several sub-consignments) or by not packing two conflicting classes of dg in the same consignment. Such strategies reduce risk but require greater competence and planning by transport customers or their forwarders. At the same time, part of the planning also falls to the shipping line, which in their stowage planning and allocation of cargo between various departures and vessels can help to “transform” the goods, so to speak, and thereby allow more dg to be transported. That type of planning, although typically already part of most shipping lines’ operations as a way to maximise revenue, requires striking a balance between meeting customers’ needs (e.g. preferred departures) and optimising operations and revenue. A further challenge for the approach is that data about consignments are not known in advance. Deadlines for booking transport of dg are set relatively early, ranging from a few hours but more often 24 hours prior to departure, to allow time for stowage planning.[[72]](#footnote-72) Even then, customers cannot know what dg other customers plan to transport on the same vessel, while shipping lines cannot know what additional bookings to expect.

All six approaches compared, applying brute force option exerts the most negative impact on safety as well as directly violates regulations. As for the other five approaches, all of which observe regulations, denying transport is largely chosen on legal grounds as it for commercial reasons is less attractive to turn away customers, particularly considering that most customers transport more than simply dg. Beyond that, when regulations prohibit the transport of dg in its current form, transport operators can turn to the four other approaches, all geared towards completing transport with as little disturbance and additional cost as possible. From a short-term perspective, that decision is largely an operational one. However, across a longer time frame, such trends may prompt structural changes to supply chains in order to avoid disruptive links.

5 Dangerous Goods Transport is Part of a Complex Transport System

Regulations about transporting dg on RoRo and RoPax vessels can impact supply chain operations by forcing transport customers to postpone or reroute consignments. In general, the six approaches described in the previous section, except for applying brute force, help to raise safety as the rerouting is caused by shipping’s inability to meet the required safety standard for that specific transport. Nevertheless, shipping is generally regarded as a safer traffic mode than road.[[73]](#footnote-73) As a consequence, however, the modal shift towards road due to some rerouting options can be negative. Reducing rerouting towards road by improving shipping’s ability to meet the needs of transport customers thus stands to increase the safety of transport overall.

From a societal perspective, the aim should be to minimise the risk of significant accidents involving dg. There are many definitions of risk, as elaborated on by Mullai[[74]](#footnote-74) and Ellis and others[[75]](#footnote-75) most centre around three factors: What can happen? How likely is it to happen? If it does happen, then what are the consequences? From a logistics perspective, the likelihood is the factor that can be most influenced. What can happen and the consequences are mainly tackled by the regulations by setting requirements on packaging, stowage and separation. However, the likelihood is influenced by the actors’ behaviour, most notably how well they comply with the regulations, as long as they are adequately designed, but also by how the supply chain is designed.

Although the regulations discussed in this chapter have been established to improve safety in shipping, overly strict, complicated regulations also raise the risk that consignors, whether knowingly or not, choose to apply brute force. In response, more accommodating rules, including the Baltic Agreement’s allowing RoRo and RoPax shipping under certain conditions to follow adr regulations instead of the more demanding imdg Code, contribute to reducing such “hidden” dg. In turn, simplified rules can boost safety by increasing shipping’s attractiveness and making dg more visible to shipping lines, assuming that the simplifications are appropriately designed. As the adr and imdg Code, though rather similar, contain different requirements, the Baltic Agreement reduces or sometimes eliminates the need for consignments to follow different regulations in each link of the transport chain. In the Baltic Agreement, the simplifications take their starting point in the lower wave heights in the area, which allow more lenient requirements than in transoceanic shipping performed under potentially far more adverse conditions. They also partly target administrative procedures, including about labelling load units. In intermodal supply chains, where efficient shipment between traffic modes is critical, the reduced administrative burden consequently has a positive effect on RoRo and RoPax competitiveness.

In Northern Europe, as this chapter has shown, RoRo and RoPax shipping lines often form only a minor part of the transport chain, one not only embedded in a road transport service but also subject to competition from land-based transport options. A good example is the 4-km Helsingborg–Helsingør route, which takes only 20 minutes on RoPax vessels that depart frequently throughout the day. Such circumstances separate those modes from other parts of the shipping sector—for example tanker, dry bulk and intercontinental container shipping—that form a far larger, central part of the supply chain and both require and can support tougher regulations. In a more extreme example, services via smaller domestic road ferries in Sweden,[[76]](#footnote-76) always operating close to shore, are allowed to follow adr regulations instead of the imdg Code or the Baltic Agreement, albeit with a few added requirements regarding vessel operation and the master mariner’s qualifications. From the standpoint of logistics, those simplifications are positive because they ease operations. Even so, all RoRo and RoPax shipping lines in the region did not choose to follow the Baltic Agreement, which is most popular on routes in low wave heights areas that enjoy the greatest simplifications.[[77]](#footnote-77)

In any case, compliance with regulations requires knowledge and understanding among all parties in the transport chain. For one, consignors need to know that consignments should be transported by sea and what regulations should be followed to ensure safe transport. At the same time, personnel who prepare consignments for transport are not necessarily aware that sea transport will be involved, which may be decided later in the transport chain or not even communicated to the consignor.[[78]](#footnote-78) That lack of coordination poses a special challenge for intermodal chains involving only a small share of sea transport, particularly when consignments are diverted or postponed or when alternative links are used, which can require following somewhat different regulations.

Any logistics system can also be viewed from a short-term operational perspective, a midterm tactical perspective and long-term strategic perspective. Typically, designing a supply chain’s overall structure is a long-term decision considering factors such as where factories and warehouses are located, which suppliers to use and which customers to serve. In turn, those high-level, strategic decisions determine overall transport flows and are often maintained for years. In the midterm, the transport system is a consequence of that framework and determines how transport is conducted, for instance which transport operators and traffic modes to use. Although transport systems can be periodically reviewed, because the workload involved in redesigning systems—for instance, finding new transport operators and negotiating contracts—they tend to be rather stable for a few years. From a short-term perspective, operational decisions address how to perform day-to-day transport, including about what to do when a ferry is fully booked, during a labour market conflict in a port or during congestion on a road section. Those low-level decisions are often made by drivers or transport planners.

Even though regulations target operations, they are also considered by corporate decision makers from a tactical and strategic level but then from a more general perspective, for example if extra transport costs are incurred. Whether or not corporate decision makers are familiar with regulations about transporting dg in any detail, their strategic decisions typically have far-reaching, long-term impacts for large flows of goods. It is noteworthy that a large share of the decisions impacting transport safety has already been made long before each specific instance of transport and often with limited consideration for the impact of regulations. It is therefore important that risk associated with transport of dg is given sufficient consideration also at the strategic and tactical level.[[79]](#footnote-79)

A long-term perspective should also be taken in designing ships for transport, because RoRo and RoPax vessels typically operate for 30 to 40 years. They can be lengthened by adding sections, and if transferred to new routes, then RoPax vessels in particular are often rebalanced regarding space for cabins, restaurants, shops and entertainment,[[80]](#footnote-80) even if possibilities for major reconstruction are limited. Thus, ship designers need to estimate the long-term demand for transport on routes and balance that demand against current and expected regulations to determine the best designs. A design that, for example, limits the possibility to store dg on deck will impact the transport system for decades. Indeed, RoPax ferries cater to both freight and passenger transport at the same time, which are different target markets with starkly different requirements.

In the Baltic Sea, RoPax shipping previously targeted passenger transport fuelled by tax-free shopping that was permitted as the ships crossed international borders. The dominant ship design was the cruiseferry, built to offer passengers on-board leisure opportunities with restaurants, bars, spas, cinemas and tax-free shopping. Some passengers did not even disembark upon reaching the destination but simply returned on the same ship. However, when most countries in the region joined the European Union in the late 1990s and early 2000s, the possibility of tax-free shopping disappeared, which changed the focus towards freight transport that began generating the bulk of the income. That shift can be seen in ship designs, namely from the closed cruiseferry to the more open-air RoPax design with less space for passengers and more for freight, including more on-deck storage for dg. A noteworthy exception is the Stockholm–Helsinki ferry route that exploits an exception to EU tax-free regulations by briefly stopping at the island of Åland to permit tax-free sales. The shipping lines on that route also differ by continuing to use cruiseferries.

From the perspective of logistics, stricter regulations do not necessarily boost safety, because they also raise the risk of misdeclared or undeclared dg as well as steer the transport chain away from shipping and towards potentially more dangerous traffic modes. Research on risk has long recognised that overly rigid regulations prompt actors to disrespect regulations, to take shortcuts and to ignore rules.[[81]](#footnote-81) Rasmussen[[82]](#footnote-82) has also highlighted that dynamic by discussing how the boundaries of economic failure and unacceptable workload encourage systems to adopt unsafe behaviour, as shown in Figure 9.5.

Figure 9.5 Here

There is an economic pressure to avoid costly safety measures, at the same time as employees are trying to avoid having an unacceptable workload due to the safety measures which pushes the boundary of acceptable behaviour into unsafe domains. That effect highlights the dynamic by which human behaviour constantly adapts to current situations such that formal rules become replaced by personal experience, know-how and local company culture. Rasmussen[[83]](#footnote-83) has also identified the dispersed process by which regulations are set as challenges from the perspective of risk. Rules and instructions are often designed separately for each task, whereas the tasks are in fact performed in parallel or subject to several set of rules.

In the transport of dg, those situations can be observed in the partly different imdg, adr and rid regulations that should be applied in the same transport chain as well as in their intersections with related considerations, including regulations about workplace safety and ship design. That interaction risks situations in which rules are not followed to the letter but instead gives room to more rational, practical processes with good intentions but nevertheless increasing risk. Regulators attempt to combat such developments by setting performance-based regulations that remain applicable even during rapid technological change and do not hamper innovation. Those endeavours imply regulating what standards or goals should be met, not how they should be met. One example is the regulation of sulphur emission control areas (seca) for shipping that stipulates using bunker fuel with no more than 0.1% sulphur but nevertheless tolerates the installation of cleaning devices with an equivalent result in the plume instead of simply using low-sulphur fuel.

However, regulations about dg continue to largely follow a prescriptive, highly detailed approach. That approach’s strengths include a reduced need for expert technical knowledge among the vast number of actors and individuals, because regulations can largely be translated into checklists to follow. Similarly, compliance can be measured by verifying formal adherence, not necessarily goal achievement. As observed at police and coast guard inspections, for instance, the focus is ensuring that measurable characteristics (e.g. expiration dates on fire extinguishers, required safety equipment, documentation and classification of packaging) are correct.

Obviously, developing that complex legal framework has taken countless experts extremely long time and remains a highly complicated task. The process of changing the regulations is also tedious, as is the case for all international regulations, because numerous actors need to agree for each change. Providing particular inertia to changing legislation in shipping is the longevity of ships and the reluctance to new rules that would force economically or technically premature scrapping. In relation to dg, the slow progress of regulations has become evident during the recent drastic increase in the transport of lithium batteries and subsequent increase in cargo fires were regulations were not adapted to new flows of dg. Societies and their values, norms and regulations are also subject to cultural lag,[[84]](#footnote-84) which implies that that society tend to lag behind the technical development and change only after technology does. When new technology is introduced, it takes society some time to adapt to this new reality. Such lag is a prominent drawback of prescriptive regulations, however, a transport chain handling dg involves an array of individuals, many of whom are likely to have limited experience with dg and handle dg only on occasion. Prescriptive regulations allow those individuals to perform the safe handling of dg. The time lag between regulations and technical development can also be filled by industry standards and conditions of carriage, as for example seen by the steep fees introduced by container shipping lines for misdeclared cargo. Industry associations such as the Cargo Incident Notification System (cins), an industry safety organisation formed by five of the largest container shipping lines in the world, has also issued guidelines to help operators prevent further incidents.[[85]](#footnote-85) Other parts of the shipping industry, such as the bulk and tanker segments, have elaborated industry standards as manifested by the prevalent vetting system[[86]](#footnote-86) for oil tankers.

Risk management often builds upon a defence-in-depth strategy in which several safety measures have already been breached before an accident occurs, as depicted in the so-called “Swiss cheese model” in Figure 9.6. Similar to holes in cheese, breaches in safety need to align before an accident occurs. In transporting dg, behaviour such as applying brute force erodes layers in the defence, trusting the other layers to stay intact and assuming that no other actors are also eroding layers with their behaviour. However, transporting dg involves many individuals, some of whom tend to maximise their own outcomes and following the drifting behaviour towards failure (Figure 9.5).

Figure 9.6 Here

6 Conclusions

The greatest threat to safely transporting dg is the individual’s expectation that another layer of safety always exists ready to absorb the risk, because that expectation condones ignoring regulations. Prescriptive regulations enforce that assumption because their complexity makes taking shortcuts attractive and because the ways in which detailed compliance ensures safety is not directly apparent to the individual. It is quite easy to assume, for example, that it does not matter whether a fire extinguisher’s expiration date has passed because it will most likely function anyway. However, each similar act erodes a layer of safety. For example, as stated by the marketing manager at the Port of Karlshamn,[[87]](#footnote-87) if a port is not notified that goods are dangerous, then the goods is likely to slip through the net and do not receive special consideration at port or on board.

When accidents occur, because they are normally caused by multiple errors, it is a mistake to only put the blame on the final stage in the chain of events. For example, if a container stowed in the wrong position is causing a major fire, then a long list of previous events allowed the container to be stowed incorrectly. Rasmussen[[88]](#footnote-88) has explained that in a six-level framework consisting of government, legislators, corporations, company management, staff and technical base. The overall intention set by governments of having safe dg transport are formalised by regulators, applied by corporations and contextualised in the particular company to form processes that management imposes on personnel who perform them in the physical context. All levels are linked together to form the events leading up to the accident. Rasmussen[[89]](#footnote-89) uses shipping as an example wherein rapid technological change hampers policymakers’ and legislators’ role to safeguard the public interest as classification societies and shipowners move forward, albeit too quickly for ship designers and shipyards to communicate properly and keep safety in focus. As a consequence, the gaps may result in failures to instruct on-board staff about the conditions and limits of operating vessels safely.

At all levels, actors active in transport of dg are exposed to conflicting interests, from working conditions to maintaining a profitable business to safeguarding the public interest. As made evident by our discussion on the six approaches to handling dg, the actual transport performed depends upon a complex range of factors of which safety is only one. Important aspects of risk management are a consensus on what objectives need to be fulfilled and feedback about compliance to be able to launch appropriate actions when required. Such feedback and consensus are also important between the levels, because legislators need to understand the behaviour and reasoning among corporate actors and staff to become able to design and implement appropriate, effective legislation.

All told, this chapter marks an attempt to expand understandings in the legal community about how regulations concerning dg are interpreted and implemented in practice, largely in the hope that members of the community can help to increase the safety of transporting dg. On the whole, those regulations have proven successful in contributing to the safe transport of dg, although the logistics industry would further benefit from a reduction in their complexity and administrative burden.

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table 9.1 Estimated shares of vehicles with dg signage in bridge substitute ports or RoPax ports, in a freight-only port and over the Øresund Bridge in West and South Sweden

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Swedish bridge substitute RoPax ports sorted from northwest to southeast |  | Semi-trailers and trucks | Share of dg,  2016–2017 | | |
| Primary routes | 2019 (1000) | Inbound | Outbound | Total |
| Strömstad | Norway (Sandefjord) | 5a | 2.0% | 1.0% | 1.5% |
| Gothenburg Germany Ferry Terminal | Germany (Kiel) | 60b | 0.0% | 16.0% | 8.0% |
| Gothenburg Denmark Ferry Terminal | Denmark (Fredrikshavn) | 150b | 2.0% | 5.0% | 3.5% |
| Varberg | Denmark (Grenå) | 35 | 2.0% | 4.0% | 3.0% |
| Helsingborg | Denmark (Helsingør) | 435 | 6.0% | 2.0% | 4.0% |
| Malmö | Germany (Travemünde) | 243 | 3.0% | 2.0% | 2.5% |
| Trelleborg | Germany (Rostock, Sassnitz, Travemünde), Poland (Swinoujscie), Lithuania (Klaipeda) | 776 | 5.0% | 2.0% | 3.0% |
| Ystad | Denmark (Rönne), Poland (Swinoujscie) | 267 | 0.0% | 2.0% | 1.0% |
| Karlshamn | Lithuania (Klaipeda) | 80 | 4.0% | 1.0% | 2.5% |
| Karlskrona | Poland (Gdynia) | 133 | 2.0% | 3.0% | 2.5% |
| *All bridge substitute RoPax ports* | | *2184* | *3.7%* | *3.1%* | *3.2%* |
| Gothenburg roro  (i.e. freight only) | Belgium (Zeebrügge, Ghent), UK (Immingham) | 280c | 13.0% | 13.0% | 13.0% |
| *All RoRo and RoPax ports* | | *2464* | *4.7%* | *4.1%* | *4.3%* |
| Øresund Bridge, Malmö | Denmark (Copenhagen) | 599d | 9.0%e | 7.0%e | 7.5% |
| *Total border-crossing semi-trailers and trucks* | | *3063* | *5.5%* | *4.7%* | *4.9%* |

*Note.* Share of dg compiled and calculated using data from The Swedish Transport Administration (2018) based on interviews in ports in 2016 and 2017 and the number of semi-trailers and trucks in 2019 from Ports of Sweden (2020). a Transport Analysis and Statistics Sweden (2020c); b Estimate based on Transport Analysis and Statistics Sweden (2020c), Ports of Sweden (2020) and earlier data; c Gothenburg roro Terminal (2021). d The Øresund Bridge (2021b); e Inbound flow of trucks registered in Denmark and outbound flow of trucks registered in Sweden.

figure 9.1 Map of RoRo and RoPax shipping lines from Southern Sweden

figure 9.2 Transport chains with a semi-trailer full load of dg and one with a part load of dg transported by semi-trailer tractors and a RoRo vessel. Note how dg are mixed with non-dg in semi-trailers and on board

figure 9.3 Transport chains with general cargo handled at consolidation terminals and transported by truck and a RoPax vessel. Note how dg are mixed with non-dg on the trucks and with the passengers on board

figure 9.4 Six approaches to handling dg in transport chains (Woxenius and others, 2001). In each approach, the white cylinder represents normal goods, whereas the white cube represents dg

figure 9.5 Behaviour drifting towards becoming unsafe. Adapted from Rasmussen (1997)

figure 9.6 The Swiss cheese model of accident prevention (Wikimedia Commons, 2014)

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