Analysis of fires and firefighting operations on fully cellular container vessels over the period 2000 – 2015

Diploma dissertation

for the award of the academic degree

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Examined by:	**Professor Captain Thomas Jung**
Co-examiner:	**Captain Ute Hannemann**

Submitted by: Helge Rath, Neustadtswall 14, 28199 Bremen, Germany

Phone: 0170-5582269
Email: helge_rath@gmx.de

Student registration no.: 355621

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Foreword

I remember walking with my grandfather by the locks of the Kiel Canal in Brunsbüttel as a small child and marveling at the ships there. Thanks to his many years working as an electrician on the locks, my grandfather was able to tell me a lot about the ships that passed through. And it was these early impressions that first awakened my interest in shipping. Having completed a "vacation internship" at the age of 17 at the shipping company *Leonhardt & Blumberg (Hamburg)*, I decided to train as a ship's mechanic. A year later, I started training at the Hamburg-based shipping company *Claus-Peter Offen* and qualified after 2 ½ years. I then worked for 18 months as a ship's mechanic on the jack-up vessel THOR, operated by *Hochtief Solutions AG*, which gave me the opportunity to gain a wealth of experience in all things nautical.

While studying for my degree in nautical science at the Bremen University of Applied Sciences, I spent the semester breaks on two different fully cellular container vessels owned by the shipping company *Claus-Peter Offen* to further my knowledge as a ship's engineer and prospective nautical engineer.

The *Verein Hanseatischer Transportversicherer e.V. (VHT)* approached me with the idea for this dissertation. I had previously worked there as a student assistant for over a year. Fire protection was a topic that immediately aroused my interest, as I had already been thinking about construction and fire protection in the context of fully cellular container vessels during my early training. These initial critical considerations were reinforced by my observations of the operations on a vessel when working as a ship's mechanic. And so I decided to write this dissertation.

I should like to take this opportunity to thank the *Verein Hanseatischer Transportversicherer e.V.* for their support in the form of a workplace and the opportunity of gaining further expertise while working on this dissertation. Furthermore, my thanks go to my examiners, Professor Captain Thomas Jung and Captain Ute Hannemann, who have supported me throughout.

I hope that this dissertation will make thought-provoking reading for hull and cargo insurers, shipping companies and freight forwarders and will highlight inadequacies in respect of fire safety.

Bremen, 1 September 2016

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Abbreviations used

AB	Able-bodied seaman
CABA	Compressed air breathing apparatus
cf	compare/see also
CMA CGM	Compagnie Maritime d'Affrètement & Compagnie Générale Maritime, French shipping company
CO_2	Carbon dioxide
COSCO	China Ocean Shipping (Group) Company, Chinese shipping company
CSCL	China Shipping Container Lines, Chinese shipping company
DMAIB	Danish Maritime Accident Investigation Board
DNV · GL	Det Norske Veritas & Germanischer Lloyd, merger of the Norwegian and German classification societies
dwt	Deadweight tonnage
FCC fleet	Fully cellular container ship fleet
Feeder	Feeder vessel
FEU	40-foot-equivalent unit, standard 40-foot container
FNFW	Normausschuss Feuerwehrwesen, German Firefighting and Fire Protection Standards Committee
FSA	Formal Safety Assessment
FSS code	International Code for Fire Safety Systems
GDV	Gesamtverband der Deutschen Versicherungswirtschaft e. V., German Insurance Association
GL	Germanische Lloyd SE, classification society
Handy	Handysize, vessel size
HHI	Hyundai Heavy Industries Co, Ltd.
Hom TEU	Homogeneously loaded 20-foot standard container
IMO	International Maritime Organization
ISL	Institut für Seeverkehrswirtschaft und Logistik, German Institute of Shipping Economics and Logistics
ITF	International Transport Forum
LOA	Length overall
m TEU	Million 20-foot standard containers
MSC	Mediterranean Shipping Company, Swiss shipping company
MSC'	Maritime Safety Committee
Nom TEU	Nominal loading capacity for 20-foot standard containers
OECD	Organisation for Economic Co-operation and Development
OS	Ordinary seaman
p.	Page
Panamax	Vessel size indicating vessels that are just able to pass through the old Panama Canal locks
Post-Panamax	Vessel size indicating vessels that are unable to pass through the old Panama Canal locks
Reefer	Reefer ship, refrigerated cargo vessel
RORO ship	Roll-on/roll-off vessel
SOLAS	International Convention for the Safety of Life at Sea
Sup-P'max	Super-post-Panamax, ship size indicating vessels >7000 TEU
TEU	20-foot-equivalent unit, standard 20-foot container
UASC	United Arab Shipping Company
UHF	Ultra-high frequency, radio frequency
VDR	Verband Deutscher Reeder, German Shipowners' Association

VHT	Verein Hanseatischer Transportversicherer e.V., Association of Hanseatic Marine Underwriters
ytd	year-to-date
ZIM	Zim Integrated Shipping Services Ltd., Israeli shipping company

1. Introduction

1.1. Relevance of the topic

The trend toward combining ever greater quantities of cargo on a single vessel, with the attendant increase in risk for both vessel and cargo, is an issue that is now being investigated by a wide range of institutions.

The 54th "Deutsche Verkehrsgerichtstag" (German Council of Transport Authorities) was held in Goslar from the 27th to the 29th of January, 2016. One of the issues discussed in Working Party VIII was "Mega container ships: Ever larger – but are they safer too?". The findings were: *"The regulations governing mega container ships must take account of the more extensive requirements in respect of emergency provisions, for instance through fire detection sensors, by further developing stationary and mobile firefighting equipment on and below deck and by fitting suitable towing facilities. Initial and ongoing training of all those involved, especially the crew, must be promoted with the aim of rapidly detecting potential risks and, where possible, avoiding or minimizing these risks by appropriate actions. In particular in the event of a fire, steps must be taken to ensure that specialist firefighters are deployed as soon as possible to support the crew. Emergency berths for damaged vessels must be available together with the necessary equipment for discharge and recovery. We would encourage the Federal Ministry for Transport and Digital Infrastructure (BMVI) to bring together the available expertise."* (-Deutsche Akademie für Verkehrswissenschaft- e.V., 2016, p. 8)
Ever larger vessels fitted with the same firefighting facilities and with crews of the same size increase the risk of a write-off if a fire breaks out.

As a qualified ship's mechanic and while working as a fitter on board international container ships of all sizes, I was able to gain an impression of the firefighting provisions in the event of a fire. And I frequently asked myself whether our equipment and the size of the crew would be enough to fight or control a fire.

Considering the fact that logistics chains are increasingly based on containers and that cargoes are increasingly being bundled on the main routes, for instance between Europe and Asia and on the new trans-Pacific route following the opening of the new Panama Canal, it seems that the time has come to question the safety of the cargo, the crew and ultimately the entire vessel given the firefighting equipment currently fitted. In the search for answers, I shall in this dissertation be investigating fires on fully cellular container vessels over recent years.

1.2. Objective and delineation of the topic

The objective of this dissertation is to establish a comprehensive overview of fires in the cargo areas on fully cellular container vessels over the period 2000-2015. Collating all these cases should make it possible to consider individual cases in greater detail and to apply analytical methods to the totality of all cases. Listing and analyzing the losses should make it possible to take a retrospective view. The financial aspect of the loss was not taken into account when considering the individual cases, as the direct costs of damage and the consequential costs would constitute sufficient material for a further scientific paper.

Furthermore, the existing firefighting equipment as laid down in SOLAS will be assessed as to its suitability. To this end, various scenarios involving container fires on a vessel and in which the crew fight the fire will be simulated. The simulation of fires on a fully cellular container vessel should illustrate the extent to which the equipment is actually fit for use. This should reveal potential weaknesses in fixed and mobile firefighting equipment and in respect of the size of the crew. The aim of this dissertation is to sharpen awareness of the shortcomings of equipment as laid down in SOLAS.

The overall objective of this dissertation is to be part of a preliminary expert report for a *Formal Safety Assessment* (FSA) regarding changes to the SOLAS Convention. In turn, the aim of this FSA is that the International Maritime Organisation (IMO) should take up this issue.

1.3. Structure of the dissertation

Excluding the Introduction and the Conclusion, this dissertation is divided into 3 sections.

The first section (Chapter 2) will show the global numbers of fully cellular container vessels. The first year surveyed is 2000. Charts and tables are used to represent and explain the makeup of the fleet. The way in which the fleet developed up to 2015 is then explained. This section deals not only with the overall capacity of the fleet, but also with individual vessels of extraordinary size. Finally, the year 2015 is considered in comparative terms and the makeup of the fleet is shown. Additionally, the future development of the fleet is discussed on the basis of orders and recent studies.

The second section (Chapter 3) presents and critically assesses the international regulations of the SOLAS Convention. Firstly, the required equipment is explained on the basis of a *Fire Control and Safety Plan* for an example vessel. This is done using the SOLAS and *International Code for Fire Safety Systems* (FSS Code) regulations. In order to critically assess the regulations, four different cargo fires are simulated. Rules for the simulations are defined beforehand to ensure that they are comparable.

In the final section, fires in the period 2000-2015 are first listed. The author created a data matrix to allow the incidents to be compared and the data to be analyzed. Furthermore, Chapter 4 analyzes the data that has been presented from different perspectives and shows the analyses in the form of charts.

2. The global FCC fleet

"Ships are getting bigger:" This is what we find in *The Impact of Mega-Ships*, published by the *Organisation for Economic Co-operation and Development* (OECD) and the *International Transport Forum* (ITF) in 2015 (cf. OECD, 2015, p. 13). The chart below shows the growth in ship size in different shipping sectors. The remarkable feature is the growth of approx. 90 % in the container ship sector over a period of around 20 years.

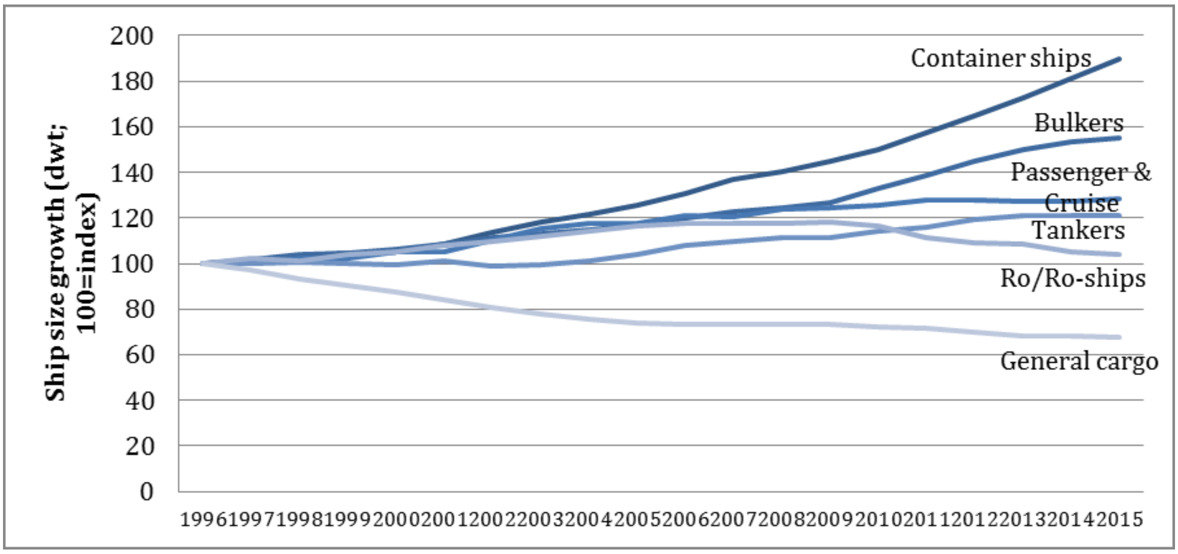


Figure 01, Growth rates of different types of ships compared
Source: (OECD, 2015, p. 17)

Starting from this statement and the chart above, this chapter first presents the development of the global FCC fleet over the period 2000 – 2015. This will allow readers to gain an impression of the enormous growth of the fleet's capacity and that of the individual vessels.

This will in turn make it possible for readers to put the safety aspects and fire incidents discussed in the later chapters in the context of the global FCC fleet. Data has been taken from articles and charts from the annual and quarterly reports published by *Clarkson Research*. Data from the Bremen-based *Institute of Shipping Economics and Logistics* (ISL) was also analyzed.

The focus is to be twofold: on the makeup of the fleet in the initial year under consideration (which also necessitates a brief retrospective into the 1990s), and on the rapid growth between the beginning of the millennium and 2015. An outlook on future trends in the fleet post-2015 will also be given.

2.1. Makeup of the FCC fleet in 2000

As shown in Table 01, the tonnage of the FCC fleet grew by 10 % per year over the period 1996-2000. At the beginning of the millennium, the capacity of the fleet was 4.3 million TEU, and the share of container vessels in the world's merchant fleet rose by 2.1% to 8.3% in 4 years. Looking at the FCC fleet at the beginning of 2000, it is noticeable that 40.6 % of all container vessels were built in the period 1995-2000. The chart below shows orders placed and capacity delivered.

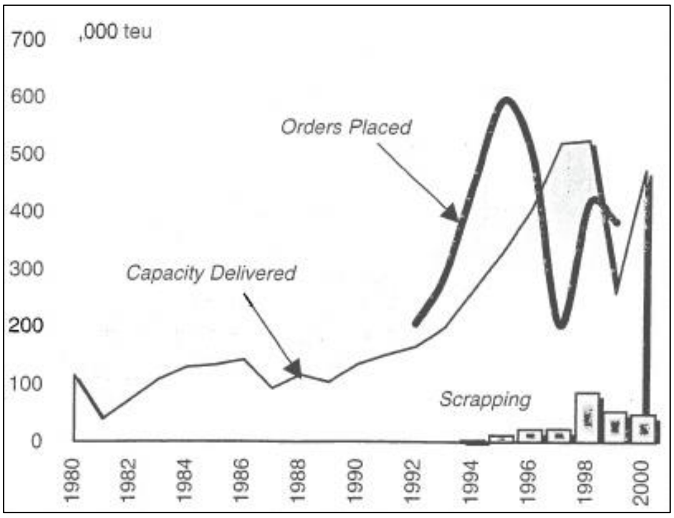


Figure 02, Orders placed and capacity delivered, 1980-2000
Source: (Clarksons Research Studies, January 2000, p. 3)

In terms of TEU, these newly-built vessels make up 46.8 % of the fleet. As a result, the average age of the fleet fell from 11.4 years to 10.3 years.

Ship type	dwt-% share of world merchant fleet		Average yearly growth rate 1996-2000 (%)			Average age (years)				
	1996	2000	No of ships	dwt	TEU	1996	1997	1998	1999	2000
Container ships	6.2	8.3	8.7	10.0	12.4	11.4	11.1	10.6	10.1	10.3

Table 01, Extract from ISL table
Source: (Institute of Shipping Economics and Logistics (ISL), 2000, p. 6)

At this time, the largest container vessels had a TEU capacity of up to 7000 and belonged to *Maersk Line* and *P&O/Nedlloyd* (cf. Institute of Shipping Economics and Logistics (ISL), 2000, p. 7;9).

The period 1994 through 1998 saw extremely high investment in fully cellular container vessels. This peaked in 1997, when 16 % of the existing fleet was delivered. In 2000, a TEU capacity of 493,000, representing 11 % of the fleet, was on the order books of the shipyards.

And in 2000, a TEU capacity of 216,000 in the form of post-Panamax vessels was also awaiting delivery, twice as much as in any previous year. In the period between 1999 and the beginning of the millennium, the focus was on orders for extremely large units (cf. Clarksons Research Studies a, 2000, p. 16;18;97).

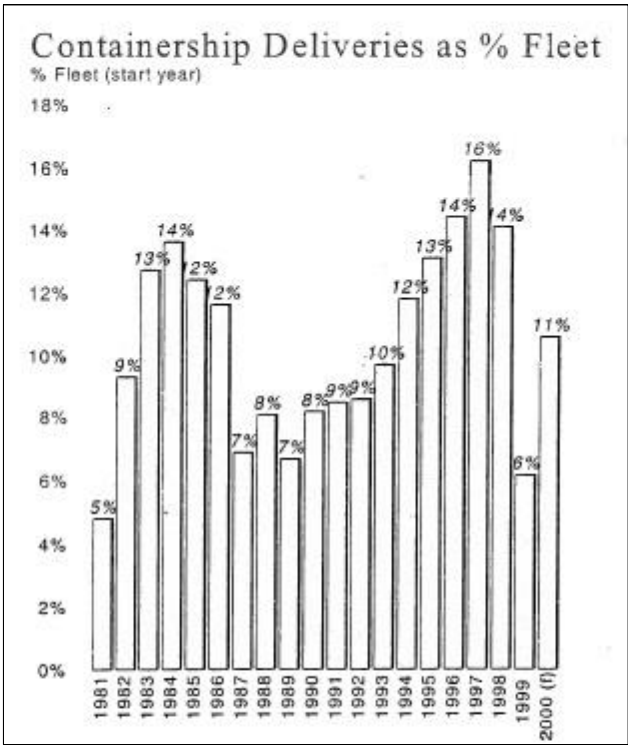


Figure 03, Deliveries, 1981-2000
Source: (Clarksons Research Studies a, 2000, p. 19)

Clarkson Research writes that in March 2000 the fleet comprised 2612 vessels and had a capacity of 4.41 million TEU. With 334 vessels on the shipyards' order books, the 5 million TEU capacity mark would be exceeded in the following year. In 2000, the average vessel was able to carry 1688 TEU. In 1999, 15 post-Panamax vessels were added to the fleet, but at the end of the year, there were 89 orders on the shipyards' order books. The size of around 2/3 of the vessels ordered was between 5000 and 5999 TEU, somewhat less than one third were between 6000 and 6499 TEU and a small percentage were even larger.

The table below shows an overview of the FCC fleet in January 2000. The largest units are listed as post-Panamax vessels and are just below the 7000 TEU mark. On average, these units have a nominal capacity of 5410 TEU. They have a length overall of up to 324 meters and a beam of up to 42.1 meters. On average, the post-Panamax fleet has an LOA of 290 meters and a beam of 40 meters. On average, around ¼ of the feeder, feedermax, handy and sub-Panamax vessels are equipped with cranes.

FCC Fleet Profile....	Avg. Size/Age					Average Speed/Cons		Average Dimensions (m.)			Geared
	Nom Teu	Hom Teu	Dwt	Dwt per Teu	Years	Knots	t/day	LOA	Beam	Draft	% N. Teu
100/249	168	142	3,368	20.4	21.7	13.1	10.3	90.8	14.8	5.3	23.5%
250/499	367	267	6,291	17.2	13.5	14.3	17.9	112.6	18.1	6.5	32.9%
Total Feeder	**305**	**251**	**5,377**	**18.2**	**16.0**	**14.0**	**16.0**	**105.9**	**17.1**	**6.1**	**31.3%**
500/749	611	410	9,342	15.2	9.8	16.0	23.9	129.2	20.3	7.5	44.8%
750/999	869	639	13,852	15.9	11.9	17.1	36.5	151.7	23.5	8.7	60.2%
Total Feedermax	**709**	**491**	**11,049**	**15.5**	**10.6**	**16.5**	**28.9**	**137.7**	**21.5**	**7.9**	**52.0%**
1000/1499	1,193	875	19,009	15.9	10.9	18.0	43.3	170.4	25.7	9.4	49.7%
1500/1999	1,694	1,284	25,811	15.2	8.5	19.5	58.5	186.4	28.0	10.4	61.1%
Total Handy	**1,399**	**1,079**	**21,800**	**15.6**	**9.9**	**18.6**	**49.8**	**177.0**	**26.6**	**9.8**	**55.4%**
2000/2499	2,234	1,807	33,815	15.1	10.0	20.1	76.2	209.6	31.0	11.4	42.2%
2500/2999	2,759	2,220	40,630	14.8	11.8	21.4	90.5	233.5	32.0	11.7	5.1%
Total Sub-Panamax	**2,468**	**1,980**	**36,850**	**15.0**	**10.8**	**20.7**	**83.0**	**220.3**	**31.4**	**11.6**	**23.7%**
3000/3499	3,218	2,521	45,545	14.2	9.9	21.8	95.5	252.0	32.2	12.0	
3500/3999	3,754	2,633	50,743	13.5	7.1	23.1	118.3	270.7	32.2	12.4	
4000&+(Panamax)	4,301	3,375	60,923	14.2	5.5	23.4	139.7	291.4	32.2	12.9	
Total Panamax	**3,721**	**2,801**	**51,981**	**14.0**	**7.6**	**22.8**	**118.5**	**270.0**	**32.2**	**12.4**	
4000/4499	4,382	3,477	58,314	13.3	8.7	24.1	149.7	275.7	37.9	13.3	
4500/4999	4,842	4,679	65,098	13.4	4.6	24.2	180.9	284.4	39.0	13.5	
5000/5499	5,253		66,460	12.7	2.8	25.0	201.0	279.8	40.0	13.0	
5500/5999	5,583		68,291	12.2	2.5	24.5	203.3	279.9	40.0	13.4	
6000+	6,691		92,606	13.8	2.4	24.7	209.3	324.0	42.1	14.2	
Total Post-Panamax	**5,410**	**4,378**	**71,171**	**13.1**	**3.9**	**24.5**	**191.0**	**290.4**	**40.0**	**13.5**	
TOTAL	1,685	1,135	24,835	15.6	10.7	18.6	59.8	179.8	25.9	9.5	24.5%

Table 02, Profile of the FCC fleet, January 2000
Source: (Clarksons Research Studies, January 2000, p. iii)

2.2. Development of the FCC fleet up to 2015

After the turn of the millennium, demand for the transport of cargo on container vessels rose sharply. In each of the years 2002, 2003 and 2004, demand grew by more than 10 %. This resulted particularly from strong overseas trade from China (cf. Witthöft, 2013, p. 60).

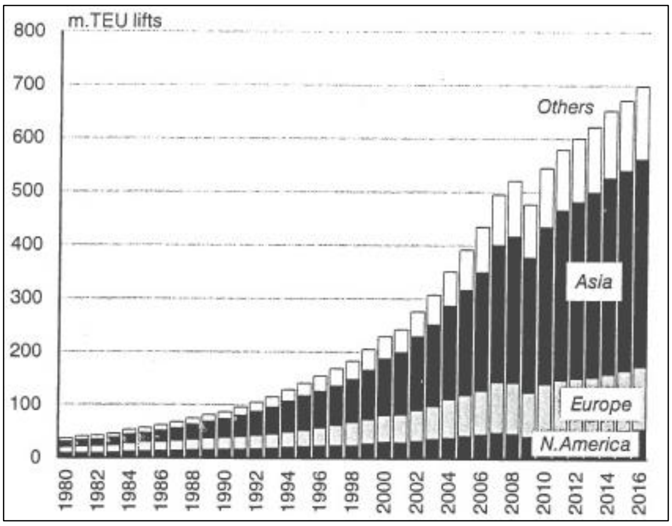


Figure 04, Demand for container transport capacity, 1980-2016
Source: (Clarksons Research, November 2015, p. 3)

At the end of 2003, more than 80 ships with a capacity in excess of 8000 TEU were on the order books of Korean shipyards, and a series of vessels with a capacity in excess of 9500 TEU were ordered. For the first time, a vessel was built in 2005 that was able to carry 18 containers next to each other on deck. With a potential TEU capacity of 9178, the MSC PAMELA was the first fully cellular container vessel with a beam of more than 45 meters. The 9500 TEU mark was broken in 2006 by the XIN LOS ANGELES, which has a capacity of 9580 TEU. In the same year, the shipping world found out that *Germanische Lloyd* (GL) had joined forces with the Korean shipyard *Hyundai Heavy Industries* (HHI) to design a vessel with a capacity of 13,000 TEU. This vessel was designed in such a way that 21 rows of containers could be stowed side by side on deck and 19 rows could be stowed side by side below deck (cf. Witthöft, 2013, pp. 117-118).

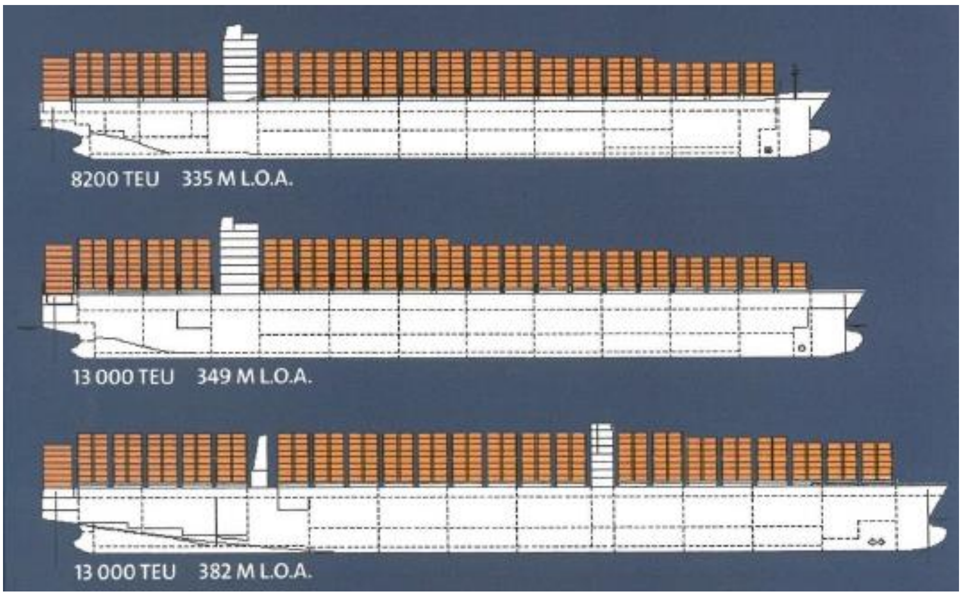


Figure 05, Size comparison and draft designs from GL and HHI
Source: (Witthöft, 2013, p. 118)

In 2004, London-based shipbroker *Braemar* predicted the growth to 2007 resulting from a predicted quarterly increase in the fleet of 60 vessels with a total capacity of around 200,000 TEU. This would peak in 2006, when a TEU capacity of 400,000 would reach the market.

The chart below shows that the company was proved right.

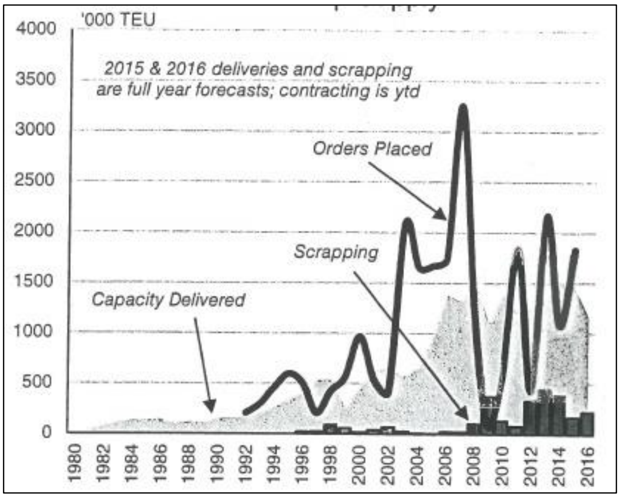


Figure 06, Delivery, orders and scrapping of container vessels, 1980-2016
Source: (Clarksons Research, November 2015, p. 3)

In April 2005, shipping expert Dirk Visser of the Dutch *DynamarBV* drew attention to the fact that, given the fleet size and known orders at the time, there would be some 4530 container vessels of different sizes with a total capacity of 11.5 million TEU on the seas at the beginning of 2009. This did not take account of scrapping **(cf. Witthöft, 2013, pp. 61-62)**.

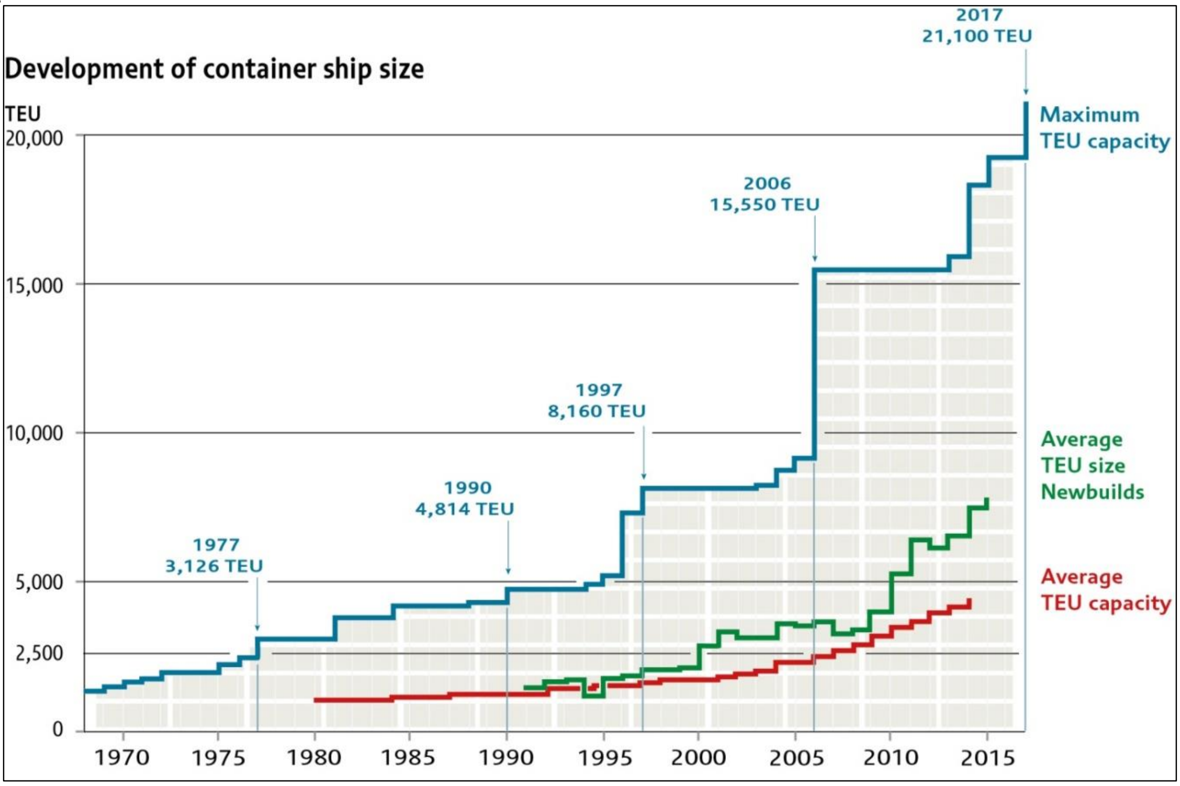
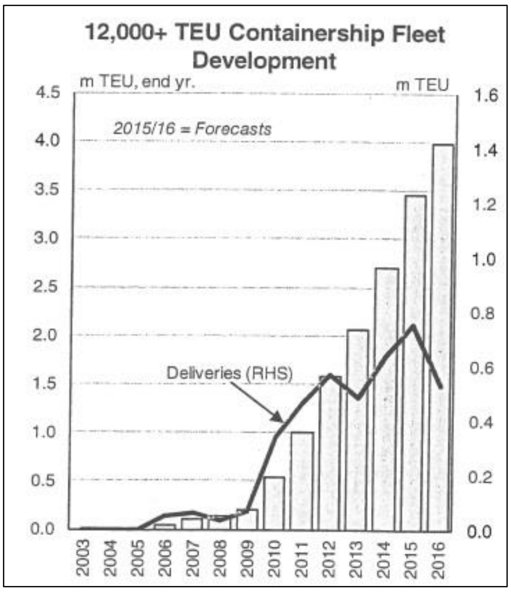


Figure 7, Growth of container vessel size in terms of TEU capacity
Source: (OECD, 2015, p. 18)

In its 2006 Annual Report, the German Shipowners' Association (VDR) announced that in October of that year, 1247 vessels with a total TEU capacity of 4.6 million were either being constructed or had been ordered by German shipowners. Of these, 78 had a cargo capacity greater than 9000 TEU. Spurred on by the EMMA MAERSK, which had a TEU capacity of 12,508 and was already operational, the shipowners ZIM, MSC and COSCO ordered 17 new vessels, each of which had a capacity greater than 10,000 TEU. French shipowner CMA CGM alone ordered 8 vessels with a TEU capacity of 11,400 each. The then widespread trend towards *economies of scale*, according to which the transport costs per container would fall as ship sizes grew, encouraged the shipowners to purchase ever larger units (cf. Witthöft, 2013, p. 147).

Despite criticism and misgivings about ever larger ships and doubts about the actual benefits delivered by the *economies of scale*, the VDR annual report for 2007 indicated that by the end of the second quarter of that year, German shipowners had ordered 17 super-post-Panamax vessels. These orders represented a TEU capacity of 215,000.



In the third quarter of 2007, orders had seen a more than threefold increase. The VDR reported that by the end of the third quarter, vessels had been ordered with a total TEU capacity of more than 6.4 million . In the chart on the left, the *Deliveries* line and the scale on the right show the annual deliveries and the bar chart and the scale on the left show the fleet size at the end of the year. According to Dr. Burkhard Lemper from ISL, the year 2007 was to go down in the history of container shipping as the year of the 12,000 TEU vessels, since in the fall, the Korean shipyards already had 115 orders for this new class .

Figure 08, Deliveries of vessels with more than 12,000 TEU, 2003-2016
Source: (Clarksons Research a, Herbst 2015, p. 69)

In 2008, the Korean *Samsung Heavy Industries* shipyard delivered the MSC DANIELA which had a capacity of 13,500 TEU and was at the time the world's largest fully cellular container vessel. The MSC DANIELA has a length overall of 366 meters and a beam of 51 meters. The deckhouse and engine room are split in a twin-island configuration (see Figure 5), which was at the time an innovation on container vessels.

Figure 09, MSC DANIELA during sea trials
Source: (Vesseltracker, 2009)

Following further high order volumes, more than 90 vessels with a capacity in excess of 12,000 TEU were operating on East/West routes in 2011. The next generation of mega-carriers became operational in 2012: With a TEU capacity of 16,020, the CMA CGM MARCO POLO set a new record for fully cellular container vessels. It has a length overall of 396 meters, a beam of 53.6 meters and a draft of 16 meters.

With the start of construction of the first 18,000 TEU vessel, Danish shipowner *Maersk Line* set yet another mark in 2012. 20 vessels of this Triple-E class were ordered for trade between Europe and Asia. Other trade routes such as the Asia/US west coast cannot be considered due to the restrictions of the US ports. As well as the Danes, the Kuwaiti *United Arabian Shipping Company* (UASC), MSC, and the *China Shipping Container Line* (CSCL) have also ordered further 18,000 TEU vessels (cf. Witthöft, 2013, p. 154). The table shows the growth and scrappage of vessels by class. The growth in vessels of the 8000-9999 TEU and >10,000+ TEU classes is particularly noticeable.

TEU-Klasse	2011			2012			2013		
	Zugang	Abgang	Veränd. in TEU	Zugang	Abgang	Veränd. in TEU	Zugang	Abgang	Veränd. in TEU
2000–2999	14	5	25986	6	13	−15200	10	12	−5050
3000–3999	8	4	15200	4	9	−16950	28	9	71450
4000–5149	38	1	164450	35	3	142850	31	3	135200
5150–7999	30	0	198300	30	0	200800	12	0	78400
8000–9999	19	0	157100	14	0	119300	75	0	682776
>10 000+	47	0	569300	71	0	886500	45	0	1006926

Table 03, Fleet growth, 2011-2013
Source: (Witthöft, 2013, p. 95)

2.3. State of the fleet in 2015 and possible future trends in the FCC fleet

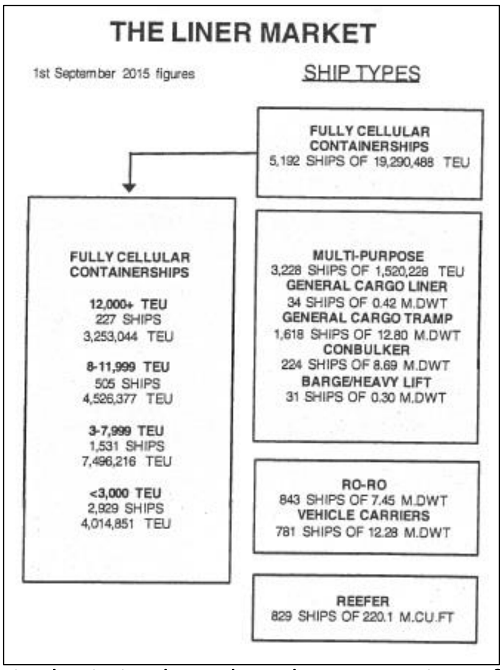


Figure 10, The fleet in September 2015
Source:

In September 2015, the capacity of the global FCC fleet was 19.3 million TEU, which represents an increase of 7.7 % compared with the previous year. Total deliveries in 2015 amounted to 1.6 million TEU, and the fleet numbered 5192 vessels. In the first eight months of the year, 113 fully cellular container vessels with a TEU capacity of 1.3 million containers were ordered. The focus was primarily on very large vessels and to a certain extent on the feeder market (cf. Clarksons Research a, Herbst 2015, p. 24). Growth in container capacity in 2015 was 7 %, which was above the growth in trade volume. At the end of the year, the market totaled 21.9 million TEU.

Comparison of the fleet profiles for 2015 and 2000 reveals a number of significant changes:

vessels equipped with cranes has more than halved, er very obvious change is that the capacity of the largest vessels has increased almost threefold. According to Table 2 (page 4), in 2000 there were vessels with a TEU capacity of up to 6691. In 2015 there were operational vessels with a TEU capacity of up to 18,582 TEU. On average, the nominal capacity of a fully cellular container vessel has increased by 2055 TEU over the past 15 years. As a percentage, this represents an increase of 121.95 %. The average length of the vessels has increased by 21.91 % from 179.8 meters to 219.2 meters. The average beam increased by 5.1 meters, from 25.9 meters to 31 meters, an increase of 19.69 %. In this context, it should be mentioned that the widest container vessels can have a beam of more than 50 meters.

FCC Fleet Profile (by TEU size range)	Avg. Size/Age Nom Teu	Hom Teu	Dwt	Dwt per Teu	Years	Average Speed/Cons Knots	t/day	Average Dimensions (m.) LOA	Beam	Draft	Geared % N. Teu
100/999 (Feeder)	610	440	8,208	13.5	16.2	16.1	25.3	122.3	19.6	7.0	39%
1000/1999 (Handy)	1,406	1,010	19,137	13.6	12.0	19.2	47.9	166.3	25.6	9.3	53%
2000/2999 (Sub-P'max)	2,530	1,919	34,806	13.8	11.9	21.7	81.8	208.0	30.5	11.4	54%
Sub-3,000	**1,365**	**1,036**	**18,628**	**13.6**	**13.5**	**18.6**	**49.5**	**159.6**	**24.5**	**9.0**	**51%**
3000/3999 (Panamax)	3,400	2,467	43,786	12.9	11.7	22.7	109.7	237.3	32.2	11.7	24%
4000/4999 (Panamax)	4,387	2,950	55,389	12.6	10.0	24.1	143.4	273.0	32.2	12.7	0%
5000&+ (Panamax)	5,076	3,336	66,305	13.1	8.4	25.0	166.7	294.1	32.2	13.3	
Panamax 3,000+	**4,207**	**2,865**	**53,597**	**12.7**	**10.3**	**23.8**	**137.3**	**266.1**	**32.2**	**12.5**	**5%**
<5000 (Post-Panamax)	4,376	3,255	57,437	13.1	4.6	22.0	127.7	251.3	37.1	12.9	33%
5000/5999 (P-P'max)	5,559	4,143	68,286	12.3	11.4	24.7	187.2	275.9	39.7	13.6	
6000/6999	6,560	4,853	81,245	12.4	8.7	24.9	219.0	298.9	40.5	14.1	
7000/7999	7,291	5,718	91,219	12.5	9.0	24.2	209.3	304.5	43.2	14.0	
Post-Panamax <8,000	**5,762**	**4,308**	**71,964**	**12.5**	**8.8**	**24.1**	**188.1**	**280.3**	**39.7**	**13.7**	**4%**
8000/8999	8,436	6,450	103,229	12.2	6.2	24.6	239.8	327.2	44.2	14.3	
9000/9999	9,352	7,171	111,421	11.9	5.1	24.1	244.4	329.4	45.9	14.5	
10000/11999	10,475	7,793	121,215	11.6	3.5	24.5	237.6	344.3	46.7	14.8	
Post-Panamax 8-11,999	**8,977**	**6,776**	**108,032**	**12.0**	**5.5**	**24.4**	**240.5**	**330.3**	**45.0**	**14.4**	
12000/13999	11,781	8,453	130,319	11.1	2.8	21.0	220.3	323.8	43.5	13.5	
14000/15999	14,461	10,490	156,931	10.9	3.1	23.8	333.9	374.2	52.1	15.6	
16000/17999	17,118	12,025	186,179	10.9	1.1	23.7	330.8	397.2	53.9	15.3	
18000&+	18,582		194,358	10.5	0.9	23.0	349.2	399.0	58.9	15.6	
Post-Panamax 12,000+	**14,390**	**9,761**	**156,972**	**10.9**	**2.8**	**23.9**	**287.0**	**373.7**	**51.3**	**15.4**	
TOTAL	**3,740**	**2,468**	**46,344**	**12.4**	**11.1**	**21.0**	**110.8**	**219.2**	**31.0**	**11.0**	**12%**

Table 04, Profile of the FCC fleet, December 2015
Source: (Clarksons Research, November 2015, p. 6)

At the beginning of September 2015 there were 227 vessels in the FCC fleet with a TEU capacity in excess of 12,000. These represented a total capacity of 3.3 million TEU. In the first eight months of 2015, this sector grew by 21 % with 34 vessels being delivered. By comparison: Over the same period, the overall FCC fleet grew by only 5.8 %.

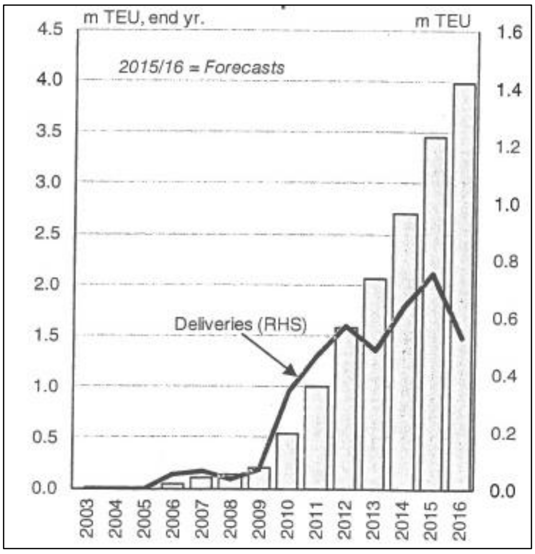


Figure 11, 12,000+ TEU fleet development 2003-2016
Source: (Clarksons Research a, Herbst 2015, p. 69)

In September 2015, the 12,000+ TEU fleet represented a 17 % share of the TEU capacity of the entire fleet. At this time, orders for 12,000+ TEU vessels stood at 128 vessels, representing a capacity of 2.1 million TEU and 65 % of that of the existing 12,000+ TEU fleet. Many shipowners had already ordered a total of 62 vessels with a TEU capacity in excess of 12,000 over the period January-August 2015. Of these, 37 vessels had a capacity greater than 18,000 TEU. Overcapacity is expected to continue into the future against the background of a challenging environment on the Europe-Asia route. An expected slight growth in trade and a smaller number of vessels delivered in 2016 will not change this. The 12,000+ TEU vessels will squeeze the smaller vessels from the primary routes and possibly become established on the trans-Pacific routes.

At the beginning of September **2015**, a total of 505 vessels with a capacity of 8000-12,000 TEU were operating around the globe. Since the beginning of the year, the addition of 46 vessels has increased capacity by 11 % to a total of 4.5 million TEU. At the beginning of the month, the shipyards had orders for 110 vessels, with a TEU capacity of one million, representing 22 % of the capacity of the existing fleet. Over the whole of 2015, around 0.6 million TEU will have been added to the existing fleet capacity in the 8000-12,000 TEU class.

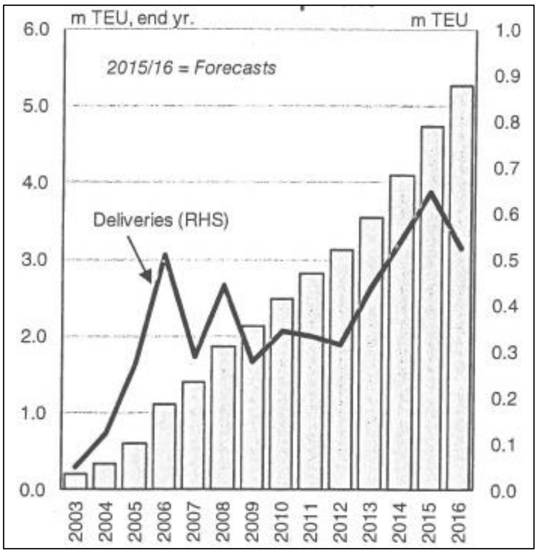
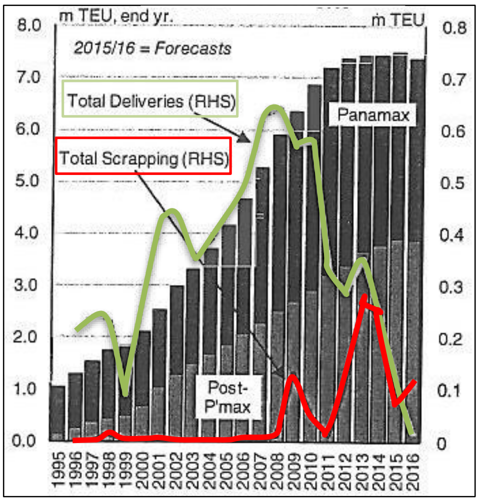


Figure 12, 8000 - 12,000 TEU
Fleet development 2003-2016
Source: (Clarksons Research a, Herbst 2015, p. 71)

For **2016**, slightly lower growth of 0.5 million TEU is expected, given that there were 18 vessels on the order books of the shipyards by September 2015. Growth of 11 % is expected for 2016, even if more vessels are replaced by 12,000+ TEU vessels on the Far East / Europe route as a result of the cascade effect. Vessels with a capacity of 8000-12,000 TEU will benefit from the opening of the new Panama locks, since this means that as of the second quarter of 2016, vessels with a TEU capacity of up to 12,000 will be able to sail from Asia to the eastern seaboard of the United States on the trans-Pacific route.

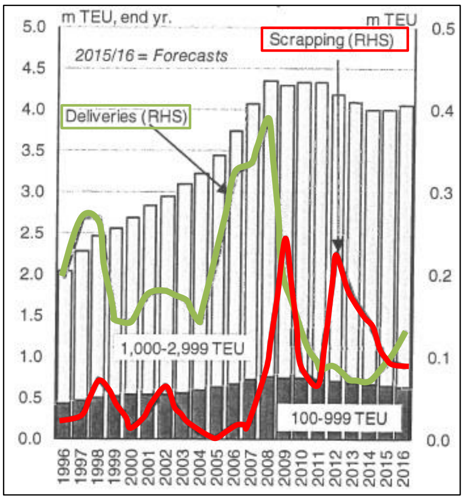
The segment of the fleet covering vessels with a TEU capacity between 3000 and 8000 numbered 1531 vessels in September 2015 (cf. Clarksons Research a, Herbst 2015, p. 67). This meant that this class contributed 7.49 million TEU to the total capacity of the global FCC fleet. The narrow beam of the Panamax vessels makes it possible for them to use the old locks on the Panama Canal. However, only 19 % of the vessels operate on the trans-Pacific route and use the locks, whereas 31 % of the vessels operate on north/south routes and 13 % are used on intra-regional routes. Because there is little interest in building new Panamax vessels and a large number were scrapped in the period 2012-2014, the capacity of this fleet has fallen by 10 % since 2012. In 2015, only a small number of Panamax vessels were scrapped.



The post-Panamax fleet, i.e. vessels that cannot pass through the Canal, grew by 3 % in the first eight months of the year. At the beginning of September, the shipyards had orders for 22 post-Panamax vessels with a TEU capacity of 3000-8000, representing a total of 0.1 million TEU or 3 % of the existing fleet capacity. Orders for Panamax vessels were insignificant, which is primarily explained by the new locks on the Panama Canal .

Figure 13, <3000 TEU fleet development, 1995-2016
Source: (Clarksons Research a, Herbst 2015, p. 73)

The fleet of fully cellular container vessels with a capacity of less than 3000 TEU numbered 2929 vessels in September 2015. This class contributed a capacity of 4 million TEU to the global fleet. Limited investment in new builds and continued scrapping have meant that the fleet has shrunk by 8 % since September 2011. In 2014, for example, 115 vessels were scrapped, while just 51 were delivered. In 2015, 41 vessels were scrapped and just 36 were delivered.



With 23 new orders in the first 8 months of 2015, 0.3 million TEU or 8 % of the existing capacity of the < 3000 TEU fleet were ordered. It is only the minor routes and the growing intra-regional trade in Asia that have any demand for feeder ships and that offer this sector the potential for future growth .

Figure 14, <3000 TEU fleet development, 1996-2016
Source: (Clarksons Research a, Herbst 2015, p. 75)

The current generation of the largest container vessels could reach their limits at a capacity of 22,000 TEU. This would only require relatively minor optimization of the design of the existing vessels. In essence, the vessels would be constructed in a way similar to *Maersk Line's* Triple-E class (cf. OECD, 2015, p. 19). In order to move up to ships with a capacity of 24,000 TEU, they would have to have an overall length of 456 meters and a beam of 56 meters. Such ships would have 25 rows of containers stowed next to each other on deck, along with three additional 40' bays (cf. Lane, A., Moret, C., 2015, p. 42). As early as 2008, *Germanische Lloyd*, together with the South Korean *STX Corporation*, announced that they had developed the plans for a ship with a capacity of 22,000 TEU. The length of the planned vessel would be 460 meters (cf. Witthöft, 2013, p. 155) (cf. STX Corporation, 2008, p. 01). In 2014, reports emerged of plans for a 24,000 TEU vessel by *Ocean Shipping Consultants*, part of the Dutch consulting company *Royal HaskoningDHV*. This would have a length of 430 meters and a beam of 62 meters (cf. World Maritime News d, 2014).

Shipping line	Name	TEU capacity	Since
Maersk	Triple E series	18,100	2013
China Shipping	CSCL Globe series	19,100	2014
MSC	Oscar, Oliver	19,200	2015
MOL	n.a	20,000	2017 (expected)
CMA*CGM	n.a	20,600	2017 (expected)
OOCL	n.a	21,100	2017 (expected)

Table 05, The largest container vessels of our time and in the near future
Source: (OECD, 2015, p. 18)

3. Fire protection system as per SOLAS

The *International Convention for the Safety of Life at Sea* (SOLAS) is published by the *International Maritime Organisation* and has a history stretching back more than 100 years. The first version took effect in 1914 after the Titanic disaster. The current version dates from 1974 and took effect in 1980. SOLAS lays down minimum safety standards for the construction, equipment and operation of ships. The rules and regulations in the convention are binding for the global shipping industry, including any changes and supplements (cf. International Maritime Organization, 1974).

This chapter will examine and discuss the regulations laid down in Chapter II of SOLAS.

Chapter II regulates fire protection, fire detection and firefighting equipment. In most cases, SOLAS regulates fire protection on ships with reference to the *International Code for Fire Safety Systems* (FSS Code). This was approved by the *Maritime Safety Committee* (MSC) in 2000 and took effect in July 2002.

This contains the technical requirements in respect of fire protection systems as per SOLAS 74, Chapter II in standardized form (cf. International Maritime Organization b, 2007, p. iii).

In order to examine the convention, its implementation on a fully cellular container vessel will be explained. The discussion will then be based on theoretical simulations of fires on this vessel.

3.1. Implementation of the SOLAS regulations on a fully cellular container vessel with a capacity of 5100 TEU

This dissertation will present the implementation of a fire protection system as per SOLAS on the basis of an example vessel. The plans for the vessel used here were made available by Bremen University. The hull number, the IMO number and the name of the vessel were not revealed. The plan can be found in digital form in the appendices.

The fire protection equipment in the vicinity of the cargo on the example vessel will be enumerated and explained on the basis of the *Fire Control and Safety Plan*.

3.1.1. Principal dimensions

- Length overall: 294.0 meters
- Beam: 32.20 meters
- Draft: 13.50 meters
- Accommodation: 30 persons
- Classification: Germanischer Lloyd
- Cargo capacity: 5100 TEU
- Deadweight tonnage: 63,059 tons
- Year built: 2010
- Place: Shanghai, China

3.1.2. Fire detection system

The fire detection system on the example vessel is present in the form of a combined smoke extraction and carbon dioxide (CO_2) system. A system such as this is regulated primarily by SOLAS Chapter II, Part C, Regulation 7, Paragraph 2.2.

"A fixed fire detection and fire alarm system and a sample extraction smoke detection system required in this regulation and other regulations in this part shall be of an approved type and comply with the Fire Safety Systems Code." (cf. International Maritime Organization c, 2009, p. 123) Furthermore, this regulation references the FSS Code, which regulates this type of smoke detection system in Chapter 10 (cf. International Maritime Organization b, 2007, pp. 25-26).
In systems like this, the air in the hold is constantly pumped out through the same pipes that would be used to introduce CO_2 into the hold. This air is checked for smoke particles by smoke detectors in the CO_2 room. Each of the six holds is monitored by a single smoke detector.

In both the CO_2 room and on the bridge, there is a *smoke detection panel*, that shows the hold in which smoke has been detected. There is also a *fire alarm panel* on the bridge, in the engine control room and in the *fire station* on the *coaming deck* in the deckhouse. Furthermore, there are three manual alarms on deck: in the *boatswain's store* and on the *coaming deck* on the port and starboard sides of the deckhouse. These can be used by the crew or by stevedores when the vessel is in port in order to raise the alarm in the event of a fire being noticed.

Neither flame detectors nor heat detectors are installed in the holds to detect fires.

3.1.3. CO_2 firefighting system

As described in the previous section, the CO_2 system on this vessel is combined with the smoke detection system for all six holds.
Storage of the fire extinguishing medium is regulated in SOLAS, Chapter II, Part C, Regulation 10, Paragraph 4.3: *"When the fire-extinguishing medium is stored outside a protected space, it shall be stored in a room which is located behind the forward collision bulkhead, and is used for no other purposes. Any entrance to such a storage room shall preferably be from the open deck and shall be independent of the protected space. If the storage space is located below deck, it shall be located no more than one deck below the open deck and shall be directly accessible by a stairway or ladder from the open deck. Spaces which are located below deck or spaces where access from the open deck is not provided shall be fitted with a mechanical ventilation system designed to take exhaust air from the bottom of the space and shall be sized to provide at least 6 air changes per hour. Access doors shall open outwards, and bulkheads and decks, including doors and other means of closing any opening therein, which form the boundaries between such rooms and adjacent enclosed spaces shall be gastight. For the purpose of the application of tables 9.1 to 9.8, such storage rooms shall be treated as fire control stations."* (cf. International Maritime Organization c, 2009, p. 158).

On the example vessel, the CO_2 is stored in a bottle store in a separate room at the aft of the vessel on the port side next to the *steering gear room*.
According to Chapter 5, Paragraph 2.2.1.1 of the FSS Code, the quantity of CO_2 available shall be sufficient to protect at least 30 % of the volume of the largest cargo space (cf. International Maritime Organization b, 2007, p. 8).

The release of CO_2 into the holds is triggered remotely in the *fire station* on the *coaming deck* or directly in the CO_2 room. This is to comply with Chapter 5, Paragraph 2.2.2.1 of the FSS Code, which requires at least two separate stations for releasing carbon dioxide to be present (cf. International Maritime Organization b, 2007, p. 9). Each hold can be flooded with CO_2 independently. Remote controls are available on the bridge and in the *fire station* to switch off the hold ventilators on the vessel. The ventilator flaps on the pontoon covers must also be closed to ensure that the CO_2 system is used as efficiently as possible.

3.1.4. Seawater firefighting systems

The most important system on board for extinguishing fires is the seawater firefighting system.

Provided that the pumps are intact, it provides an unlimited supply of fire extinguishing medium (seawater). The general regulations for this system are laid down in SOLAS Chapter II, Part C, Regulation 10, Paragraphs 2.1 - 2.1.1:

"Ships shall be provided with fire pumps, fire mains, hydrants and hoses complying with the applicable requirements of this regulation."

"Materials readily rendered ineffective by heat shall not be used for fire mains and hydrants unless adequately protected. The pipes and hydrants shall be so placed that the fire hoses may be easily coupled to them. The arrangement of pipes and hydrants shall be such as to avoid the possibility of freezing. Suitable drainage provisions shall be provided for fire main piping. Isolation valves shall be installed for all open deck fire main branches used for purposes other than fire fighting. In ships where deck cargo may be carried, the positions of the hydrants shall be such that they are always readily accessible and the pipes shall be arranged as far as practicable to avoid risk of damage by such cargo." (cf. International Maritime Organization c, 2009, p. 153).

3.1.4.1. Pumps

Immediate availability of water for firefighting is regulated in SOLAS, Chapter II, Part C, Regulation 10, Paragraph 2.1.2.2: *"in cargo ships: to the satisfaction of the Administration; and, with a periodically unattended machinery space or when only one person is required on watch, there shall be immediate water delivery from the fire main system at a suitable pressure, either by remote starting of one of the main fire pumps with remote starting from the navigation bridge and fire control station, if any, or permanent pressurization of the fire main system by one of the main fire pumps, except that the Administration may waive this requirement for cargo ships of less than 1,600 gross tonnage if the fire pump starting arrangement in the machinery space is in an easily accessible position."* (cf. International Maritime Organization c, 2009, p. 153).

On the example vessel, there are two main fire pumps, each with a capacity of 350 m^3 per hour. The pumps are located next to each other on the *tank top* in the forward section of the machine room and are also used as bilge pumps and general service pumps. The vessel is also equipped with an emergency fire pump with a capacity of 90 m^3 per hour. This pump is located in the combined *bow thruster & emergency fire pump room* at the forward part of the vessel. This room also contains the pump that supplies the sprinkler system in *No.2 cargo hold*. Each of the four pumps can be controlled from the bridge and from the *fire station*. This pump capacity meets the requirements of SOLAS Chapter II, Part C, Regulation 10, Paragraph 2.2.4.2:

"Each of the required fire pumps [...] shall have a capacity not less than 80% of the total required capacity divided by the minimum number of required fire pumps but in any case not less than 25m^3/h, and each such pump shall in any event be capable of delivering at least the two required jets of water. These fire pumps shall be capable of supplying the fire main system under the required conditions. Where more pumps than the minimum of required pumps are installed, such additional pumps shall have a capacity of at least 25 m^3/h and shall be capable of delivering at least the two jets of water required in paragraph 2.1.5.1." (cf. International Maritime Organization c, 2009, p. 156).

3.1.4.2. International shore connection

The international shore connection is provided for supplying water to the vessel's firefighting system from outside the vessel. The vessel under consideration in this dissertation is fitted with a connection on the port side and the starboard side of the *coaming deck* at the rear of the deckhouse. SOLAS requires all vessels with a gross tonnage above 500 tons to be fitted with a shore connection compliant with the FSS Code. It must be possible to use this connection from either side of the vessel (cf. International Maritime Organization c, 2009, p. 155). The FSS Code provides detailed descriptions of the material quality, the dimensions of the connection and on accessories such as bolts and seals (cf. International Maritime Organization b, 2007, pp. 2-3).

3.1.4.3. Seawater firefighting system on deck

On the example vessel, the seawater firefighting system on deck comprises a total of 24 hydrants on the main deck and 16 hydrants on the decks of the deckhouse, from the *navigation bridge deck* down to the *coaming deck.* Three of the hydrants on deck are on the *forecastle deck* and one is on the *aft mooring station*. There are two hydrants on each deck of the deckhouse.
The SOLAS convention regulates the number and position of the hydrants in Chapter II, Part C, Regulation 10, Paragraph 2.1.5. (1):
"The number and position of hydrants shall be such that at least two jets of water not emanating from the same hydrant, one of which shall be from a single length of hose, may reach any part of the ship normally accessible to the passengers or crew while the ship is being navigated and any part of any cargo space when empty, any ro-ro space or any vehicle space in which latter case the two jets shall reach any part of the space, each from a single length of hose. Furthermore, such hydrants shall be positioned near the accesses to the protected spaces." (cf. International Maritime Organization c, 2009, p. 154).
The *Fire Control and Safety Plan* of the vessel under consideration shows that the hydrants are at least 11.4 meters apart on the *forecastle deck* and a maximum of 37.4 meters apart in the vicinity of *cargo hold no.4*. Furthermore, SOLAS Chapter II, Part C, Regulation 10, Paragraph 2.1.6 stipulates that minimum pressure at the hydrants shall be 0.27 N/mm², with the proviso that the pressure shall not be so high as to impact on effective handling of the hoses.

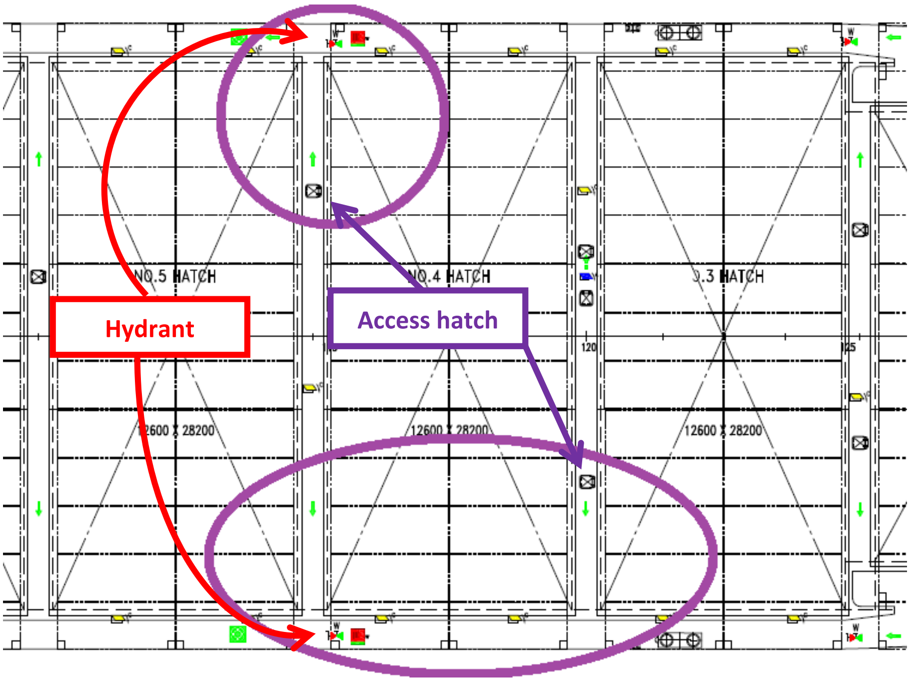
The length of the hoses is regulated by SOLAS Chapter II, Part C, Regulation 10, Paragraph 2.3.1.1, according to which all hoses on open decks on ships with a maximum breadth in excess of 30 meters must be a maximum of 25 meters in length (cf. International Maritime Organization c, 2009, p. 157). To allow firefighting crews on deck to utilize the water, there are twelve hose boxes with handline nozzles on the *upper deck*. Two further hose boxes are fitted on the *forecastle deck*. There are a total of 16 hose boxes in the deckhouse, from the *navigation bridge deck* down to the *coaming deck*, i.e. two per deck. This quantity of hoses complies with SOLAS Chapter II, Part C, Rule 10, Paragraph 2.3.2.3.1:
"In cargo ships of 1,000 gross tonnage and upwards, the number of fire hoses to be provided shall be one for each 30 m length of the ship and one spare, but in no case less than five in all. This number does not include any hoses required in any engine-room or boiler room. The Administration may increase the number of hoses required so as to ensure that hoses in sufficient number are available and accessible at all times, having regard to the type of ship and the nature of trade in which the ship is employed. Ships carrying dangerous goods in accordance with regulation 19 shall be provided with three hoses and nozzles, in addition to those required above." (cf. International Maritime Organization c, 2009, p. 157).

The distance between the hose boxes on the *coaming deck* and the closest hose boxes aft on the *upper deck* is 17 meters on both the port and starboard sides. Apart from the hose boxes in the deckhouse, these boxes have the least distance between them.
The greatest distance between two hose boxes is 56 meters between the hose boxes on *hatch no. 4* and the hose boxes on the *forecastle deck*.

It should be noted that, according to the plan, not every hydrant on deck has a hose box in its immediate vicinity:
The hydrants between *hatch no. 2* and *hatch no. 3*, the hydrants at *hatch no. 14* and the hydrants at the *aft mooring station* do not have a hose box in their direct vicinity.

3.1.4.4. Seawater firefighting system in the cargo space

The previous section has already quoted SOLAS Chapter II, Part C, Regulation 10, Paragraph 2.1.5.1, which stipulates that any part of the empty cargo space must be able to be reached by two jets of water from two separate, single lengths of hose. The vessel under consideration fulfills this regulation by arranging the hydrants in each hold in such a way that two hydrants are provided, one on the port and one on the starboard side, each in the vicinity of an access hatch to the hold.



The figure shows that, on both sides of the vessel, there is a hold access hatch that is closer to a hydrant, and that this can thus be reached by a 25 meter hose. This example, showing hold no. 2, is also applicable to the other holds on the vessel.

Figure 15, Arrangement of the hydrants for protection of the cargo space
Source: Own presentation, source of data: Fire Control and Safety Plan of the example vess

In addition to the hydrants on deck, there are four hydrants in the *passageway* on the starboard side of the *platform deck*. Each hold has two entrances from the *passageway* to the lateral passages, which can also be reached from the access hatches on deck. This does not apply to hold 1, to which there is only one entrance from deck and one entrance from the *passageway*. The *passageway* can be accessed from aft, from the engine room and from forward. This means that it is also possible to reach the holds from here using jointed lengths of hose.

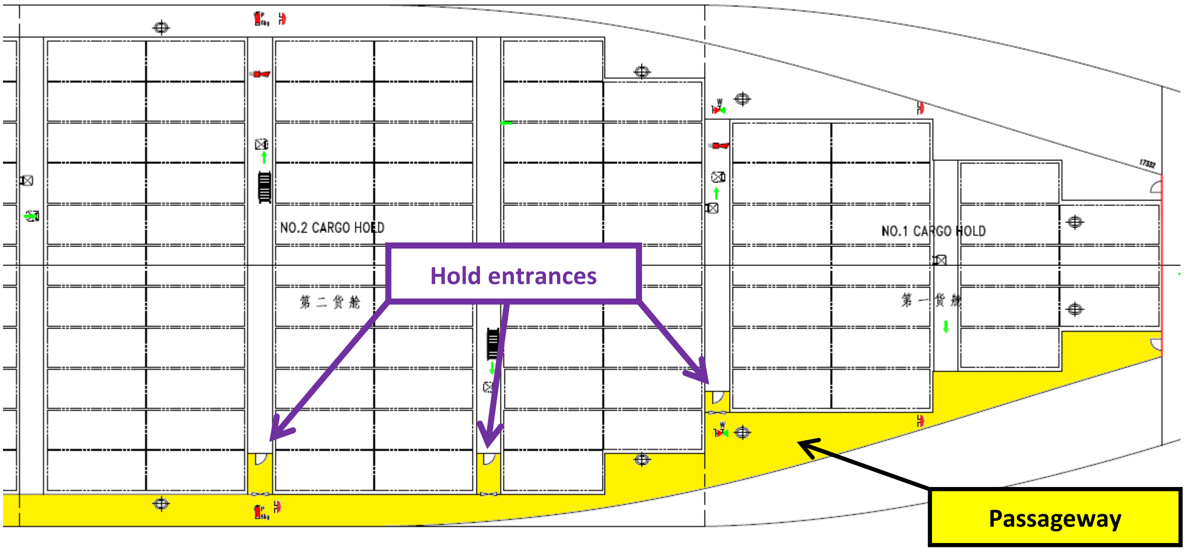


Figure 16, Entrances to the hold from the passageway
Source: Own presentation, source of data: Fire Control and Safety Plan of the example vessel

Only *no. 2 cargo hold* is fitted with a seawater sprinkler system to protect the cargo, particularly hazardous cargo. This is supplied by the above-mentioned pump in the *bow thruster & emergency fire pump room*, and can be started both from the bridge and from the *fire station*. The plans available show no further details of the seawater sprinkler system.

The personal experience on container vessels of the author of this dissertation suggests that the pipes and nozzles are integrated in the pontoon covers. This means that in the event of a fire, it is necessary to connect hoses between the hydrants and the pontoon covers.

According to SOLAS Chapter II, Part G, Regulation 19, Paragraph 3.1.3, the sprinkler system must be capable of delivering at least five liters of water per square meter per minute (cf. International Maritime Organization c, 2009, p. 185) to comply with the regulations for transporting hazardous goods.

3.1.5. Personal fire protection equipment

The *Fire Control and Safety Plan* describes not only the equipment requirements in respect of the construction of the vessel, but also the personal fire protection equipment of each member of a firefighting crew. It states that each *fireman's outfit* must comprise protective clothing, boots and an adjustable helmet. It furthermore includes an explosion-proof flashlight, an axe with handle insulated to high voltages, compressed air breathing apparatus (CABA) and a 30-meter fireproof safety line. The compressor for refilling the compressed air bottles is located in the *safety locker* on C deck. There should be two spare bottles for each compressed air breathing apparatus. Each of these should have a capacity of 1200 liters.

According to the plan, there are two CABAs on board: One is located in the *fire station* on the *coaming deck* and the other in the *safety locker* on C deck. This meets the international regulations for cargo ships as laid down in SOLAS Chapter II, Part C, Regulation 10, Paragraph 10.2.1 in combination with Chapter 3, Paragraph 2.1 of the FSS Code (cf. International Maritime Organization c, 2009, p. 163) (cf. International Maritime Organization b, 2007, p. 3). The two *fireman's outfits* are located in the *boatswain's store* in the *forecastle* and in the *fire station* on the *coaming deck*. There is an axe in the *boatswain's store* and on the *aft mooring station* (*fire axe*).

The table in the *Fire Control and Safety Plan* does not list the two additional CABAs required for classification as per SOLAS II-2, Regulation 19. The classification details in the *Fire Control and Safety Plan* show that the example vessel is approved for transporting hazardous goods and is thus obliged to carry additional protection/fire protection equipment.

GL ⊞ 100A5, E, Container Ship, SOLAS II–2 Reg.19, IW, BWM
⊞ MC, AUT,E

Figure 17, Extract from *Fire Control and Safety Plan* with classification details
Source: Fire Control and Safety Plan of the example vessel

3.1.6. Drills and crew training

SOLAS also regulates the training of the crew, as well as the equipment on a ship. The conduct of firefighting drills is regulated in SOLAS Chapter III, Part B, Regulation 19, Paragraph 3.4:

"3.4.2 Each fire drill shall include,

.1 reporting to stations and preparing for the duties described in the muster list required by regulation 8;

.2 starting of a fire pump, using at least the two required jets of water to show that the system is in proper working order;

.3 checking of fireman' s outfit and other personal rescue equipment;

.4 checking of relevant communication equipment;

.5 checking the operation of watertight doors, fire doors, fire dampers and main inlets and outlets of ventilation systems in the drill area;

.6 checking the necessary arrangements for subsequent abandoning of the ship." (cf. International Maritime Organization c, 2009, p. 210).

Each member of the crew must take part in a drill with this content at least once a month. SOLAS Chapter III, Part B, Regulation 19, Paragraph 3.1-3.2 requires that the scope and content of such emergency drills should be as if there were a real emergency (cf. International Maritime Organization c, 2009, pp. 211-212).

No information is available on the initial and ongoing training of the crew of the example vessel. In his 2014 dissertation for Bremen University entitled *Brandbekämpfung auf Handelsschiffen - Potenziale zur Steigerung von Effektivität und Sicherheit durch Ausrüstung und Ausbildung*, Dennis Müller-Lohse discusses initial and ongoing training in respect of fire protection equipment. One of the conclusions of this dissertation was that only 18.5 % of the vessels surveyed made use of resources for conducting safety drills in a realistic manner (cf. Müller-Lohse, 2014, p. 94).

A questionnaire was used to collect data on the rapid deployment capabilities of the firefighting crews. The data showed that only 25 % of the vessels surveyed achieved a time of less than 5 minutes to equip the crews with CABAs. The survey showed that realistic drills using appropriate resources were only conducted on 7.9 % of the vessels surveyed. Overall, only half the vessels surveyed included in their drills all the items of drill that the author of the dissertation named in his questionnaire (cf. Müller-Lohse, 2014, pp. 79-80).

3.2. Critical examination of possible firefighting activities by theoretical simulation of fire events and firefighting measures

This chapter will confront the fire protection equipment of the example vessel as listed above with imaginary fire scenarios in order to identify how it would be possible for the crew to fight the fire with the available equipment. To do this, we shall first establish standards to ensure that each scenario is examined under the same conditions.

The *Fire Control and Safety Plan* gives the size of the crew as 30 persons. For this examination, this number will be reduced to the more realistic number of 21 persons, namely:

Ship management:	Captain, 1st Officer, 2nd Officer, 3rd Officer
Engineering:	Chief Engineer, 2nd Engineer, 3rd Engineer, Electro-technical Officer
Deck crew:	Boatswain, 3 x Able-Bodied Seaman (AB), 2 x Ordinary Seaman (OS)
Engine room crew:	Fitter, 2 x Oiler, Wiper
Stewards:	Chief Cook, Steward, Messman

This list was compiled on the basis of a current crew list of a vessel known to the author of this dissertation.

This crew size and the four CABAs available result in the following assignment of tasks:

There will be one firefighting crew and one support crew. Each crew has two apparatus wearers, who are actively deployed, and two support crew whose job is to help don the equipment and to fetch the firefighting material (hoses, nozzles, fire extinguishers, etc.) and spare bottles. Both crews are supervised by the 3rd Officer.

Together with the 2nd Officer, the Steward's department is responsible for providing first aid to any injured persons.

Firefighting crew:	AB (wearer),OS (wearer), Fitter, Oiler
Support crew:	AB (wearer),OS (wearer), Oiler, Wiper
First aid crew:	2nd Officer, Chief Cook, Steward, Messman

Together with the 3rd Engineer, the Boatswain constantly refills the compressed air bottles that are emptied during use.

Together with an AB as helmsman, the Captain is on the bridge and takes over navigation and communication with external parties.

The Chief Engineer, the 2nd Engineer and the Electro-technical Officer are in the engine control room in order to ensure the supply of power and water.

The 1st Officer is the officer in charge and is responsible for muster on deck and coordination of firefighting activities. This simulation takes no account of the possibility that hazardous goods have been stowed.

The muster station is on the port side of B deck.

This division of responsibilities between the crew was chosen by the author on the basis of his experience on various container vessels of a similar size.

The timing of the scenarios described in this chapter is not defined. This precludes any pros or cons, for instance in respect of visibility on deck or tiredness on the part of the crew. Furthermore, any possible influences of weather or rough seas are also ignored. The potential benefits of rain on a fire on deck, restrictions to movement as a result of rough seas and any reduction in the reach of handline nozzles due to strong winds are excluded from consideration in order to provide a neutral initial situation for each scenario.

In all cases, the example vessel is underway, is fully loaded with containers and is not in a position to call on external assistance. The period simulated is restricted to the time between detection of the fire and the point at which a firefighting scenario has been established in which the crew has exhausted all options for fighting the fire. The simulation will not cover any putative success or otherwise of the measures taken to fight the fire.

In each of the scenarios, the time taken to cover any distances will be shown, thus allowing the total preparation time until firefighting actually begins to be measured. The speed of a crew member will be restricted to 8 km/h (2.22 m/s). Running in the narrow passages on board while wearing the firefighting equipment is dangerous and the firefighters are forbidden to do so. The speed was chosen on the basis of the sport of *Nordic walking*, in which the aim is to walk as fast as possible without breaking into a run. One foot is always in contact with the ground when walking. In this sport, 8 km/h represents a speed within the top third of the speeds that can be achieved (cf. ProfiWalk, 2016).

In each of the simulations, the time a CABA will last is restricted to 30 minutes. Under ideal conditions, a 6-liter bottle will contain 1800 liters of air at 300 bar. Under realistic conditions, this will be 1650 liters. In the scenarios simulated, the crew's consumption of air is estimated to be approximately 50 liters per minute while carrying out comparatively strenuous work. This results in a realistic operational time of 33 minutes ($1650^{\text{liters}} / 50^{\text{liters/minute}}$ = 33 minutes) (cf. Freiwillige Feuerwehr Semd e.V., n.d.).

In each case, the position of the fire is marked by a red rectangle in both an overall view and a detailed view. In each scenario, a 40-foot container with unknown contents is on fire. A considerable amount of smoke is being produced and flames are occasionally observed.

3.2.1 Scenario 1: Fire forward of the deckhouse, on deck

In the first scenario, a container in the forward part of the vessel is on fire. The container is in bay no. 3, row 02 and tier no. 3.

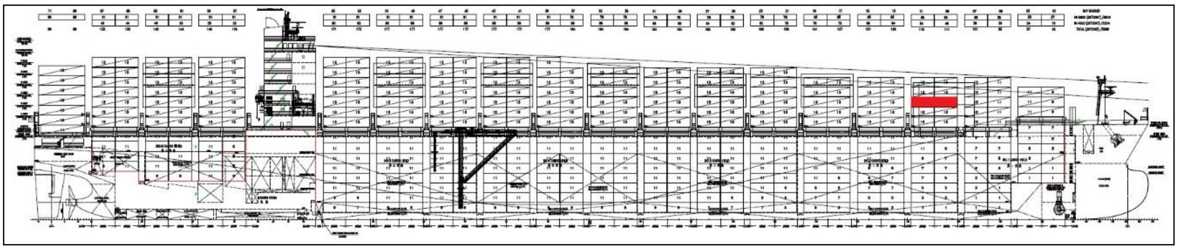


Figure 18, Side view of the entire vessel with burning container, scenario 1
Source: Own presentation, source of data: *Fire Control and Safety Plan* of the example vessel

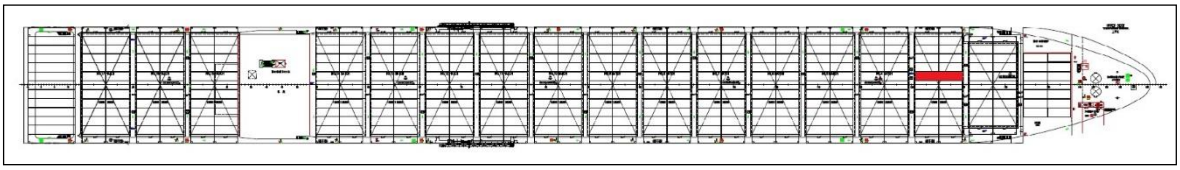


Figure 19, Top view of the entire vessel with burning container, scenario 1
Source: Own presentation, source of data: *Fire Control and Safety Plan* of the example vessel

The considerable amount of smoke produced causes the officer on watch on the bridge to first notice the fire. After informing the captain, the officer sounds the general alarm, thus causing the crew to muster.

10 minutes are needed for the entire crew to report to the muster station after the general alarm has sounded. After the crew have been informed of the reason for the muster, the firefighting crew and the support crew are equipped with CABAs. This takes a further 10 minutes.
The officer in charge decides to cool the front and back of the burning container and the neighboring containers with seawater. Including the distance from B deck to the *upper deck*, the distance from the deckhouse to the deployment area is approximately 180 meters. The crews require 1.5 minutes to cover this distance.
Both crews advance to *hatch no. 4*. Each connects a 25-meter length of hose (shown in magenta in Figure 21) to the nearest hydrant and starts cooling the containers. There is no hose box in the immediate vicinity of the hydrant in front of the location of the fire, and so it is necessary to take a hose from a different hydrant (shown in blue in Figure 21). A further 5 minutes are needed to connect and roll out the hoses and for the firefighting crew and support crew to double-check their personal protection equipment before the command to turn on the water can be given.
Thus, more than 27 minutes have passed since the general alarm was sounded.

It is <u>not possible</u> for the crew to take the following actions:

- The introduction of water directly into the burning container and the neighboring containers would only be possible at extreme risk to the members of the crews wearing breathing apparatus and by means of ladders and breaking or cutting tools. This is therefore not an option.
- No further cooling measures in the danger area can be undertaken directly by the firefighting and support crews because there are no more CABAs available.

It is <u>possible</u> for the crew to take the following actions:

- Improvised monitors can be constructed in the lateral passages by securing handline nozzles with ropes or wire ropes. These would be used to provide further cooling in order to mitigate the risk of the container stack collapsing.
- Laying out handline nozzles on the hatch covers can deliver water to protect the covers from the heat of the fire.
- Further improvised monitors can be used to create a water curtain to contain the fire.

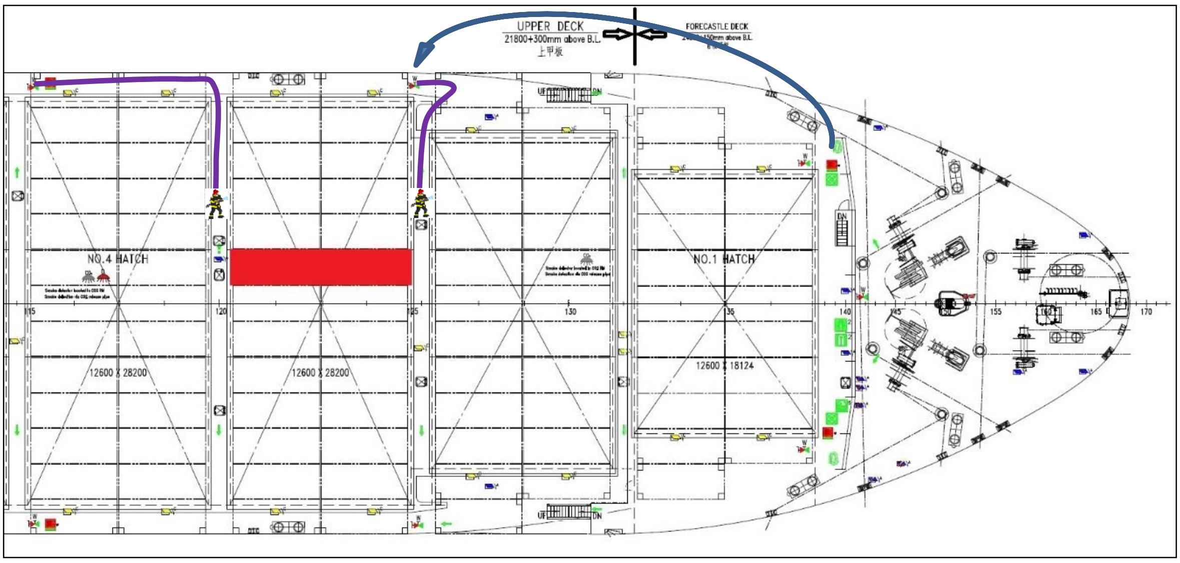


Figure 20, Top view of the forward part of the vessel with burning container
Source: Own presentation, source of data: *Fire Control and Safety Plan* of the example vessel

The possible additional measures on the part of the crew as listed above would require the constant deployment of at least four persons with breathing apparatus, as they would repeatedly have to work in the area affected by fumes. The rest of the crew would fetch the required firefighting resources and would relieve the persons wearing the breathing apparatus after a maximum of two consecutive periods of active firefighting to allow them to recuperate.

The fire on the CHARLOTTE MAERSK in 2010 provides a good comparison. The fire broke out on deck. It was only possible for the crew to control the fire until an external firefighting team arrived the next day. The crew made no attempt to open the containers or to puncture the container walls. To prevent the fire from spreading to the next bay and to allow the crew to be deployed more flexibly, handline nozzles were secured with ropes and used as improvised monitors. (cf. Danish Maritime Accident Investigation Board, 2012, pp. 12-19)

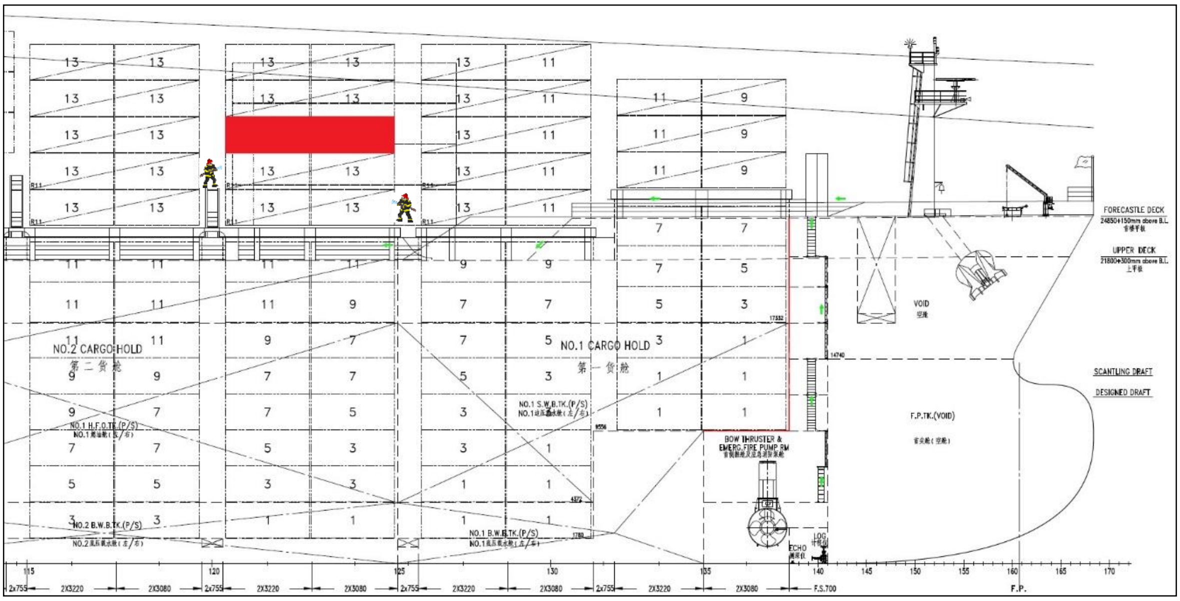


Figure 21, Side view of the forward part of the vessel with burning container
Source: Own presentation, source of data: *Fire Control and Safety Plan* of the example vessel

3.2.2 Scenario 2: Fire forward of the deckhouse, below deck

In the second scenario, a container below deck in the forward part of the vessel is on fire. The container is located in bay no. 7, row 01, tier no. 6 in hold 3.

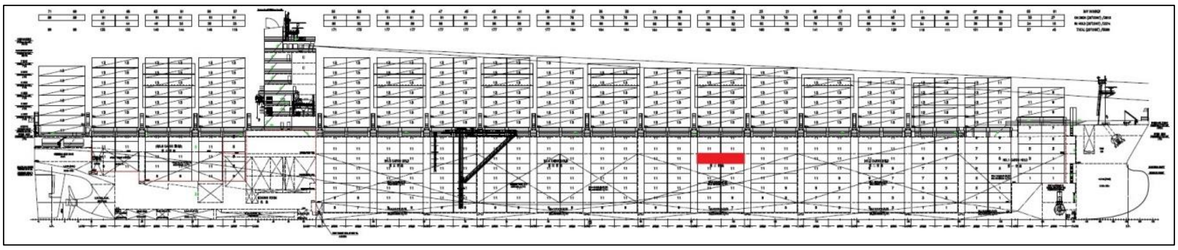


Figure 22, Side view of the entire vessel with burning container, scenario 2
Source: Own presentation, source of data: *Fire Control and Safety Plan* of the example vessel

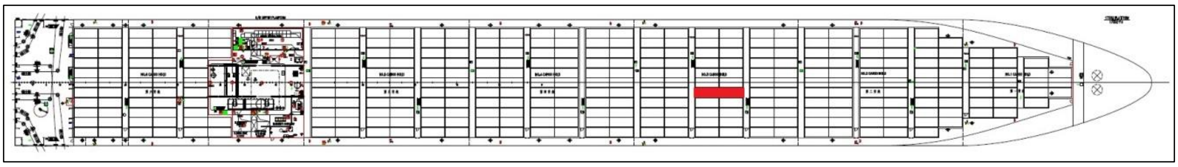


Figure 23, Top view of the entire vessel with burning container, scenario 2
Source: Own presentation, source of data: *Fire Control and Safety Plan* of the example vessel

The fire in hold 3 is reported by the *smoke detection panel* of the combined smoke extraction and carbon dioxide system on the bridge.

To eliminate the possibility of a false alarm, the duty AB is equipped with a UHF radio and sent to check the affected hold. The duty AB requires 2 minutes to cover the distance of approximately 150 meters from the bridge to the hold. He uses the UHF radio to report to the bridge that smoke is billowing from the ventilation outlet flaps. The captain is informed, general alarm is sounded and the muster procedure is started. It takes 10 minutes to muster and to inform the crew of the situation.

The officer in charge decides to flood the hold with CO_2. The bridge deactivates ventilation in all holds. The ventilation flaps have to be closed by hand. To do this, the firefighting crew and the support crew are issued with CABAs. A further 10 minutes are needed to issue the equipment.

The firefighting crew and the support crew approach on both the port and starboard sides and close all 14 ventilation flaps of hold no. 3. It takes 15 minutes to close the flaps including the time taken for the crews to cover the distance there and back.
After the ventilation flaps have been closed and a further check has been performed at the muster station to ensure that all the crew are present, CO_2 starts to be introduced to the hold.

Thus, 35 minutes have passed since the fire was detected.

It is not possible for the crew to take the following actions:

- To attempt to cool or extinguish the container directly would require an extensive search of the smoke-filled hold to find the container, which would represent a considerable risk to the crew. This measure cannot be considered, since, in the event of an incident that could immobilize one of the crew in the hold, there would not be sufficient time to undertake a rescue before the affected crew-member's compressed air ran out.

It is possible for the crew to take the following actions:

- Hoses can be laid out on deck to cool the vessel's structure and the pontoon hatch cover by pumping water over a large area (shown in green in Figures 25 and 26).
- A makeshift sprinkler system can be made by opening the ventilation grilles on the *upper deck* or by cutting through the ventilation flaps with cutting equipment to pump water into the hold (shown in magenta and blue in Figures 25 and 26). This would require a considerable amount of time working in the danger zone. The bilge pump of the hold would have to be able to pump out the quantity of water introduced in order to avoid free surface effects.

The cooling measures described would require the use of hoses and handline nozzles from the entire *upper deck*, as there is insufficient firefighting equipment in the direct vicinity.

A comparable incident occurred in 2005 on the German container vessel CMS PUNJAB SENATOR. In this case, nobody entered the hold in order to localize the fire. Instead, a visual inspection was carried out through the hold access hatch. The measures taken by the crew were restricted to the introduction of CO_2, the introduction of water through a modified ventilation flap and cooling of the *upper deck* and the pontoon cover (cf. Bundesstelle für Seeunfalluntersuchung, 2006, pp. 8-10).

Figure 24, Modified ventilation flap on the CMS PUNJAB SENATOR
Source: (Bundesstelle für Seeunfalluntersuchung, 2006, p. 9 Reederei Laeisz)

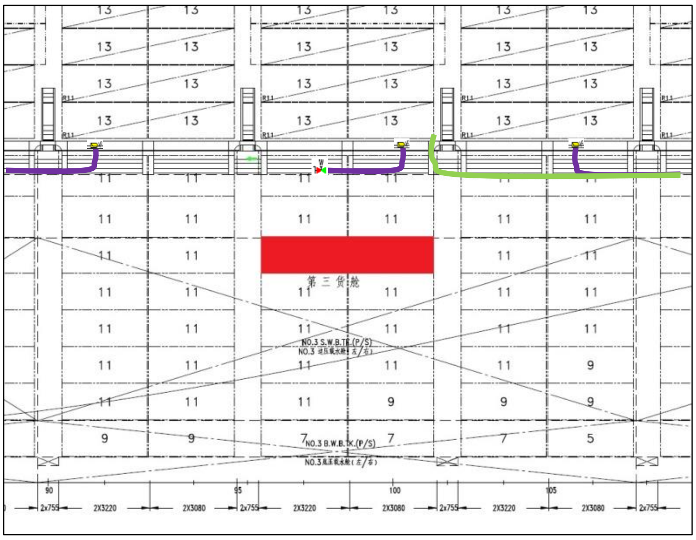


Figure 25, Side view of *platform deck*, hold 3 with burning container
Source: Own presentation, source of data: *Fire Control and Safety Plan* of the example vessel

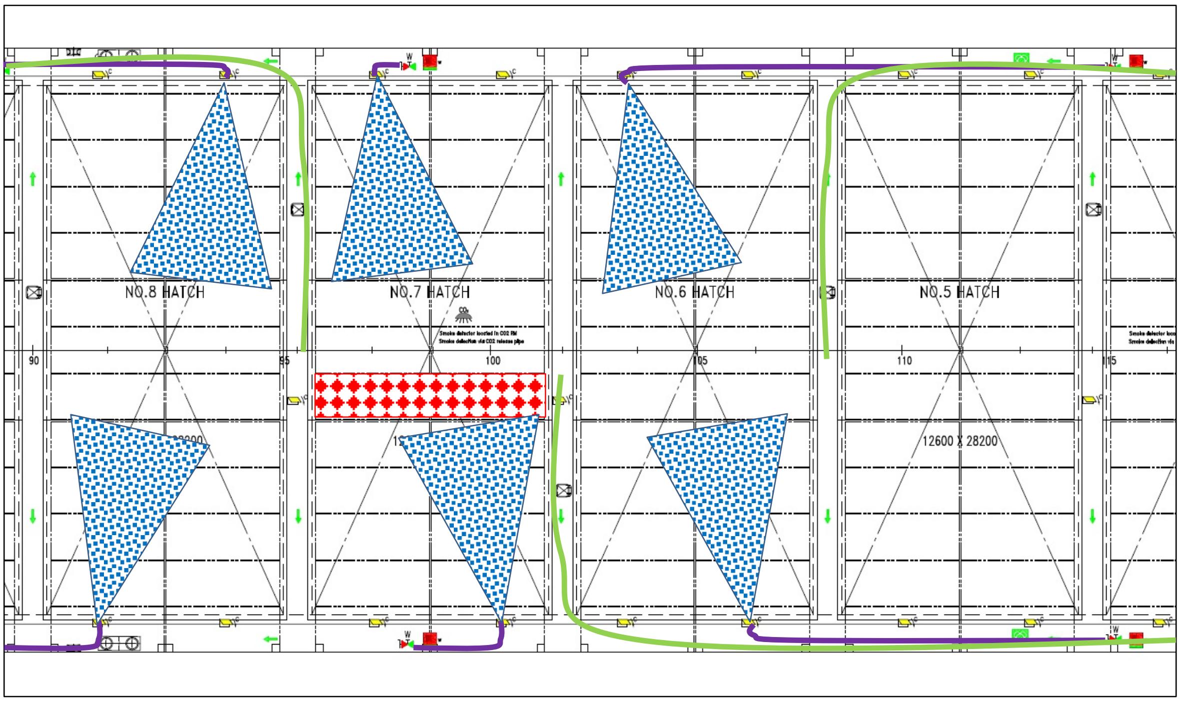


Figure 26, Top view of *upper deck*, hold 3 with burning container in hold
Source: Own presentation, source of data: *Fire Control and Safety Plan* of the example vessel

3.2.3 Scenario 3: Fire aft of the deckhouse, on deck

In the third scenario, a container at the aft of the vessel is on fire. The container is in bay no. 17, row 00 and tier no. 4.

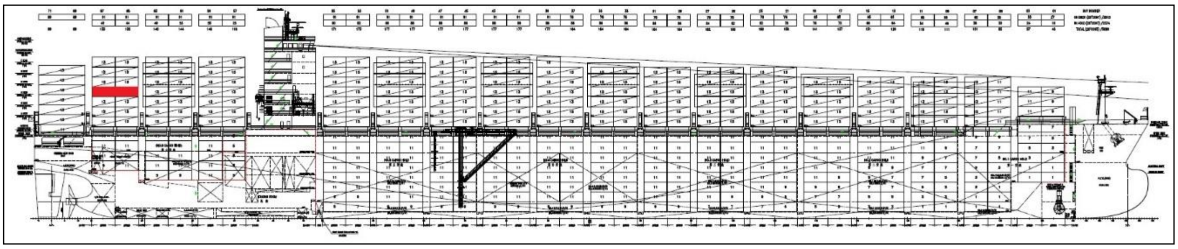


Figure 27, Side view of the entire vessel with burning container, scenario 3
Source: Own presentation, source of data: *Fire Control and Safety Plan* of the example vessel

The duty navigation officer on the bridge notices smoke at the aft of the vessel. After the master has been informed, general alarm is sounded from the bridge. The entire crew is mustered on the port side of B deck and muster is completed after 10 minutes. At the same time, the ventilators for the holds, the air conditioning and the engine room ventilators are all stopped.

The officer in charge decides that the firefighting crew and the support crew will be equipped with CABAs and will investigate the fire from the port side. To do this, the vessel is turned into the wind. The assignment of tasks, and the process of equipping the crew and turning the vessel into the wind take a further 10 minutes. The distance to the location of the incident is less than 50 meters and can be covered in less than a minute.

Hoses can be taken from the boxes and connected directly at the location of the incident. The firefighting crew and the support crew each advance to the location of the fire behind the affected container through a lateral passage with a connected hose and start fighting the fire. A little more than 20 minutes have passed since the fire was detected by the bridge officers.

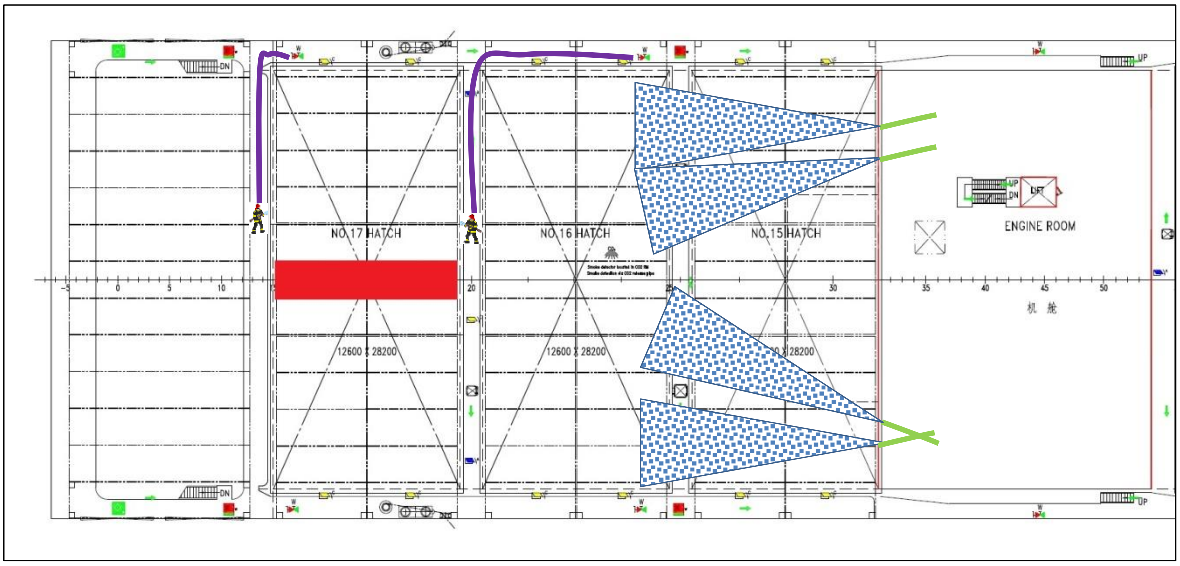


Figure 28, Top view of aft of vessel with burning container
Source: Own presentation, source of data: *Fire Control and Safety Plan* of the example vessel

It is <u>not possible</u> for the crew to take the following actions:

- As in the first scenario, the container is stowed in a tier that prevents the crew from puncturing the door or rear wall of the container to pump in water without the use of a ladder. In this scenario, the use of ladders cannot be considered for reasons of safety relating to the speed of escape in the event of deflagration or an explosion and the risk of falling.

It is <u>possible</u> for the crew to take the following actions:

- To at least make it more difficult for the fire to spread to containers stowed further forward of the fire or to the deckhouse, the crew can fix handline nozzles from the deckhouse pointing aft (shown in green and blue in Figures 28 and 29).
- Additional hoses secured in the lateral passages can make it more difficult for the fire to spread and protect the structural integrity of the stack of containers (shown in green and blue in Figure 29).

As in the first scenario, possible additional measures on the part of the crew would require the constant deployment of at least four persons with breathing apparatus, as they would repeatedly have to work in the area affected by fumes. Deployment with breathing apparatus is extremely strenuous and is stressful for the people concerned. The members of the firefighting crew and the support crew must be relieved after a maximum of two consecutive 30-minute stints. The additional firefighting equipment for installing the improvised monitors and deploying the hoses used for cooling is present on every deck of the deckhouse. There is one hose box and one hydrant on the port and starboard sides on each deck.

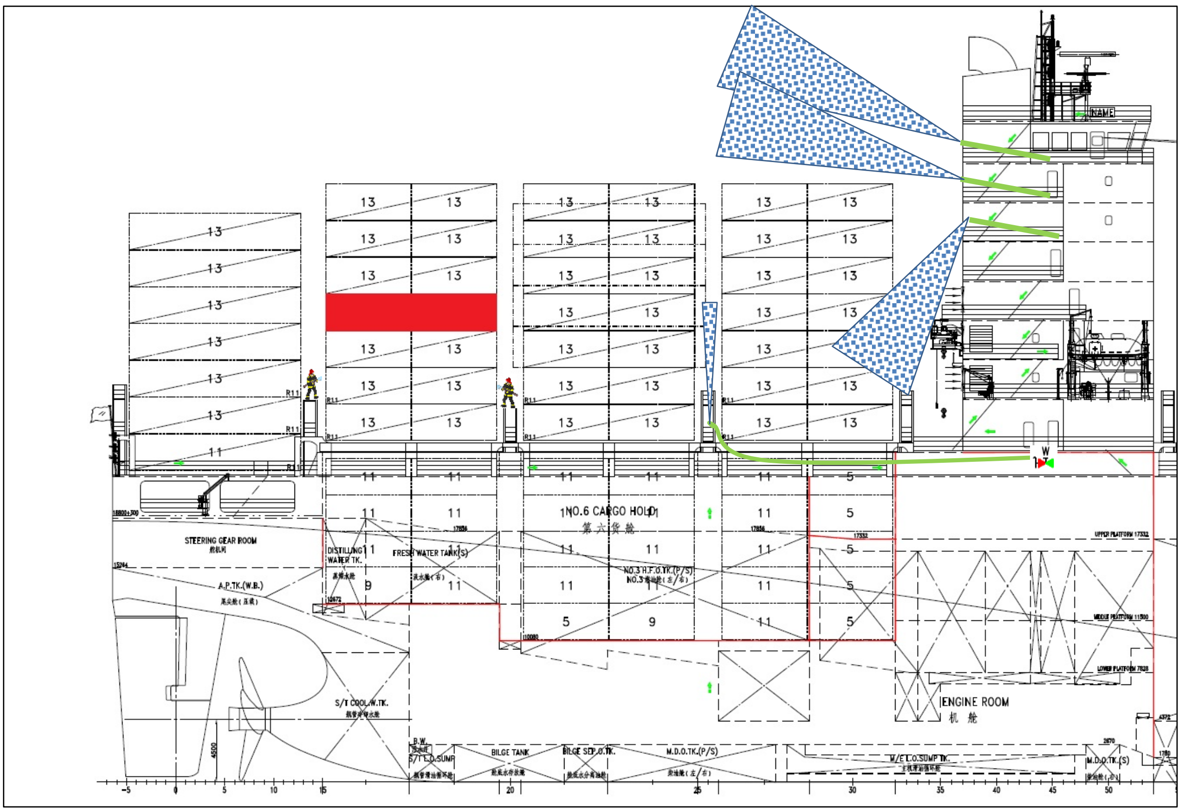


Figure 29, Side view of the aft of the vessel with burning container
Source: Own presentation, source of data: *Fire Control and Safety Plan* of the example vessel

A comparable scenario occurred on the EUGEN MAERSK in June 2013, when a container caught fire in a position at the aft of the vessel that was difficult for the crew to access. The fire broke out in the aftermost bay above the transom.
According to the crew, it was not possible to use special tools to penetrate the container due to the intense heat. The crew also reported that the tools were not strong enough to penetrate the walls of the container.
Furthermore, problems were reported concerning the vertical reach of the handline nozzles, which was judged to be inadequate for effective use against a fire in the upper tiers (cf. Danish Maritime Accident Investigation Board b, 2014, p. 10).

3.2.4 Scenario 4: Fire aft of the deckhouse, below deck

In the fourth scenario, a container in the aft of the vessel is on fire. The container is located in bay no. 15, row 09, in the first tier on the *tank top* in hold no. 6.

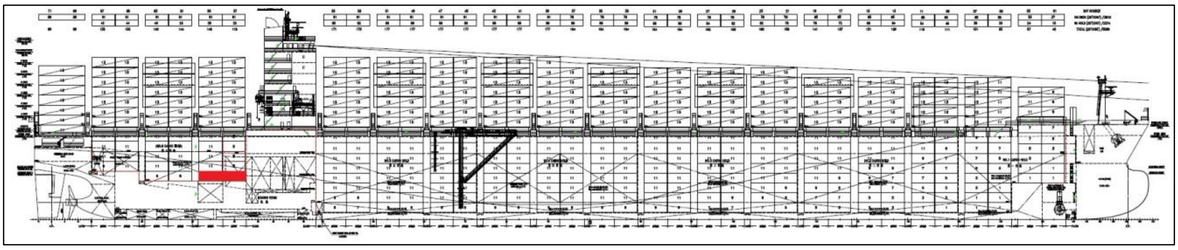


Figure 30, Side view of the entire vessel with burning container, scenario 4
Source: Own presentation, source of data: *Fire Control and Safety Plan* of the example vessel

As in the second scenario, the fire in hold 6 is reported by the *smoke detection panel* of the combined smoke extraction and carbon dioxide system on the bridge. Because the hold is immediately adjacent to the deckhouse, the duty officer can see from the bridge that smoke is coming from the ventilation flaps. In consultation with the master, the general alarm is sounded to muster the entire crew.

It takes 10 minutes until the entire crew is present. It takes a further 10 minutes to inform the crew and equip the firefighting crew and the support crew. All four persons equipped with breathing apparatus immediately start closing the ventilation flaps on the pontoon hatch covers and in the lateral passages. In the meantime, the remaining members of the crew prepare hoses and handline nozzles on the *upper deck*. The bridge deactivates the hold ventilators, the air conditioning and the engine room ventilators. The vessel is also turned into the wind.

When the firefighting crew reports heavy smoke in the hold, the officer in charge decides, after consultation with the bridge, to flood the hold with CO_2. A further 10 minutes are needed to close the 14 ventilation flaps.
After double-checking that everyone is present, CO_2 is pumped into the hold to extinguish the fire. 30 minutes have passed between the time the fire was detected and the time the extinguishing agent is pumped in.

It is not possible for the crew to take the following actions:

- As in the previous scenario, to attempt to cool or extinguish the container directly would require an extensive search of the smoke-filled hold to find the container, which would represent a considerable risk to the crew.

It is possible for the crew to take the following actions:

- Hoses on deck can be used to cool the vessel's structure and the pontoon hatch covers (shown in green in Figures 31 and 32).
- Again, a makeshift sprinkler system can be made by opening the ventilation grilles on the *upper deck* or by cutting through the ventilation flaps with cutting equipment to pump water into the hold (shown in magenta and blue in Figures 31 and 32). This would require a considerable amount of time working in the danger zone. The bilge pump of the hold would have to be able to pump out the quantity of water introduced in order to avoid free surface effects.
- Again, the crew can fix handline nozzles from the deckhouse pointing aft to protect the deckhouse and to cool the deck by pumping water over a large area (shown in green and blue in Figures 31 and 32).

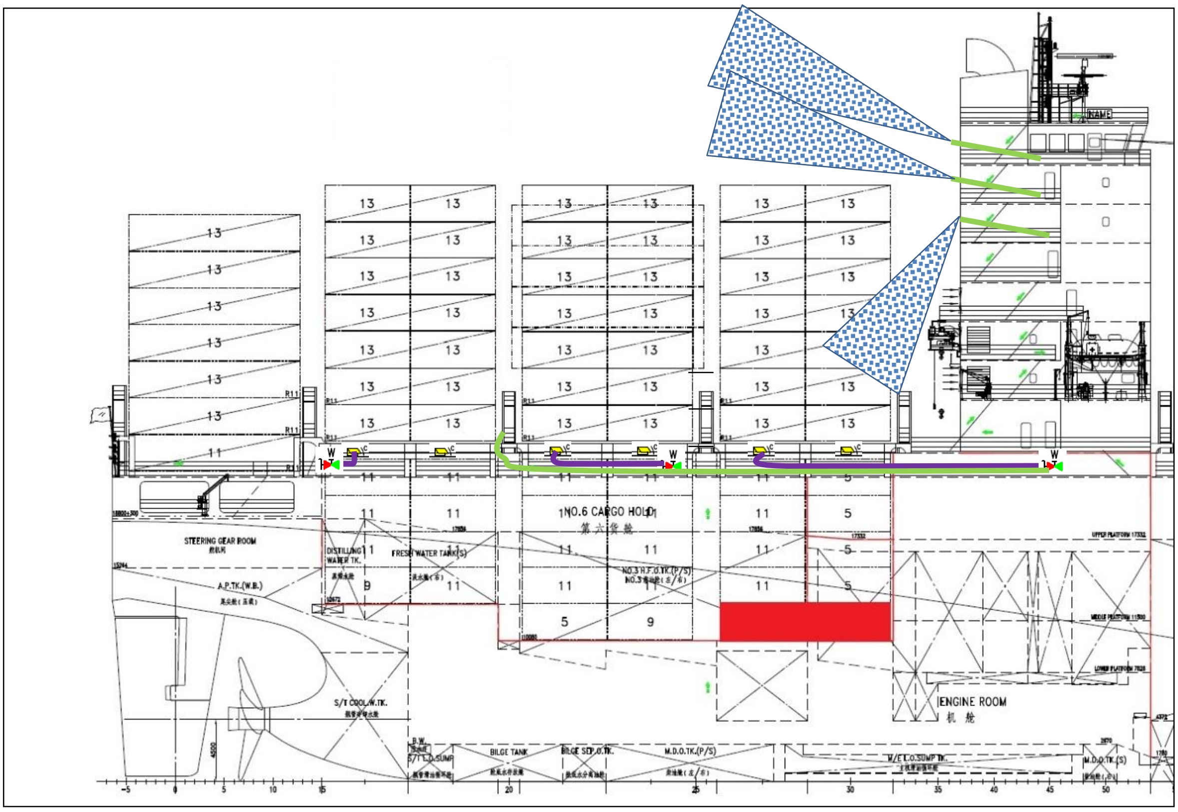


Figure 31, Side view of the aft of the vessel, hold 6 with burning container
Source: Own presentation, source of data: *Fire Control and Safety Plan* of the example vessel

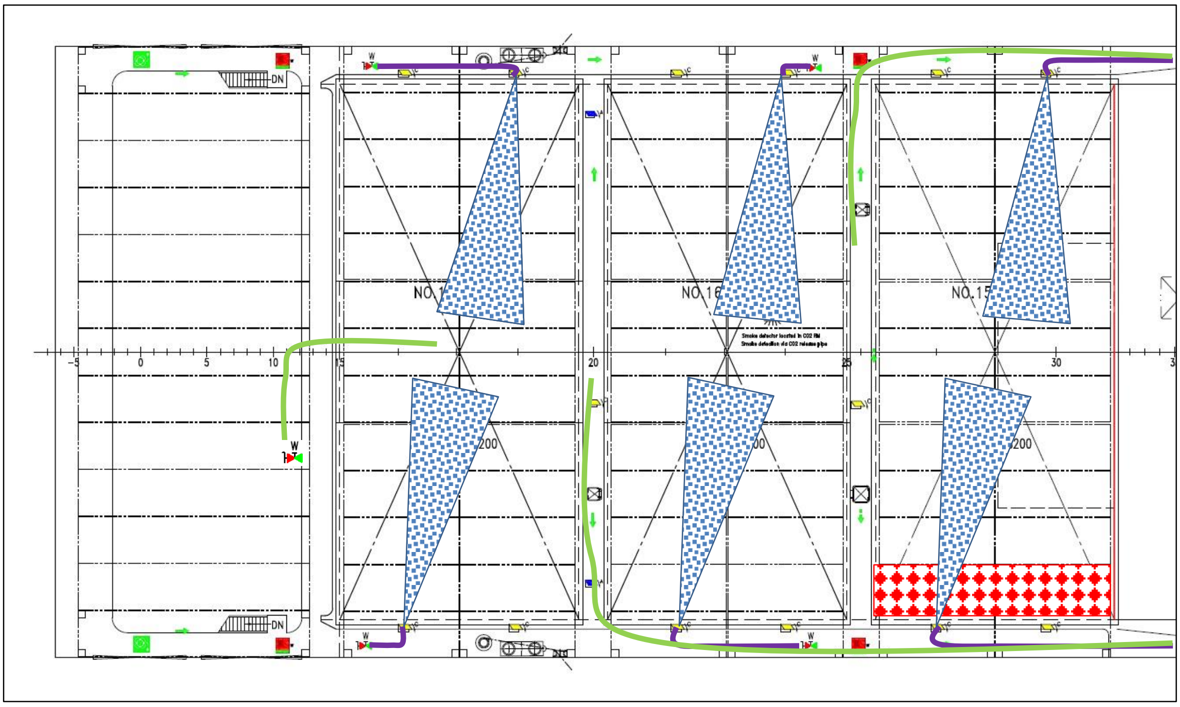


Figure 32, Top view of aft of vessel, *upper deck*, with burning container in hold
Source: Own presentation, source of data: *Fire Control and Safety Plan* of the example vessel

4. Analysis of losses resulting from fires on ships in the period 2000-2015

The primary focus of this dissertation is to collate incidences of cargo fires on fully cellular container vessels from the past 15 years and subject the collated data to scientific analysis.

The data collected falls within the following boundaries:

- Period: 01 January 2000 – 31 December 2015
- Vessel type: Fully cellular container vessel
- Kind of incident: Fire and/or explosion emanating from the cargo

The past 15 years was chosen as a suitable period since the size of the global FCC fleet, the sizes of the vessels themselves and the quantity of containers shipped globally have all shown significant growth during this time (cf. OECD, 2015, p. 15 ff).

The decision to restrict the analysis to fully cellular container vessels was taken jointly in advance by the *Gesamtverband der deutschen Versicherungswirtschaft e.V.* (GDV), the *Verein Hanseatischer Transportversicherer* e.V. (VHT), the examiner from Bremen University, the second examiner from the VHT, and the author of this dissertation in order to ensure a greater level of comparability between the individual incidents.

The decision only to consider incidents emanating from the cargo was also taken in advance of work on the topic by the author and the examiners.

4.1. Description of the procedure used

To allow scientific analysis of the collated incidents, a record was created for each incident comprising 16 items of data together with the name of the vessel. This data should allow the individual cases to be compared and will be used for an analysis elsewhere in this dissertation.

The following data was recorded:

- **Name of the vessel:**
  Name of the vessel at the time of the incident. The name of the vessel may have changed several times up to the present time as a result of a change of owner or charterer.
- **Year built:**
  This is always the year in which the vessel was delivered. The date is taken from the *Internet Ship Register* (cf. Internet Ships Register, 2016). Access to the register was made available by the VHT.
- **IMO number:**
  The IMO number identifies the hull from the start of construction through to the time the vessel is scrapped. It thus uniquely identifies the vessel independently of the name given to it by the owner or the charterer.
- **TEU capacity:**
  The capacity has deliberately been given as TEU (twenty-foot equivalent unit) rather than gross registered tonnage in order to make clear the relationship between damaged containers and the maximum number of containers that can be carried.

- **Flag:**
  The flag of the country in which the vessel was registered at the time of the incident.
- **Date:**
  Date of the incident.
- **Position of vessel:**
  The position of the vessel when the incident first arose. Here, the regions are given, rather than the precise geographical position, as it was not possible to identify the precise position in all cases.
- **Route:**
  Last port visited and next scheduled port for the vessel at the time of the incident.
- **Fatalities:**
  Persons who died as a direct result of the incident itself or as a consequence of the incident.
- **Injuries:**
  Persons injured as a direct result of the incident itself.
- **Destroyed/damaged containers:**
  Number of containers damaged or destroyed by fire, explosion, heat, mechanical forces, water or activities on the part of the firefighters.
- **Extent of fire as per DIN EN 14010:**
  In order to allow the individual cases to be compared, it was decided to classify the fires in accordance with DIN 14010 of the German Firefighting and Fire Protection Standards Committee (FNFW) entitled *Statements for Fire Statistics* (cf. Normenausschuss Feuerwehrwesen im DIN, 2005) (available in German only). DIN 14010 categorizes the extent of individual fires by the materials used to fight the fire.

The terms *small fire a*, *small fire b*, *medium fire* and *large fire* must be used and the fire extinguishing equipment used must be declared when marking the scope of the fire in accordance with DIN 14010.

A *small fire a* is defined as a fire for which a small extinguishing device was used.

A *small fire b* is defined as a fire for which a maximum of one C hose was used.

A *medium fire* is defined as a fire for which two to three C hoses were used simultaneously.

A *large fire* is defined as a fire for which more than three C hoses were used simultaneously.

DIN 14010 also includes a comparison of the extinguishing devices used to determine the scope of the fire:

According to DIN 14010, a small extinguishing device corresponds to:

- fire flapper
- bucket of sand
- pump-type fire extinguisher or stirrup pump
- fire extinguisher
- 1 DM sprinkler pipe
- 1 sprinkler

According to DIN 14010, one C hose corresponds to:

- handline nozzle delivering up to 200 liters/minute
- fog nail
- S2 heavy foam nozzle
- M2 medium foam nozzle
- light foam generator up to 200 liters/minute
- powder extinguisher with a firefighting agent capacity of up to 250 kg
- carbon dioxide extinguisher with a firefighting agent capacity of up to 200 kg
- 2 to 3 sprinklers

According to DIN 14010, two C hoses correspond to:

- BM handline nozzle
- handline nozzle delivering more than 200 liters/minute
- C hose delivering CAFS foam
- S4 heavy foam nozzle
- M4 medium foam nozzle
- light foam generator delivering more than 200 liters/minute
- extinguisher with a firefighting agent capacity between 250 kg and 750 kg

According to DIN 14010, four C hoses correspond to:

- heavy foam nozzle
- powder extinguisher with a firefighting agent capacity greater than 1500 kg

Figure 33. Own presentation, source: DIN 14010, 10.2005, pp. 13-14

This categorization must be supplemented by the firefighting agents which are used in the event of a fire on board ship. In this dissertation, the use of the carbon dioxide extinguishing system in the hold will be taken to identify a fire as a "medium-sized fire", as the existing categorization for a "small fire" only applies to the use of up to 200 kg of carbon dioxide.

Furthermore, support from firefighting monitors on a tug will identify a fire as a large fire. Abandonment of the vessel is also taken to identify a fire as a "large fire" in the framework of DIN 14010 in this dissertation.

- **Location of fire on board:**
  To identify the position of the fire on board, the vessel was broadly divided into 4 zones:

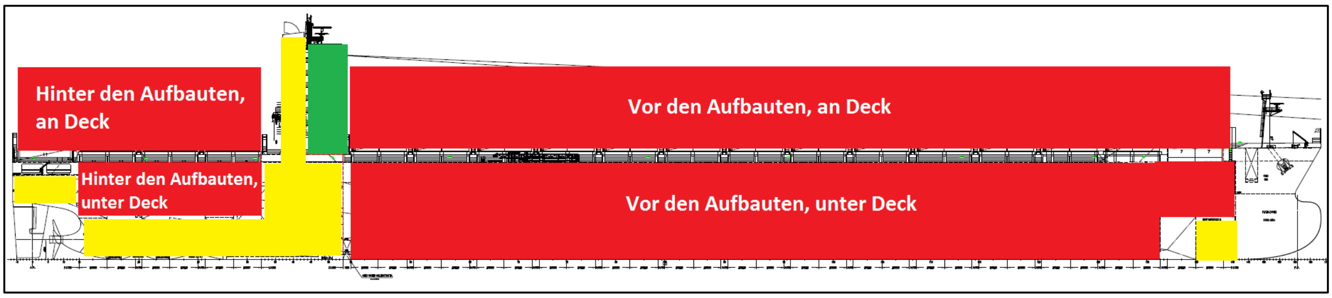


Figure 34, Division of the vessel into zones
Source: Own presentation

The red areas represent the cargo area, the yellow areas the engine and engineering areas and the green area represents the deckhouse.

- **Characteristics of fire:**
  A short description of the fire.
- **Time required to fight fire:**
  The period from the time at which the fire started up to the time that it was declared as extinguished. The time is given in days and hours.
- **External assistance:**
  List of the shore-based or water-based measures taken to support the firefighting.
- **Vessel salvaged / vessel scrapped:**
  Comments on what happened to the vessel after the incident.

4.2. Data basis

In order to collate the information on fires on fully cellular container vessels, the author searched the online archives of institutions of the various flag states responsible for investigating incidents on board ships in order to identify matching cases. These institutes include, for instance, the *Danish Maritime Accident Investigation Board* (DAMAIB) in Copenhagen and the *Bundesstelle für Seeunfalluntersuchung* in Hamburg. In addition, existing scientific papers and dissertations listing incidents that coincide with those considered in this dissertation were used.

These include, for instance, a Master's thesis from the World Maritime University in Malmö entitled *Application Of HFACS Tool For Analysis Of Investigation Reports Of Accidents Involving Containerized Dangerous Cargoes* (cf. Ren, 2009) from 2009 and a diploma dissertation from Bremen University entitled *Untersuchung von Ladungsbränden auf Containerschiffen (Investigation of cargo fires on container vessels)* (cf. Riecke, 2004) from 2004. Other incidents were identified as a result of searching through the weekly Casualty Newsletter published by London-based law firm *Roose & Partners*. Other sources that were used were statements from *Havariekommando* and the archive of the *Vereins Hanseatischer Transportversicherer e.V.*.

This research identified a total of 56 incidents of fires on fully cellular container vessels that fell within the scope considered in this dissertation.

A report in the *Container Ship Update*, published by DNV · GL, stated that there were 143 fire incidents on container vessels in the period 2000-2015, 56 of which were in the cargo area. The author of this report points to figures in the *IHS Fairplay Damage Database*. After comparing the number of incidents listed in the *CINS – Cargo Incident Notification System* and the incidents reported in the *IHS Fairplay Damage Database*, the author suggests that only around 10 % of explosion and fire incidents on fully cellular container vessels are made public (cf. Jost Bergmann, 01-2016, p. 28).

Using different research methods and different sources, this dissertation arrives at the same number of incidents using the same criteria for consideration. This allows us to consider the data basis to be confirmed.

The two charts below provide an overview of the quantity and quality of the collected data. The first chart shows the level of completeness of all the records: Thus, for example, there are 25 records for which all the data is present and 5 records for which only one value could be found.

The second chart shows that for more than two thirds of the incidents identified, 50% or more of the required data could be found. During subsequent analysis of the data, however, records with a completeness level less than 50% will also be used for some analyses, provided that the relevant data is present.

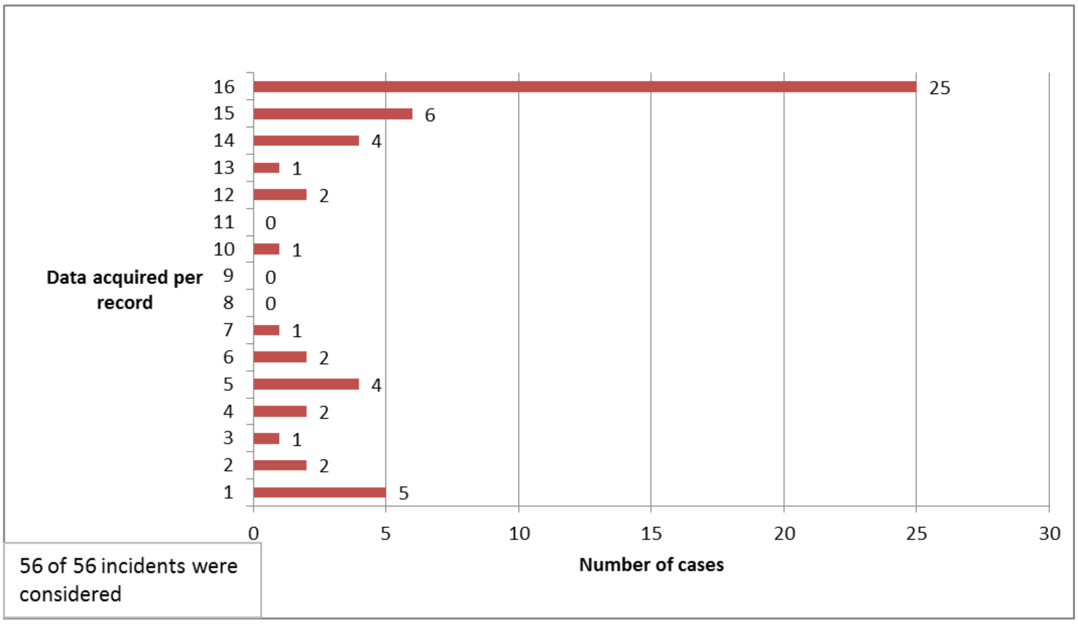


Figure 35, Completeness of the records
Source: Own presentation, source of data: List of incidents

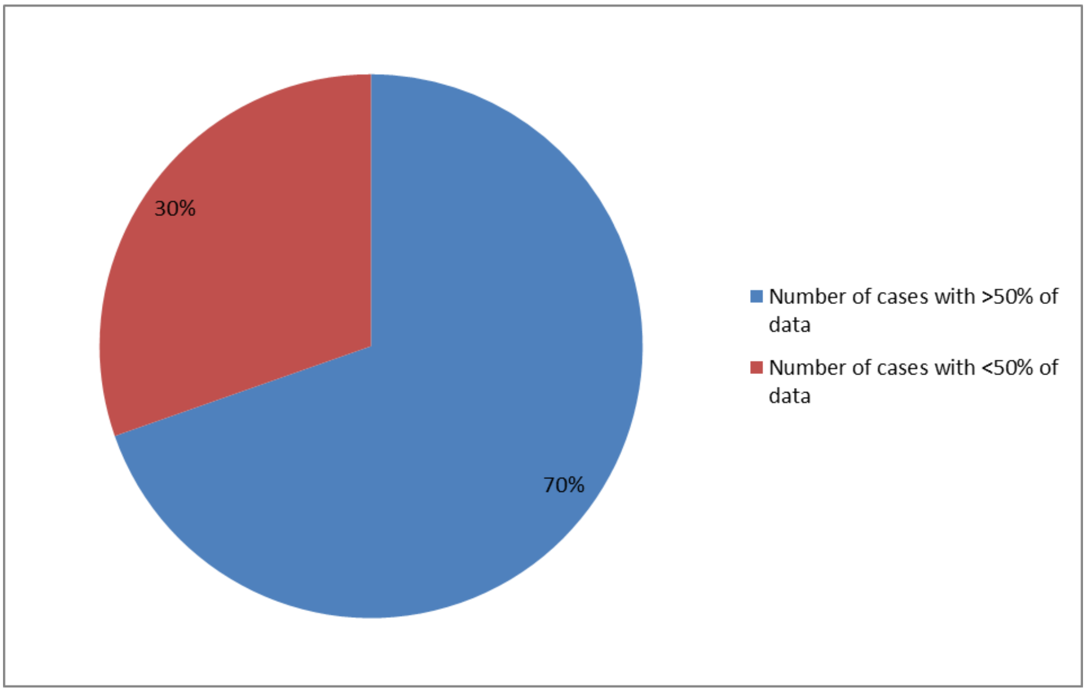


Figure 36, Share of usable records
Source: Own presentation, source of data: List of incidents

4.3. List of incidents

This section lists the results of the research.

Irrespective of whether a record is complete, incomplete or unusable, all the records are presented in the form of a table.

UNI WINNER			
Year built:		IMO number:	
TEU capacity:		Flag:	
Date:	6/9/2000	Position of vessel:	
Route:		Fatalities:	
Injuries:		Destroyed/damaged containers:	
Extent of fire as per DIN EN 14010:		Location of fire on board:	
Characteristics of fire:		Time required to fight fire:	
External assistance:		Vessel salvaged / vessel scrapped:	

Table 06, UNI WINNER
Source: Own presentation, source of data: (Ren, 2009, S. 49 ff)

CONTSHIP CHAMPION			
Year built:	1988	IMO number:	8714217
TEU capacity:	2797	Flag:	
Date:	9/19/2000	Position of vessel:	
Route:		Fatalities:	
Injuries:		Destroyed/damaged containers:	
Extent of fire as per DIN EN 14010:		Location of fire on board:	
Characteristics of fire:		Time required to fight fire:	
External assistance:		Vessel salvaged / vessel scrapped:	

Table 07, CONTSHIP CHAMPION
Source: Own presentation, source of data: (Ren, 2009, S. 49 ff)

HANJIN BREMEN			
Year built:	1990	IMO number:	9001045
TEU capacity:	2932	Flag:	
Date:	5/24/2000	Position of vessel:	Indian Ocean, Maldives
Route:	Singapore -> Hamburg	Fatalities:	0
Injuries:	0	Destroyed/damaged containers:	5
Extent of fire as per DIN EN 14010:	Medium-sized fire	Location of fire on board:	Forward of the deckhouse on deck
Characteristics of fire:	Cargo in container caught fire	Time required to fight fire:	5 days
External assistance:	None	Vessel salvaged / vessel scrapped:	Vessel continued voyage

Table 08, HANJIN BREMEN
Source: Own presentation, source of data: (Riecke, 2004, S. 77 ff)

CHOYANG SUCCESS			
Year built:	1988	IMO number:	8714217
TEU capacity:	2797	Flag:	Panama
Date:	9/1/2000	Position of vessel:	Straits of Malacca, coast of Malaysia
Route:		Fatalities:	0
Injuries:	0	Destroyed/damaged containers:	10
Extent of fire as per DIN EN 14010:	Large fire	Location of fire on board:	Forward of the deckhouse below deck
Characteristics of fire:	Several containers caught fire in the hold	Time required to fight fire:	48 hours
External assistance:	Salvage tug, floating crane and firefighting crew	Vessel salvaged / vessel scrapped:	Vessel continued voyage after cleaning and repairs

Table 09, CHOYANG SUCCESS
Source: Own presentation, source of data: (Riecke, 2004, S. 59), (Tsavliris, 2000), (Alphaliner, 2001), (Marinetraffic, 2016), (Kasel Salvage, 2000)

CMA CGM PUGET			
Year built:		IMO number:	
TEU capacity:		Flag:	
Date:	9/19/2000	Position of vessel:	
Route:		Fatalities:	
Injuries:		Destroyed/damaged containers:	
Extent of fire as per DIN EN 14010:		Location of fire on board:	
Characteristics of fire:		Time required to fight fire:	
External assistance:		Vessel salvaged / vessel scrapped:	

Table 10, CMA CGM PUGET
Source: Own presentation, source of data: (Ren, 2009, S. 49 ff)

KITANO			
Year built:	1990	IMO number:	8914001
TEU capacity:	3618	Flag:	Japan
Date:	3/22/2001	Position of vessel:	Chebucto Head, Nova Scotia, Canada
Route:	New York -> Halifax	Fatalities:	0
Injuries:	0	Destroyed/damaged containers:	15
Extent of fire as per DIN EN 14010:	Large fire	Location of fire on board:	Forward of the deckhouse on deck
Characteristics of fire:	Activated charcoal pellets caught fire in container, 4 containers on fire	Time required to fight fire:	30 hours
External assistance:	Support from tug and firefighting crew	Vessel salvaged / vessel scrapped:	Vessel continued voyage

Table 11, KITANO
Source: Own presentation, source of data: (Riecke, 2004, S. 59), (Transportation Safety Board of Canada, 2003)

WAN HAI 161			
Year built:		IMO number:	
TEU capacity:		Flag:	
Date:	7/18/2001	Position of vessel:	
Route:		Fatalities:	
Injuries:		Destroyed/damaged containers:	
Extent of fire as per DIN EN 14010:		Location of fire on board:	
Characteristics of fire:		Time required to fight fire:	
External assistance:		Vessel salvaged / vessel scrapped:	

Table 12, WAN HAI 161
Source: Own presentation, source of data: (Ren, 2009, S. 49 ff)

HANJIN PENNSYLVANIA			
Year built:	2002	IMO number:	9232096
TEU capacity:	4389	Flag:	Panama
Date:	11/11/2002	Position of vessel:	Indian Ocean, 88 NM south of "Dondra Head", Sri Lanka
Route:	Singapore -> Hamburg	Fatalities:	2
Injuries:	0	Destroyed/damaged containers:	Approx. 1750 TEU
Extent of fire as per DIN EN 14010:	Large fire	Location of fire on board:	Forward of the deckhouse, on deck and below deck
Characteristics of fire:	Firework products caught fire, explosions on and below deck	Time required to fight fire:	28 days
External assistance:	Up to four salvage tugs	Vessel salvaged / vessel scrapped:	Sold for scrap, hull reused

Table 13, HANJIN PENNSYLVANIA
Source: Own presentation, source of data: (Riecke, 2004, S. 59), (Weeth), (Holt, n.d.), (Cargolaw, 2002), (Riecke, 2004, S. 81 ff), (Shipspotting, 2007)

ARA J			
Year built:	1998	IMO number:	9163984
TEU capacity:	1150	Flag:	Germany
Date:	1/22/2003	Position of vessel:	Blount Island, Jacksonville, Florida, USA
Route:	Jamaica -> USA	Fatalities:	0
Injuries:	2	Destroyed/damaged containers:	
Extent of fire as per DIN EN 14010:	Large fire	Location of fire on board:	Forward of the deckhouse on deck
Characteristics of fire:	Containers caught fire in hold	Time required to fight fire:	12 hours
External assistance:	Tug with monitor	Vessel salvaged / vessel scrapped:	Vessel salvaged

Table 14, ARA J
Source: Own presentation, source of data: (Ren, 2009, S. 49 ff), (Marinelink, 2003), (The Florida Times-Union, 2003), (First Coast News, 2003) (Reederei Jüngerhans, n.d.)

LT GRAND			
Year built:		IMO number:	
TEU capacity:		Flag:	
Date:	2/18/2003	Position of vessel:	Indian Ocean
Route:		Fatalities:	
Injuries:		Destroyed/damaged containers:	
Extent of fire as per DIN EN 14010:		Location of fire on board:	
Characteristics of fire:	Fire in the cargo area	Time required to fight fire:	
External assistance:		Vessel salvaged / vessel scrapped:	

Table 15, LT GRAND
Source: Own presentation, source of data: (Riecke, 2004, S. 59)

P&O NEDLLOYD NINA			
Year built:		IMO number:	
TEU capacity:		Flag:	
Date:	2/20/2003	Position of vessel:	Atlantic
Route:		Fatalities:	
Injuries:		Destroyed/damaged containers:	
Extent of fire as per DIN EN 14010:		Location of fire on board:	
Characteristics of fire:		Time required to fight fire:	
External assistance:		Vessel salvaged / vessel scrapped:	

Table 16, P&O NEDLLOYD NINA
Source: Own presentation, source of data: (Riecke, 2004, S. 59)

LT UTILE			
Year built:	2000	IMO number:	9188154
TEU capacity:	3709	Flag:	Panama
Date:	8/3/2003	Position of vessel:	Off Yantian, China
Route:	Ningbo -> Yantian	Fatalities:	0
Injuries:	0	Destroyed/damaged containers:	
Extent of fire as per DIN EN 14010:	Large fire	Location of fire on board:	Forward of the deckhouse on deck
Characteristics of fire:	Fire in containers on deck	Time required to fight fire:	3 days
External assistance:	Several tugs and floating cranes	Vessel salvaged / vessel scrapped:	Vessel salvaged

Table 17, LT UTILE
Source: Own presentation, source of data: (Riecke, 2004, S. 59), (China Rescue and Salvage of Ministry of Transport of the People's Republic of China, 2011), (PSi-Daily Shipping News, 2003, p. 6),

SEA ELEGANCE			
Year built:	7/16/1980	IMO number:	7817103
TEU capacity:	766	Flag:	Singapore
Date:	10/11/2003	Position of vessel:	Off Durban, South Africa
Route:	Port Louis -> Durban	Fatalities:	1
Injuries:	0	Destroyed/damaged containers:	At least one bay
Extent of fire as per DIN EN 14010:	Large fire	Location of fire on board:	Aft of the deckhouse below deck
Characteristics of fire:	Explosion of calcium hypochlorite in hold, deckhouse fire	Time required to fight fire:	2 days
External assistance:	5 tugs, emergency rescue vessel, firefighting crew	Vessel salvaged / vessel scrapped:	Vessel salvaged, repaired

Table 18, SEA ELEGANCE
Source: Own presentation, source of data: (Riecke, 2004, S. 59;70 ff), (Hazckeck, 2003), (Ports & Ships - Shipping and Harbour News out of Africa, 2003), (Independent Online, 2003), (South African Maritime Safety Authority, 2004, p. 24 ff)

MSC PARAGUAY			
Year built:		IMO number:	
TEU capacity:		Flag:	Panama
Date:	12/12/2003	Position of vessel:	
Route:		Fatalities:	
Injuries:		Destroyed/damaged containers:	
Extent of fire as per DIN EN 14010:		Location of fire on board:	
Characteristics of fire:		Time required to fight fire:	
External assistance:		Vessel salvaged / vessel scrapped:	

Table 19, MSC PARAGUAY
Source: Own presentation, source of data: (Riecke, 2004, S. 59)

CSAV ITAJAI			
Year built:	1997	IMO number:	9128099
TEU capacity:	2113	Flag:	Marshall Islands
Date:	2/29/2004	Position of vessel:	Durban, South Africa
Route:	Hong Kong -> Rio de Janeiro	Fatalities:	0
Injuries:	5	Destroyed/damaged containers:	1
Extent of fire as per DIN EN 14010:	Medium-sized fire	Location of fire on board:	Forward of the deckhouse below deck
Characteristics of fire:	Thermal reaction in container	Time required to fight fire:	3 days 15 hours
External assistance:	Assistance from onshore firefighters	Vessel salvaged / vessel scrapped:	No damage to vessel

Table 20, CSAV ITAJAI
Source: Own presentation, source of data: (South African Maritime Safety Authority, 2004, pp. 1-33)

MSC CARLA			
Year built:		IMO number:	
TEU capacity:		Flag:	
Date:	4/5/2004	Position of vessel:	Atlantic
Route:		Fatalities:	
Injuries:		Destroyed/damaged containers:	
Extent of fire as per DIN EN 14010:		Location of fire on board:	Forward of the deckhouse, below deck
Characteristics of fire:	Containers with vegetable charcoal caught fire	Time required to fight fire:	
External assistance:		Vessel salvaged / vessel scrapped:	

Table 21, MSC CARLA
Source: Own presentation, source of data: (Riecke, 2004, S. 59)

NYK ARGUS			
Year built:	2004	IMO number:	9262716
TEU capacity:	6492	Flag:	Panama
Date:	10/19/2004	Position of vessel:	Mediterranean Sea, Algerian coast
Route:	Suez Canal -> Southampton	Fatalities:	
Injuries:		Destroyed/damaged containers:	
Extent of fire as per DIN EN 14010:		Location of fire on board:	
Characteristics of fire:		Time required to fight fire:	
External assistance:		Vessel salvaged / vessel scrapped:	

Table 22, NYK ARGUS
Source: Own presentation, source of data: (Ren, 2009, S. 49 ff), (Lloydslist, 2004)

GLORY BRIDGE			
Year built:		IMO number:	
TEU capacity:		Flag:	
Date:	3/14/2005	Position of vessel:	
Route:		Fatalities:	
Injuries:		Destroyed/damaged containers:	
Extent of fire as per DIN EN 14010:		Location of fire on board:	
Characteristics of fire:		Time required to fight fire:	
External assistance:		Vessel salvaged / vessel scrapped:	

Table 23, GLORY BRIDGE
Source: Own presentation, source of data: (Ren, 2009, S. 49 ff)

PAC MAKASSAR			
Year built:	2003	IMO number:	9264221
TEU capacity:	639	Flag:	Panama
Date:	8/7/2005	Position of vessel:	Gulf of Thailand
Route:	Singapore -> Jakarta	Fatalities:	0
Injuries:	0	Destroyed/damaged containers:	
Extent of fire as per DIN EN 14010:		Location of fire on board:	Forward of the deckhouse below deck
Characteristics of fire:	Explosion of containers in hold	Time required to fight fire:	
External assistance:	Discharge of affected cargo and inspection in Singapore	Vessel salvaged / vessel scrapped:	Vessel continued voyage after inspection

Table 24, PAC MAKASSAR
Source: Own presentation, source of data: (Ren, 2009, S. 49 ff), (7seasvessels, 2012), (Lloyd's Marine Intelligence Unit, 2005, p. 6)

CMS PUNJAB SENATOR			
Year built:	1997	IMO number:	9141285
TEU capacity:	4545	Flag:	Germany
Date:	5/30/2005	Position of vessel:	Bay of Bengal
Route:	Singapore -> Colombo	Fatalities:	0
Injuries:	0	Destroyed/damaged containers:	2
Extent of fire as per DIN EN 14010:	Large fire	Location of fire on board:	Forward of the deckhouse below deck
Characteristics of fire:	Explosion and fire in the hold	Time required to fight fire:	3 days
External assistance:	None	Vessel salvaged / vessel scrapped:	Vessel continued voyage

Table 25, CMS PUNJAB SENATOR
Source: Own presentation, source of data: (Ren, 2009, S. 49 ff), (Bundesstelle für Seeunfalluntersuchung, 2006)

NORASIA TAURUS			
Year built:	2001	IMO number:	9219355
TEU capacity:	3108	Flag:	Antigua & Barbuda
Date:	7/16/2005	Position of vessel:	Damietta, Egypt
Route:	Jeddah -> Damietta	Fatalities:	0
Injuries:	0	Destroyed/damaged containers:	70
Extent of fire as per DIN EN 14010:	Large fire	Location of fire on board:	Forward of the deckhouse on deck
Characteristics of fire:	Several containers caught fire on deck	Time required to fight fire:	5 days
External assistance:	Firefighting tug/salvage crew	Vessel salvaged / vessel scrapped:	Vessel returned to service after repair

Table 26, NORASIA TAURUS
Source: Own presentation, source of data: (Ren, 2009, S. 49 ff), (SMIT, 2005, p. 9), (SMIT b, 2010, p. 4), (Lloyd's Marine Intelligence Unit b, 2005, p. 6)

HORIZON NAVIGATOR			
Year built:		IMO number:	
TEU capacity:		Flag:	
Date:	8/12/2005	Position of vessel:	
Route:		Fatalities:	
Injuries:		Destroyed/damaged containers:	
Extent of fire as per DIN EN 14010:		Location of fire on board:	
Characteristics of fire:		Time required to fight fire:	
External assistance:		Vessel salvaged / vessel scrapped:	

Table 27, HORIZON NAVIGATOR
Source: Own presentation, source of data: (Ren, 2009, S. 49 ff)

CHASTINE MAERSK			
Year built:	2001	IMO number:	9219800
TEU capacity:	9578	Flag:	Denmark
Date:	8/13/2005	Position of vessel:	
Route:		Fatalities:	
Injuries:		Destroyed/damaged containers:	
Extent of fire as per DIN EN 14010:		Location of fire on board:	
Characteristics of fire:		Time required to fight fire:	
External assistance:		Vessel salvaged / vessel scrapped:	

Table 28, CHASTINE MAERSK
Source: Own presentation, source of data: (Ren, 2009, S. 49 ff)

MOL RENAISSANCE			
Year built:	2005	IMO number:	9246700
TEU capacity:	3091	Flag:	Liberia
Date:	12/28/2005	Position of vessel:	Red Sea
Route:	Singapore -> Genoa	Fatalities:	0
Injuries:	0	Destroyed/damaged containers:	
Extent of fire as per DIN EN 14010:	Large fire	Location of fire on board:	Forward of the deckhouse below deck
Characteristics of fire:	Container fire in hold	Time required to fight fire:	8 days
External assistance:	Firefighting unit, salvage tug	Vessel salvaged / vessel scrapped:	Vessel continued voyage

Table 29, MOL RENAISSANCE
Source: Own presentation, source of data: (Ren, 2009, S. 49 ff), (PSi-Daily Maritime Clippings, 2006, p. 9), (Burges, 2006, p. 31)

HYUNDAI FORTUNE			
Year built:	1996	IMO number:	9112272
TEU capacity:	5551	Flag:	Panama
Date:	3/21/2006	Position of vessel:	Gulf of Aden, 60 NM off the coast of Yemen
Route:	Singapore -> Rotterdam	Fatalities:	0
Injuries:	0	Destroyed/damaged containers:	851
Extent of fire as per DIN EN 14010:	Large fire	Location of fire on board:	Aft of the deckhouse below deck and on deck
Characteristics of fire:	Explosion of containers in hold, fire spread to deck cargo and deckhouse	Time required to fight fire:	approx. 14 days
External assistance:	Up to 5 salvage and harbor tugs, 1 naval vessel and salvage teams	Vessel salvaged / vessel scrapped:	Vessel was repaired in China and has returned to service

Table 30, HYUNDAI FORTUNE
Source: Own presentation, source of data: (Ren, 2009, S. 49 ff), (Flynn, 2008, p. 3 ff), (Cargo-Vessels-International, 2015), (Cargoforum, 2006), (Cargolaw a, 2006), (Runacres & Associates Ltd, n.d.)

YM GREEN			
Year built:	2001	IMO number:	9224491
TEU capacity:	5512	Flag:	Liberia
Date:	8/6/2006	Position of vessel:	Coast of Malaysia
Route:	Singapore -> Rotterdam	Fatalities:	0
Injuries:	0	Destroyed/damaged containers:	25
Extent of fire as per DIN EN 14010:	Large fire	Location of fire on board:	Forward of the deckhouse below deck
Characteristics of fire:	Container fire in hold	Time required to fight fire:	10 days
External assistance:	2 salvage tugs and salvage team	Vessel salvaged / vessel scrapped:	Vessel continued voyage

Table 31, YM GREEN
Source: Own presentation, source of data: (Ren, 2009, S. 49 ff), (Posh Terasea, 2006), (Tiedemann & Svendsen, 2006, pp. 8-9)

YM COMFORT			
Year built:	1982	IMO number:	8012657
TEU capacity:	1984	Flag:	Taiwan
Date:	3/10/2007	Position of vessel:	Colombo, Sri Lanka
Route:		Fatalities:	
Injuries:		Destroyed/damaged containers:	
Extent of fire as per DIN EN 14010:		Location of fire on board:	
Characteristics of fire:		Time required to fight fire:	
External assistance:		Vessel salvaged / vessel scrapped:	

Table 32, YM COMFORT
Source: Own presentation, source of data: (Ren, 2009, S. 49 ff), (Daily News - Sri Lanka's National Newspaper, 2007), (Containership-Info, n.d.)

ZIM HAIFA			
Year built:	2004	IMO number:	9288904
TEU capacity:	5040	Flag:	Israel
Date:	6/1/2007	Position of vessel:	Pacific
Route:		Fatalities:	
Injuries:		Destroyed/damaged containers:	100
Extent of fire as per DIN EN 14010:	Large fire	Location of fire on board:	Forward of the deckhouse below deck
Characteristics of fire:	Explosion of calcium hypochlorite in hold	Time required to fight fire:	Several days
External assistance:	Support from shore in port of refuge	Vessel salvaged / vessel scrapped:	

Table 33, ZIM HAIFA
Source: Own presentation, source of data: (Ren, 2009, S. 49 ff), (I-Law, 2007), (Institution of Chemical Engineers, 2008, p. 501), (WorldCargo News, 2007, p. 59)

CMA CGM FIDELIO			
Year built:	2006	IMO number:	9299642
TEU capacity:	9415	Flag:	France
Date:	7/4/2007	Position of vessel:	Yantian, China
Route:	-	Fatalities:	0
Injuries:	0	Destroyed/damaged containers:	1
Extent of fire as per DIN EN 14010:	Small fire	Location of fire on board:	
Characteristics of fire:	Explosion in container	Time required to fight fire:	
External assistance:	Container was discharged	Vessel salvaged / vessel scrapped:	No damage to vessel

Table 34, CMA CGM FIDELIO
Source: Own presentation, source of data: (Ren, 2009, S. 49 ff), (Lloyd's Marine Intelligence Unit c, 2007)

MSC ROMA			
Year built:	2006	IMO number:	9304447
TEU capacity:	9178	Flag:	Liberia
Date:	3/9/2008	Position of vessel:	Suez Canal, Egypt
Route:		Fatalities:	
Injuries:		Destroyed/damaged containers:	
Extent of fire as per DIN EN 14010:		Location of fire on board:	
Characteristics of fire:		Time required to fight fire:	
External assistance:		Vessel salvaged / vessel scrapped:	

Table 35, MSC ROMA
Source: Own presentation, source of data: (Ren, 2009, S. 49 ff)

APL PERU			
Year built:	2002	IMO number:	9252230
TEU capacity:	4713	Flag:	Antigua and Barbuda
Date:	10/5/2008	Position of vessel:	Pacific/Seattle, USA
Route:	Hong Kong -> Seattle	Fatalities:	0
Injuries:	0	Destroyed/damaged containers:	At least 2
Extent of fire as per DIN EN 14010:	Medium-sized fire	Location of fire on board:	Forward of the deckhouse below deck
Characteristics of fire:	Container fire in hold	Time required to fight fire:	1 day
External assistance:	Burning containers were discharged and extinguished by fire service	Vessel salvaged / vessel scrapped:	Vessel continued voyage

Table 36, APL PERU
Source: Own presentation, source of data: (Ren, 2009, S. 49 ff), (Milgram, 2008), (Professional Mariner, 2008), (Nall, 2008, p. 65)

MAERSK ITEA			
Year built:	1994	IMO number:	9057496
TEU capacity:	2780	Flag:	
Date:	11/3/2008	Position of vessel:	
Route:	Canada -> Far East -> Mediterranean	Fatalities:	0
Injuries:	0	Destroyed/damaged containers:	16
Extent of fire as per DIN EN 14010:		Location of fire on board:	Forward of the deckhouse below deck
Characteristics of fire:	Container fire in hold	Time required to fight fire:	4 hours
External assistance:	None	Vessel salvaged / vessel scrapped:	

Table 37, MAERSK ITEA
Source: Own presentation, source of data: (Ren, 2009, S. 49 ff), (Countryman & McDaniel, 2008)

YM UNION			
Year built:	1997	IMO number:	9126754
TEU capacity:	1445	Flag:	Turkey
Date:	12/2/2008	Position of vessel:	
Route:		Fatalities:	
Injuries:		Destroyed/damaged containers:	
Extent of fire as per DIN EN 14010:		Location of fire on board:	
Characteristics of fire:		Time required to fight fire:	
External assistance:		Vessel salvaged / vessel scrapped:	

Table 38, YM UNION
Source: Own presentation, source of data: (Ren, 2009, S. 49 ff)

HYUNDAI LONG BEACH			
Year built:	2009	IMO number:	9332884
TEU capacity:	6350	Flag:	United Kingdom
Date:	2/5/2009	Position of vessel:	
Route:		Fatalities:	
Injuries:		Destroyed/damaged containers:	
Extent of fire as per DIN EN 14010:		Location of fire on board:	
Characteristics of fire:		Time required to fight fire:	
External assistance:		Vessel salvaged / vessel scrapped:	

Table 39, HYUNDAI LONG BEACH
Source: Own presentation, source of data: (Ren, 2009, S. 49 ff)

IRAN ILAM / SEPITAM			
Year built:	2004	IMO number:	9283033
TEU capacity:	2724	Flag:	Iran
Date:	2/5/2009	Position of vessel:	
Route:		Fatalities:	
Injuries:		Destroyed/damaged containers:	
Extent of fire as per DIN EN 14010:		Location of fire on board:	
Characteristics of fire:		Time required to fight fire:	
External assistance:		Vessel salvaged / vessel scrapped:	

Table 40, IRAN ILAM / SEPITAM
Source: Own presentation, source of data: (Ren, 2009, S. 49 ff)

MOL PROSPERITY			
Year built:	2006	IMO number:	9321031
TEU capacity:	6350	Flag:	Panama
Date:	7/2/2009	Position of vessel:	Hong Kong
Route:	Mediterranean -> Far East	Fatalities:	0
Injuries:	1	Destroyed/damaged containers:	263
Extent of fire as per DIN EN 14010:	Large fire	Location of fire on board:	Forward of the deckhouse below deck
Characteristics of fire:	Container fire in hold, bottom layer	Time required to fight fire:	1 week
External assistance:	4 firefighting vessels, 2 floating cranes, firefighting crew	Vessel salvaged / vessel scrapped:	Vessel continued voyage

Table 41, MOL PROSPERITY
Source: Own presentation, source of data: (Ren, 2009, S. 49 ff), (Baird Maritime, 2009), (Dolphin Maritime and Aviation Services, 2009), (OOCL, 2009), (Shipping Online, 2009)

MSC INES			
Year built:	2006	IMO number:	9305714
TEU capacity:	9113	Flag:	Panama
Date:	7/8/2009	Position of vessel:	Suez Canal, Egypt
Route:	Suez Canal -> Bremerhaven	Fatalities:	0
Injuries:	0	Destroyed/damaged containers:	
Extent of fire as per DIN EN 14010:		Location of fire on board:	
Characteristics of fire:		Time required to fight fire:	
External assistance:		Vessel salvaged / vessel scrapped:	Vessel continued voyage

Table 42,MSC INES
Source: Own presentation, source of data: (Ren, 2009, S. 49 ff), (Lloyd's Marine Intelligence Unit d, 2009, p. 7)

XIN LOS ANGELES			
Year built:	2006	IMO number:	9307217
TEU capacity:	9572	Flag:	Hong Kong
Date:	12/3/2009	Position of vessel:	Suez Canal, Egypt / coast of Spain
Route:	Yantian -> Felixstowe	Fatalities:	0
Injuries:	0	Destroyed/damaged containers:	
Extent of fire as per DIN EN 14010:	Medium-sized fire	Location of fire on board:	Forward of the deckhouse below deck
Characteristics of fire:	Container fire in hold	Time required to fight fire:	
External assistance:	None, CO^2 was released	Vessel salvaged / vessel scrapped:	Vessel continued voyage

Table 43, XIN LOS ANGELES
Source: Own presentation, source of data: (Dolphin Maritime and Aviation Services b, 2009), (7seasvessels b, 2012)

CHARLOTTE MAERSK			
Year built:	2001	IMO number:	9245744
TEU capacity:	9612	Flag:	Denmark
Date:	7/7/2010	Position of vessel:	Straits of Malacca, Port Klang
Route:	Port Klang -> Salalah	Fatalities:	0
Injuries:	1	Destroyed/damaged containers:	160
Extent of fire as per DIN EN 14010:	Large fire	Location of fire on board:	Forward of the deckhouse on deck
Characteristics of fire:	Container fire on deck in vicinity of hazardous cargo	Time required to fight fire:	12 days
External assistance:	1 airtanker, 2 tugs with monitors, salvage captain, firefighting teams from the Netherlands	Vessel salvaged / vessel scrapped:	Vessel underway again after repairs

Table 44, CHARLOTTE MAERSK
Source: Own presentation, source of data: (Danish Maritime Accident Investigation Board, 2012)

MSC FLAMINIA			
Year built:	2001	IMO number:	9225615
TEU capacity:	6732	Flag:	Germany
Date:	7/14/2012	Position of vessel:	North Atlantic
Route:	Charleston -> Antwerp	Fatalities:	3
Injuries:	2	Destroyed/damaged containers:	1440
Extent of fire as per DIN EN 14010:	Large fire	Location of fire on board:	Forward of the deckhouse below deck and on deck
Characteristics of fire:	Fire and explosion in hold	Time required to fight fire:	3 months 9 days
External assistance:	3 salvage tugs	Vessel salvaged / vessel scrapped:	Vessel operational again since 07/2014 after repairs

Table 45, MSC FLAMINIA
Source: Own presentation, source of data: (Bundesstelle für Seeunfalluntersuchung b, 2014), (Reederei NSB, 2012)

MAERSK KINLOSS			
Year built:	2008	IMO number:	9333022
TEU capacity:	6696	Flag:	United Kingdom
Date:	7/17/2012	Position of vessel:	Ilyichevsk, Ukraine
Route:	Constanța -> Ilyichevsk	Fatalities:	0
Injuries:	0	Destroyed/damaged containers:	3
Extent of fire as per DIN EN 14010:	-	Location of fire on board:	Forward of the deckhouse below deck
Characteristics of fire:	Explosion of chemicals in containers in the hold, no fire	Time required to fight fire:	No firefighting activities took place
External assistance:	Emergency team for hazardous cargo	Vessel salvaged / vessel scrapped:	Vessel undamaged

Table 46, MAERSK KINLOSS
Source: Own presentation, source of data: (Containeroperations Wordpress, 2012), (Maritime Bulletin, 2012), (Ships For Sale, 2012), (Safety4sea, 2012), (Marinelink b, 2012)

AMSTERDAM BRIDGE			
Year built:	2009	IMO number:	9450911
TEU capacity:	4380	Flag:	Germany
Date:	9/9/2012	Position of vessel:	Mumbai Bay
Route:	Mumbai -> Colombo	Fatalities:	0
Injuries:	0	Destroyed/damaged containers:	7
Extent of fire as per DIN EN 14010:	Large fire	Location of fire on board:	Forward of the deckhouse on deck
Characteristics of fire:	Containers caught fire on deck	Time required to fight fire:	3 days
External assistance:	1 coastguard vessel, 1 salvage tug	Vessel salvaged / vessel scrapped:	Vessel sent for repair

Table 47, AMSTERDAM BRIDGE
Source: Own presentation, source of data: (Containeroperations Wordpress, 2012), (Maritime Bulletin b, 2012)

EUGEN MAERSK			
Year built:	2008	IMO number:	9321550
TEU capacity:	15550	Flag:	Denmark
Date:	6/18/2013	Position of vessel:	Gulf of Aden
Route:	Tanjung Pelepas -> Rotterdam	Fatalities:	0
Injuries:	0	Destroyed/damaged containers:	16
Extent of fire as per DIN EN 14010:	Large fire	Location of fire on board:	Aft of the deckhouse on deck
Characteristics of fire:	Container fire on deck	Time required to fight fire:	5 days
External assistance:	Firefighting crew from salvage company after going alongside in port of refuge	Vessel salvaged / vessel scrapped:	Vessel docked in port of refuge with slight damage

Table 48, EUGEN MAERSK
Source: Own presentation, source of data: (Danish Maritime Accident Investigation Board b, 2014)

HANSA BRANDENBURG			
Year built:	2002	IMO number:	9236236
TEU capacity:	1740	Flag:	Liberia
Date:	7/15/2013	Position of vessel:	Indian Ocean, northeast of Mauritius
Route:	Singapore -> Durban	Fatalities:	0
Injuries:	0	Destroyed/damaged containers:	83
Extent of fire as per DIN EN 14010:	Large fire	Location of fire on board:	Forward of the deckhouse on deck
Characteristics of fire:	Containers caught fire on deck forward of the deckhouse	Time required to fight fire:	5 days
External assistance:	Fire extinguished by tugs, crew did not fight the fire, crew abandoned ship immediately	Vessel salvaged / vessel scrapped:	Vessel was scrapped

Table 49, HANSA BRANDENBURG
Source: Own presentation, source of data: (Blacksea News, 2013), (gCaptain, 2013), (Roose+Partners, 2013), (Verein Hanseatischer Transportversicherer - Hamburg, 2013)

MAERSK KAMPALA			
Year built:	2001	IMO number:	9215311
TEU capacity:	6802	Flag:	Netherlands
Date:	8/28/2013	Position of vessel:	Red Sea, Ras Gharib
Route:	Jeddah -> Algeciras	Fatalities:	0
Injuries:	0	Destroyed/damaged containers:	At least 2
Extent of fire as per DIN EN 14010:	Large fire	Location of fire on board:	Forward of the deckhouse on deck
Characteristics of fire:	Fire in containers on deck	Time required to fight fire:	1 week
External assistance:	7 salvage tugs, 3 barges, firefighting crew	Vessel salvaged / vessel scrapped:	Vessel made for repair harbor

Table 50, MAERSK KAMPALA
Source: Own presentation, source of data: (gCaptain b, 2013), (MaerskLine, 2013), (Roose+ Partners b, 2013), (Roose+Partners c, 2013), (Ahram Online, 2013)

SANTA ROSA			
Year built:	2011	IMO number:	9430363
TEU capacity:	7100	Flag:	Liberia
Date:	1/26/2014	Position of vessel:	North Sea
Route:	South America -> Hamburg	Fatalities:	0
Injuries:	0	Destroyed/damaged containers:	1
Extent of fire as per DIN EN 14010:	Small fire	Location of fire on board:	Forward of the deckhouse on deck
Characteristics of fire:	Container fire on upper deck	Time required to fight fire:	A few hours
External assistance:	Crew extinguished fire without assistance	Vessel salvaged / vessel scrapped:	Vessel continued voyage

Table 51, SANTA ROSA

Source: Own presentation, source of data: (Havariekommando, 2014), (Havariekommando b, 2014), (Roose+Partners c, 2014) (feuerwehr.de, 2014)

MAERSK LONDRINA			
Year built:	2012	IMO number:	9527037
TEU capacity:	8700	Flag:	Hong Kong
Date:	4/25/2015	Position of vessel:	Indian Ocean, 600 NM from Port Louis
Route:	Tanjung Pelepas -> Brazil	Fatalities:	0
Injuries:	0	Destroyed/damaged containers:	
Extent of fire as per DIN EN 14010:	Large fire	Location of fire on board:	Aft of the deckhouse below deck
Characteristics of fire:	Fire and explosion in hold	Time required to fight fire:	2 days
External assistance:	1 salvage tugs	Vessel salvaged / vessel scrapped:	Vessel made for port of refuge

Table 52, MAERSK LONDRINA

Source: Own presentation, source of data: (Dolphin Maritime and Aviation Services c, 2015), (World Maritime News, 2015), (Roose+Partners d, 2015)

HANJIN GREEN EARTH			
Year built:	2013	IMO number:	9503732
TEU capacity:	13092	Flag:	Isle of Man
Date:	5/1/2015	Position of vessel:	Port Said
Route:	Jeddah -> Hamburg	Fatalities:	0
Injuries:	0	Destroyed/damaged containers:	60
Extent of fire as per DIN EN 14010:	Large fire	Location of fire on board:	Aft of the deckhouse on deck
Characteristics of fire:	Container fire on deck	Time required to fight fire:	8 days
External assistance:	Up to 5 salvage tugs, harbor tugs and naval vessels	Vessel salvaged / vessel scrapped:	Vessel continued voyage after emergency anchorage

Table 53, HANJIN GREEN EARTH
Source: Own presentation, source of data: (Dolphin Maritime and Aviation Services d, 2015), (FleetMon, 2015), (Roose+Partners e, 2015), (Falck, 2015)

KAMALA			
Year built:	1999	IMO number:	9187320
TEU capacity:	2011	Flag:	Liberia
Date:	7/11/2015	Position of vessel:	East China Sea, Kuchinoshima
Route:	Surabaya -> Ulsan	Fatalities:	0
Injuries:	0	Destroyed/damaged containers:	30
Extent of fire as per DIN EN 14010:	Large fire	Location of fire on board:	Forward of the deckhouse on deck
Characteristics of fire:	Container fire on deck	Time required to fight fire:	
External assistance:	2 coastguard vessels with monitors 1 boarding team	Vessel salvaged / vessel scrapped:	

Table 54, KAMALA
Source: Own presentation, source of data: (gCaptain c, 2015), (Dolphin Maritime and Aviation Services e, 2015), (Roose+Parters f, 2015, p. 1)

MAERSK SEOUL			
Year built:	2006	IMO number:	9306550
TEU capacity:	8401	Flag:	Liberia
Date:	7/21/2015	Position of vessel:	Ras Al Khaimah, United Arab Emirates
Route:	United Arab Emirates -> Mediterranean	Fatalities:	0
Injuries:	0	Destroyed/damaged containers:	At least 15
Extent of fire as per DIN EN 14010:	Large fire	Location of fire on board:	Forward of the deckhouse on deck
Characteristics of fire:	Container fire on deck	Time required to fight fire:	3 days
External assistance:	Tug and firefighting crew	Vessel salvaged / vessel scrapped:	Vessel salvaged

Table 55, MAERSK SEOUL

Source: Own presentation, source of data: (Dolphin Maritime and Aviation Services f, 2015), (Roose+Partners g, 2015, p. 2), (Lloyd's, 2015), (Falck, 2015)

CAROLINE MÆRSK			
Year built:	2000	IMO number:	9214903
TEU capacity:	8401	Flag:	Denmark
Date:	8/26/2015	Position of vessel:	Coast of Vietnam
Route:	Chiwan -> Tanjung Pelepas	Fatalities:	0
Injuries:	0	Destroyed/damaged containers:	3
Extent of fire as per DIN EN 14010:	Medium-sized fire	Location of fire on board:	Forward of the deckhouse below deck
Characteristics of fire:	Container fire on deck	Time required to fight fire:	4 days 8 hours
External assistance:	Salvage team	Vessel salvaged / vessel scrapped:	Vessel continued voyage after cleaning and repairs

Table 56, CAROLINE MÆRSK

Source: Own presentation, source of data: (Danish Maritime Accident Investigation Board c, 2016)

UASC ALULA			
Year built:	2012	IMO number:	9525883
TEU capacity:	13296	Flag:	Malta
Date:	8/28/2015	Position of vessel:	Hamburg, Waltershof terminal
Route:	Rotterdam -> Hamburg	Fatalities:	0
Injuries:	0	Destroyed/damaged containers:	1
Extent of fire as per DIN EN 14010:	Small fire	Location of fire on board:	Aft of the deckhouse below deck
Characteristics of fire:	Containers caught fire in hold	Time required to fight fire:	3.5 hours
External assistance:	36 fire officers, port crane for discharge	Vessel salvaged / vessel scrapped:	No damage to vessel

Table 57, UASC ALULA
Source: Own presentation, source of data: (World Maritime News b, 2015), (Täglicher Hafenbericht, 2015), (Roose+Partners h, 2015, p. 1), (Ships&Ports, 2015)

UASC BARZAN			
Year built:	2015	IMO number:	9708851
TEU capacity:	18691	Flag:	Malta
Date:	9/7/2015	Position of vessel:	Cape Finisterre
Route:	Port Klang -> Felixstowe	Fatalities:	0
Injuries:	0	Destroyed/damaged containers:	
Extent of fire as per DIN EN 14010:		Location of fire on board:	Forward of the deckhouse below deck
Characteristics of fire:	Container fire in hold	Time required to fight fire:	12 hours
External assistance:	No external assistance	Vessel salvaged / vessel scrapped:	Vessel continued voyage

Table 58, UASC BARZAN
Source: Own presentation, source of data: (TheLoadStar, 2015), (Roose+Partners i, 2015, p. 2)

MARENO			
Year built:	2000	IMO number:	9175717
TEU capacity:	1174	Flag:	Antigua & Barbuda
Date:	8/30/2015	Position of vessel:	South Atlantic
Route:	Walvis Bay -> Cape Town	Fatalities:	0
Injuries:	0	Destroyed/damaged containers:	6
Extent of fire as per DIN EN 14010:	Large fire	Location of fire on board:	Forward of the deckhouse on deck
Characteristics of fire:	Containers caught fire on deck	Time required to fight fire:	A few hours
External assistance:	2 tugs	Vessel salvaged / vessel scrapped:	Vessel continued voyage after inspection

Table 59, MARENO
Source: Own presentation, source of data: (Roose+Partners h, 2015, p. 2), (FleetMon b, 2015)

CAPE MORETON			
Year built:	2005	IMO number:	9308405
TEU capacity:	2741	Flag:	Marshall Islands
Date:	9/12/2015	Position of vessel:	Manila, Philippines
Route:	Beilun -> Manila	Fatalities:	0
Injuries:	0	Destroyed/damaged containers:	1 bay
Extent of fire as per DIN EN 14010:	Large fire	Location of fire on board:	Forward of the deckhouse below deck
Characteristics of fire:	Explosion and fire in hold	Time required to fight fire:	9 hours
External assistance:	Local fire service with 20 tenders, 3 tugs with monitors	Vessel salvaged / vessel scrapped:	Vessel salvaged

Table 60, CAPE MORETON
Source: Own presentation, source of data: (Dolphin Maritime and Aviation Services g, 2015), (Roose+Partners j, 2015, p. 1)

NORTHERN VOLITION			
Year built:	2005	IMO number:	9304978
TEU capacity:	2742	Flag:	Portugal
Date:	11/23/2015	Position of vessel:	Coast of Vietnam
Route:	Ho Chi Minh City -> Shanghai	Fatalities:	0
Injuries:	0	Destroyed/damaged containers:	2
Extent of fire as per DIN EN 14010:	Large fire	Location of fire on board:	Forward of the deckhouse below deck
Characteristics of fire:	Fire in hold	Time required to fight fire:	24 hours
External assistance:	2 tugs to extinguish fire	Vessel salvaged / vessel scrapped:	Vessel berthed in port of refuge to discharge affected containers

Table 61, NORTHERN VOLITION

Source: Own presentation, source of data: (Dolphin Maritime and Aviation Services h, 2015), (Roose+Partners k, 2015), (Newsmaritime, 2015), (World Maritime News c, 2015)

4.4. Analyses

The data collected has been presented in the form of charts to aid clarity. The underlying data from the incidents was maintained in comparable form and prepared with Microsoft Excel.

4.4.1. Analysis: quantity/time

An overview of the frequency of fires over the past 15 years will first be presented in order to identify whether there are any concentrations of incidents in the period under consideration. All incidents could be considered for this purpose. A concentration of incidents can be observed in 2015 and a phase with fewer incidents can be seen in the period 2010-2014. On average, there have been approximately 4 incidents of fires in the cargo area of fully cellular container vessels per year in the past 15 years.

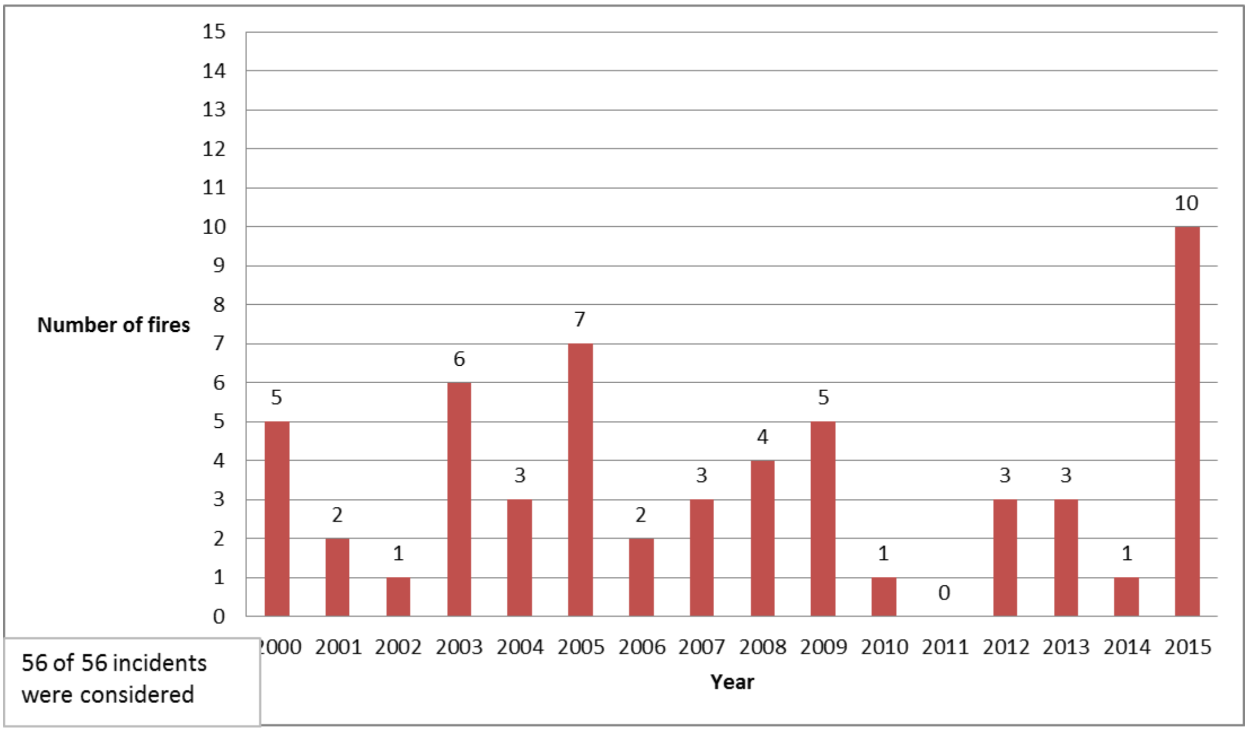


Figure 37, Frequency of fires in the past 15 years
Source: Own presentation, source of data: List of incidents

4.4.2. Analysis: quantity/vessel size

To analyze the frequency of incidents by the size of the vessels, the vessels were categorized by size in increments of 1000 TEU. There are significantly fewer incidents on vessels with a capacity greater than 10,000 TEU than on smaller vessels. Thus, only 8.5 % of the incidents under consideration occurred on vessels with a capacity larger than 10,000 TEU. Vessels of this size have been in operation since the GJERTRUD MAERSK went into service in 2005 (cf. Gesamtverband der Deutschen Versicherungswirtschaft e. V., 2015, p. 20).

Over the period under consideration, the average size of the vessels has approximately doubled, from 1700 TEU to 3600 TEU. The largest vessels on the market in 2000 had a capacity of 9500 TEU, whereas the largest vessels today are close to the 20,000 TEU mark. (cf. Jost Bergmann, 01-2016, p. 28)

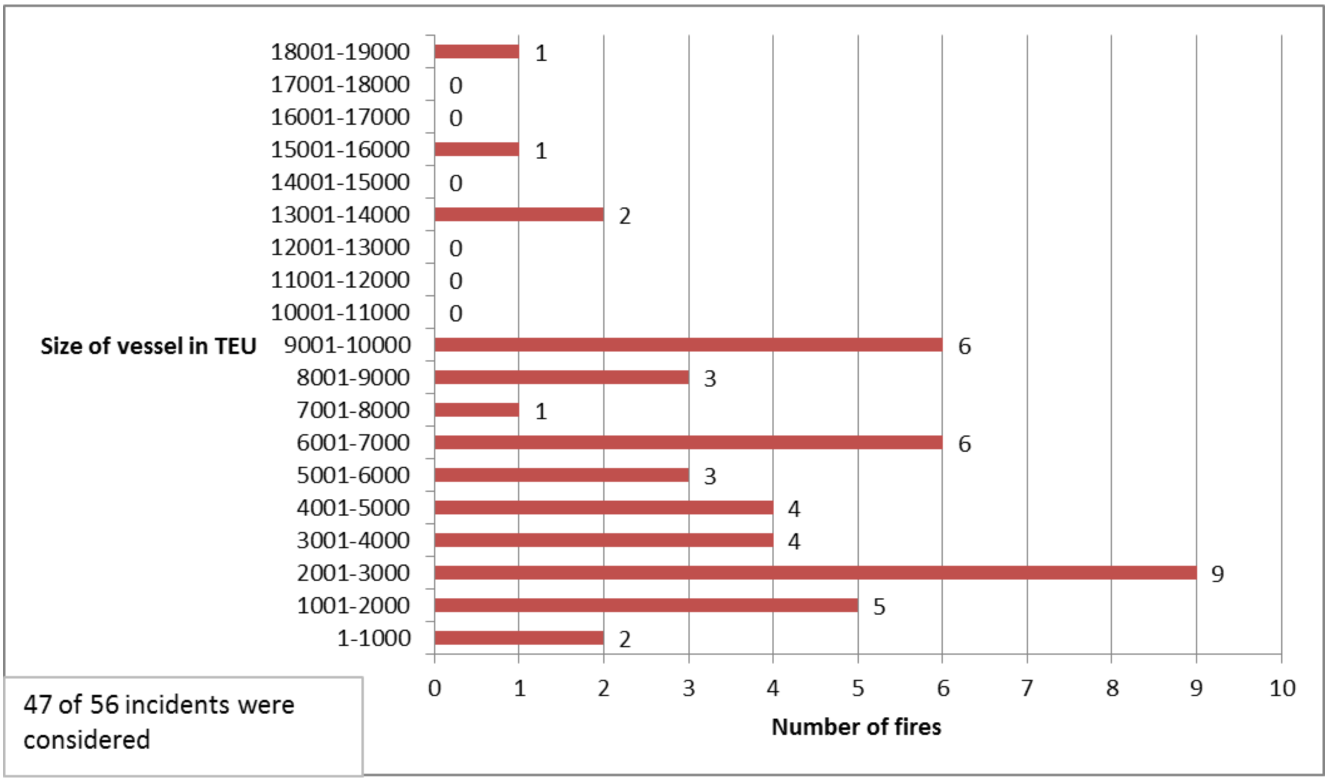


Figure 38, Frequency of fires by vessel size
Source: Own presentation, source of data: List of incidents

4.4.3. Analysis: quantity/flag

It was possible to identify the flag state for most of the incidents that were considered. The number of fires partially correlates with the relevant fleet capacity: Thus, for example, Panama and Liberia had the largest merchant fleets in 2013 in terms of gross tonnage (cf. Statista, 2013).

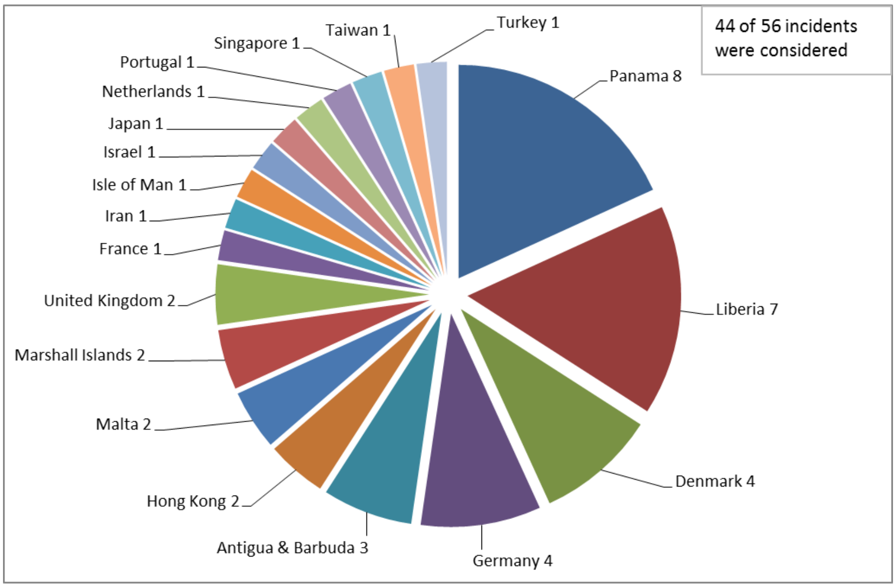


Figure 39, Frequency of fires by flag state
Source: Own presentation, source of data: List of incidents

Of particular note are the 4 incidents each on vessels under Danish and German flags, as far fewer vessels are registered under these two flags.

4.4.4. Analysis: quantity/location of fire on board

To permit more detailed analysis of the incidents, the location of the fire on board was determined where the sources provided this information. This records the location of the overall fire rather than the location at which the fire originated. Thus, for instance, a fire that initially started below deck and then spread to the deck cargo is recorded as a fire below deck and on deck.

More than three quarters of the documented incidents occurred in the forward part of the vessel. More fires occurred in the cargo holds in the forward and aft parts of the vessel than on deck. This result is similar to that shown in a chart from DNV · GL that also records 13 incidents on deck and as many as 35 incidents below deck in the period under consideration (cf. Jost Bergmann, 01-2016, p. 28). According to this survey, the frequency of fires in the cargo area, a more difficult environment for firefighting, was almost twice as high as on deck in the past 15 years.

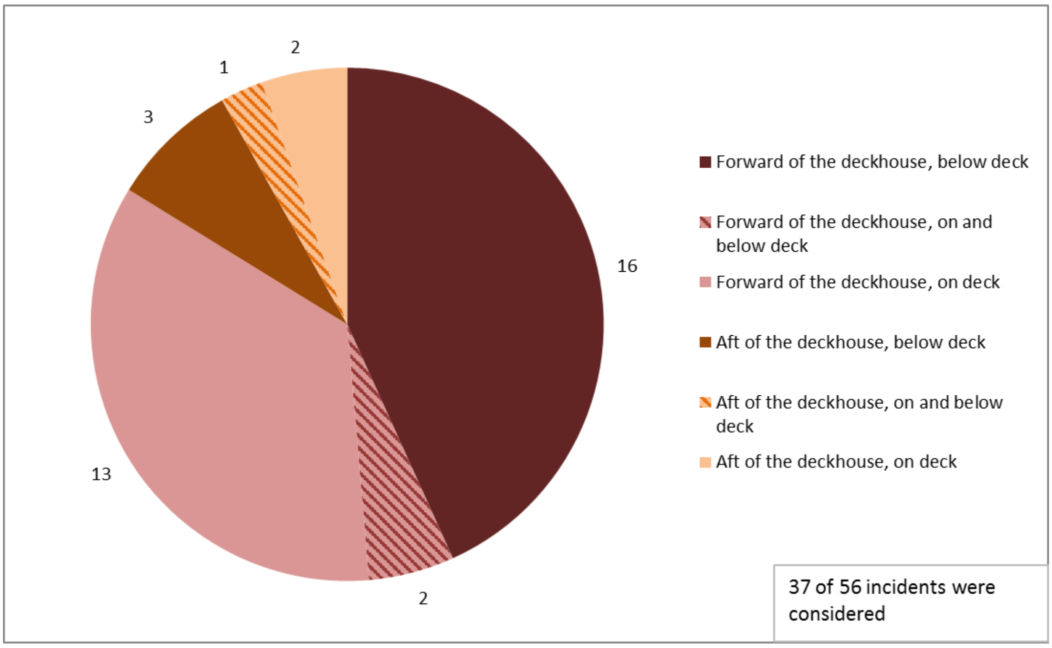


Figure 40, Locations of fires on board
Source: Own presentation, source of data: List of incidents

4.4.5. Analysis: quantity/extent of fire

As explained in the description of the procedures used, the extent of the fire was categorized using a version of the categories laid down in DIN 14010 and modified to apply to shipping. The extent of the fire was categorized for each case on the basis of the information available. The analysis shows that more than three quarters of the fires are to be classed as large fires and 15 % as medium-sized fires and that less than 10 % should be considered small fires.

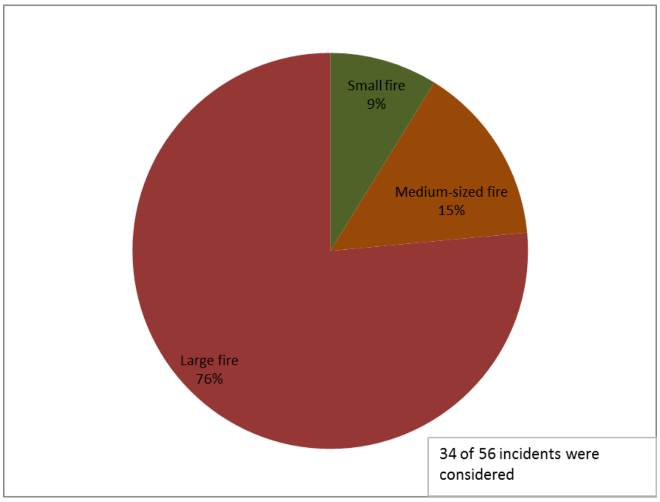


Figure 41, Extent of fires as per DIN 14010
Source: Own presentation, source of data: List of incidents

4.4.6. Analysis: quantity/age of vessel

The age of the vessel at the time of the incident was used to present the relationship between the age of the vessels concerned and the number of incidents. The age was determined by taking the delivery date from the *Internet Ship Register*. The ages range from vessels less than a year old up to 25-year-old vessels. It is immediately noticeable that 87 % of the vessels under consideration are less than 12 years old and that only 6 incidents occurred on vessels between 13 and 25 years old.

Bearing in mind the terms of reference in this dissertation, however, it seems sensible to see the incident frequency as being independent of the age of the vessel, since the dissertation only considers fires emanating from the cargo. Containers are to be considered as separate, closed cargo units that bring their own characteristics on board with them. The concentration of incidents on newer vessels correlates with the trend over the past years towards building ever larger vessels, thus increasing the concentration of risk per vessel as a result of carrying more cargo on board.

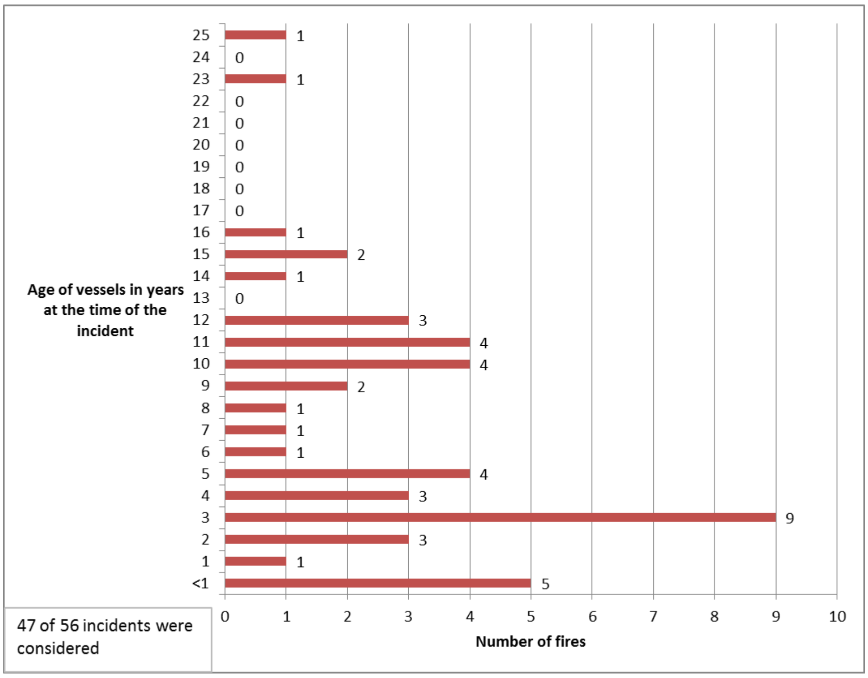


Figure 42, Frequency of fires by age of vessels
Source: Own presentation, source of data: List of incidents

4.4.7. Analysis: external assistance

In this analysis, external assistance extends from the simple use of shore-based personnel in port to support the crew right up to the use of airtankers to fight fires on deck. No external assistance was used in only 15 % of the incidents under consideration. This allows us to conclude that in the other 85 % of cases it would have been difficult or impossible to fight the fire successfully without external assistance. In any event, the vessel and the cargo would have sustained greater damage, since it would have taken longer to combat the fire. Furthermore, the 32 incidents in which external assistance was used still include cases where the vessel and the cargo were seriously damaged or completely destroyed, as was the case with the HANSA BRANDENBURG and the MSC FLAMINIA.

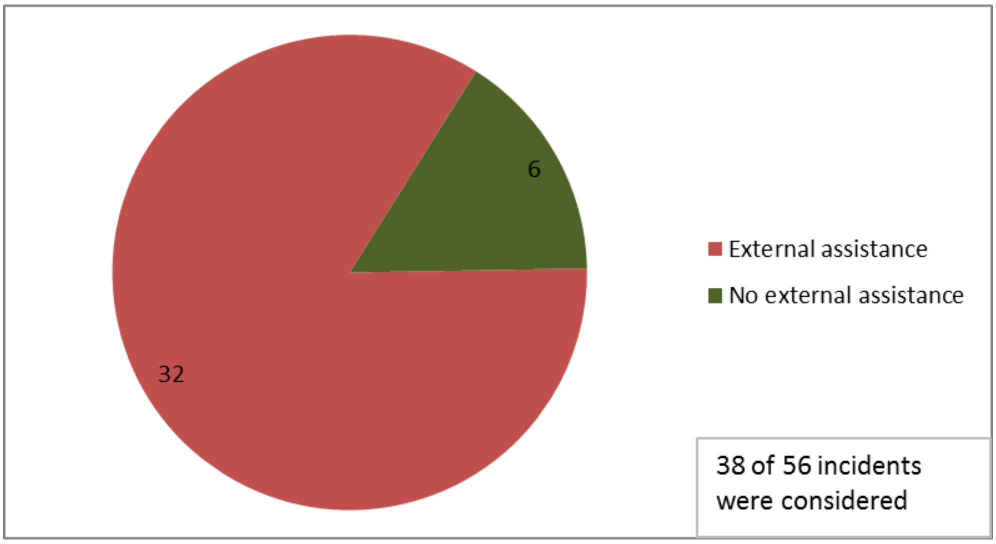


Figure 43, Use of external assistance
Source: Own presentation, source of data: List of incidents

4.4.8. Analysis: quantity/routes

In order to present the routes taken by the vessels affected, those incidents were first selected for which information was available on the routes. The routes show the route taken by the vessel at the time of the incident. This may have been one leg of a longer route. Thus, for example, in the case of a voyage from the Middle East to Europe, it was not possible to distinguish whether this represented the entire route or was part of a voyage from Asia to Europe. In order to nevertheless produce a homogeneous set of data for consideration, only the known routes were taken for the analysis. The route details shown in the list of incidents were first collated in such a way as to allow them to be compared and then counted.

The results show a concentration of incidents on routes within Asia and between Asia and Europe. This concentration of incidents on these routes can be attributed to the large quantities of cargo and the consequent increased probability of an incident occurring. The concentration can also be an indication of shortcomings in declaring the cargo and in observing packing regulations on the part of Asian container packing companies.

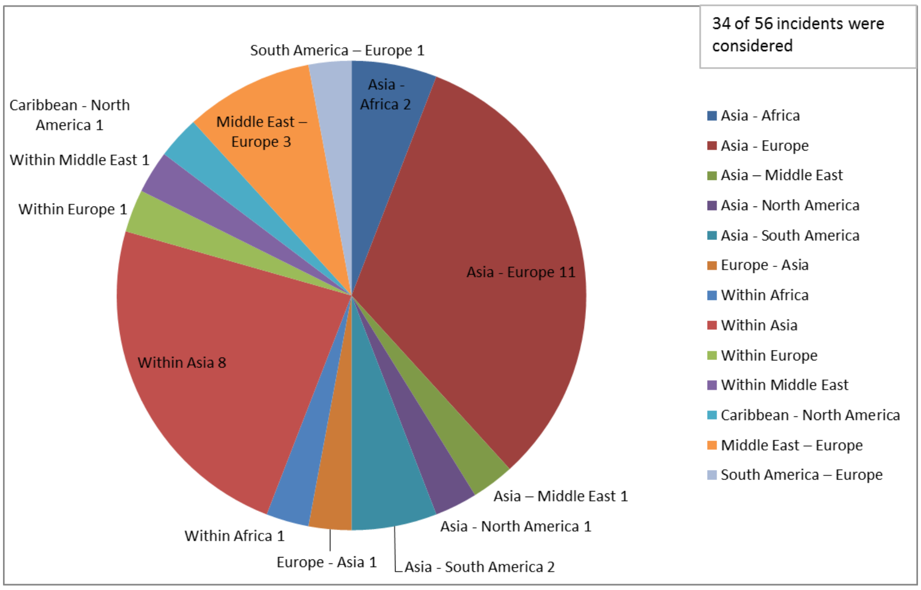


Figure 44, Frequency of fires by routes
Source: Own presentation, source of data: List of incidents

4.4.9. Analysis: injuries and fatalities

For the analysis of injuries and fatalities, the incidents under consideration were first divided into those incidents involving injuries and fatalities and those with no casualties. Those incidents involving casualties were then divided into those with injuries and those with fatalities.

The analysis of the data reveals that around 20 % of the incidents involved injuries and/or fatalities. One third of the casualties died as a result of the incident at sea and two thirds were injured.

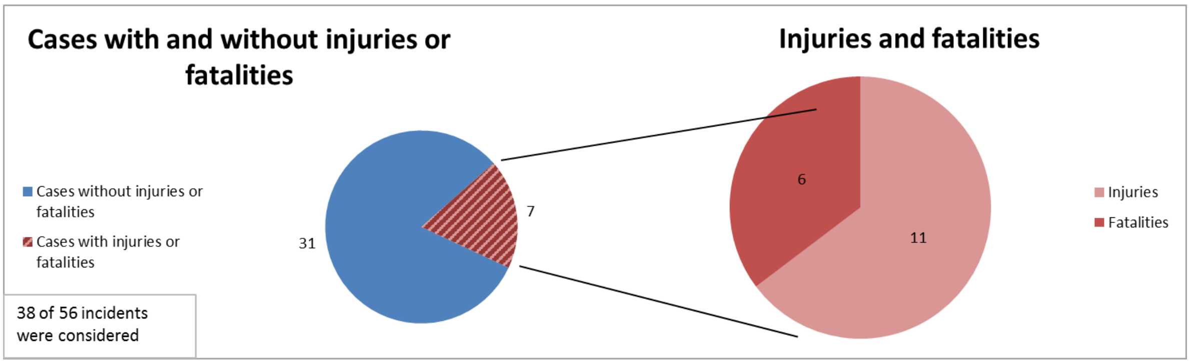


Figure 45, Injuries and casualties
Source: Own presentation, source of data: List of incidents

4.4.10. Analysis: time needed to fight fire

To provide a graphical representation of the average time needed to fight the fire without distorting the results, the categorization into small, medium-sized and large fires was again used. Where deployment times for the firefighting and rescue crews were available for incidents, these times were added together for each fire size and divided by the number of fires in order to determine the average time needed to fight the fire. To allow the incidents to be compared, hours were used as the time units.

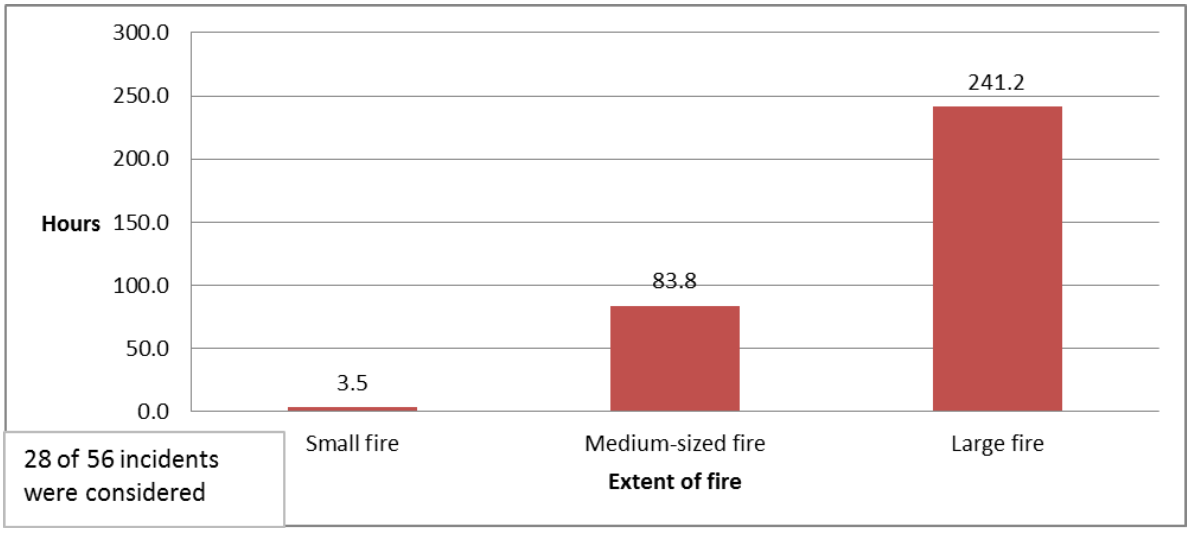


Figure 46, Average times needed to fight the fires
Source: Own presentation, source of data: List of incidents

The first chart clearly shows the different times needed to fight the fires. This representation is, however, skewed by three prominent large fires: The HANJIN PENNSYLVANIA at 672 hours, the Hyundai Fortune at 336 hours and the MSC Flaminia at 2424 hours spent extinguishing the fire cause the average time required to fight large fires to rise to 10 days. The chart below excludes these three incidents and shows a less significant rise in the time taken to fight the fires.

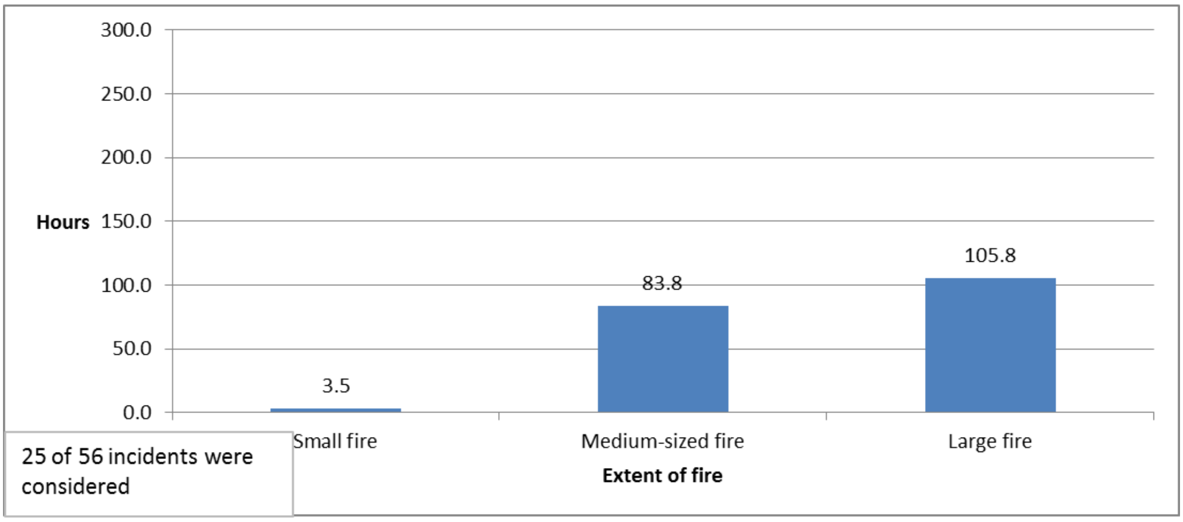


Figure 47, Average time required to fight fires excluding large-scale incidents
Source: Own presentation, source of data: List of incidents

4.4.11. Analysis: cargo loss

In this dissertation, cargo loss will be recorded in terms of the number of containers damaged, as detailed information on the goods that were lost is not available. The financial implications have also been ignored, as calculation of the direct and indirect costs resulting from the lost cargo was considered to be to extensive and beyond the scope of this dissertation. Consequently, only the number of destroyed containers was used to measure the cargo loss. No distinction was made as to whether the containers were TEUs (twenty-foot equivalent unit) or FEUs (forty-foot equivalent unit), as the reports do not generally give this information. Furthermore, whether it was a large or small cargo unit that was damaged is not crucial to the purpose of this dissertation. It should also be noted that in two cases a complete bay, i.e. a complete block of containers stowed laterally, were destroyed by fire. The estimated number of damaged and destroyed containers in these cases was not included in the table.

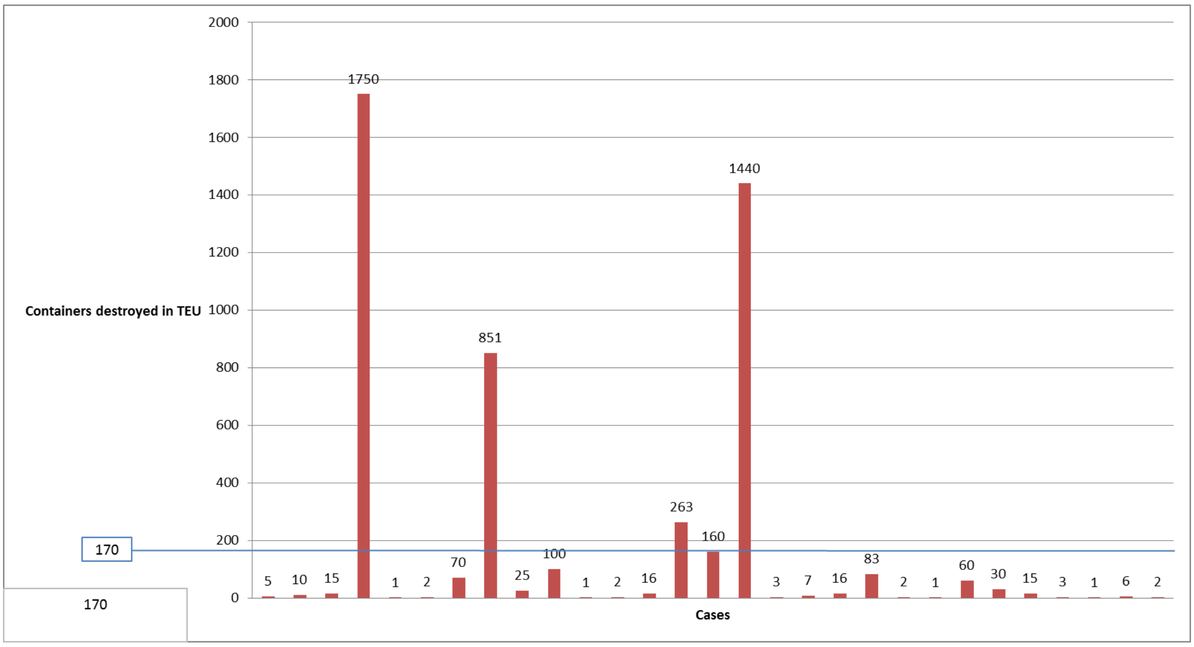


Figure 48, Number of destroyed containers in TEU
Source: Own presentation, source of data: List of incidents

The first chart shows that in 29 incidents that were considered, an average of 170 units were damaged or destroyed per incident. The three prominent cases of the HANJIN PENNSYLVANIA, HYUNDAI FORTUNE and the MSC FLAMINIA considerably increase the average. A second chart was therefore prepared excluding these cases. This shows that an average of 35 units were damaged or destroyed per incident, representing a reduction of 80 percent.

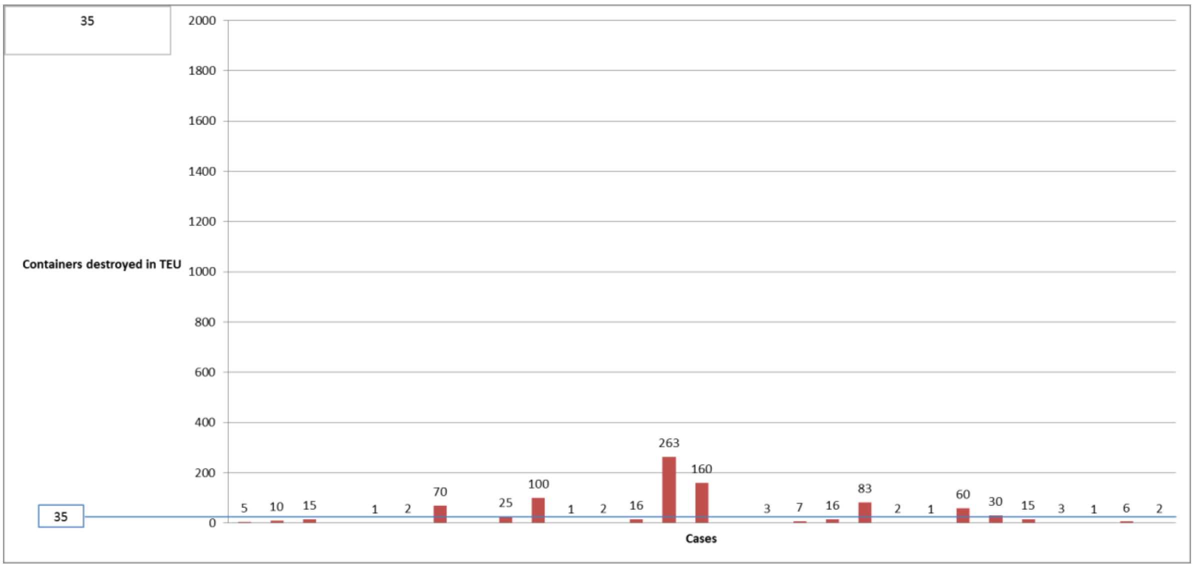


Figure 49, Number of destroyed containers in TEU excluding large-scale incidents
Source: Own presentation, source of data: List of incidents

5. Conclusion

The topic of this dissertation has aroused interest among many of those the author has talked to. Press and media coverage of the launching of new mega-class container ships means that it is not only industry specialists that are aware of the sizes of ships. To a certain extent, even the public at large are thinking about the problems associated with such ships.
Extensive Internet research revealed many instances of fire on board fully cellular container vessels. It was far more difficult, and sometimes impossible, to obtain detailed information on the individual fires.
And the accident investigation authorities of the various flag states were not always helpful, for instance in the case of vessels registered under Liberian or Panamanian flags.
Overall, it can be said that little is reported about incidents on cargo vessels, or in our case fully cellular container vessels, in the media familiar to the public at large, whether that be digitally on the Internet or in the press.
We can nevertheless claim that the objective of this dissertation, namely to provide a comprehensive overview of fires on container vessels from 2000 up to and including 2015, has been achieved. Publication of the figures by GL in *Containership Update* in January 2016 means that they have also been confirmed independently of the research done in this dissertation. Collation of the incidents and categorizing them in a uniform framework with 17 different items of data (vessel name + 16 other items) provided the basis that allowed analysis of the data. This allows each incident to be researched in greater depth. The data already available allows analysis of all the incidents. The analysis would be more informative if the records were completed. The existing data was used to produce eleven informative analyses.

The additional objective, namely to shed a critical light on the existing SOLAS convention by simulating fire incidents on an example vessel, can also be regarded as having been achieved. Four scenarios illustrated the options available to the crew on the basis of the fire protection equipment stipulated in the SOLAS convention. In none of these simulations is it possible for the crew to create a situation in which it is possible to fight the fire directly. Flooding the holds with CO_2 is not regarded as "fighting the fire directly" in this context.
It can be seen as having been substantiated that the crew in the simulations is only able to create a situation in which the fire is at least temporarily contained by rapid, well-considered and in some cases improvised actions. In none of the simulations, however, can we assume that activities could be undertaken to actually extinguish the fire.

Taking into consideration the huge increase in ship size described in Chapter 2 and the simulation on an example vessel with a TEU capacity of 5100, a number of conclusions are possible:
Firstly, vessels with almost four times the capacity are currently in regular service. In most cases, these vessels operate with crews of the same size as the vessel in the simulations.
Furthermore, new SOLAS regulations under which vessels with certain loading heights on deck have to carry portable monitors and a lance for puncturing the containers only apply to newly built vessels delivered after 01 January 2016. This means that a vessel with a capacity of around 20,000 TEU and delivered in 2015 carries the same equipment as the vessel in the simulations, notwithstanding the far greater concentration of value and risk.
This allows us to conclude that while the size and capacity of the ships has grown enormously, this has not been reflected in terms of the fire protection equipment and the size of the crew. The findings of this dissertation can convince shipowners, insurers and logistics companies to look at safety on board fully cellular container vessels from a different perspective.

Appendices

The appendices are contained on the accompanying data medium.

- Documents:
  - DIN 14010
  - OECD International Transport Forum - The Impact of Mega-Ships
- Fire and Safety Plan for example vessel:
  - Fire and Safety Plan BLACKED Page 1
  - Fire and Safety Plan BLACKED Page 2

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Email addresses / Contact persons

Mr. Uwe-Peter Schieder:	Gesamtverband der Deutschen Versicherungswirtschaft e.V., German Insurers' Association u.schieder@gdv.de
Captain Ute Hannemann:	Verein Hanseatischer Transportversicherer e.V., Association of Hanseatic Marine Underwriters uha@vht-online.de
Mr. Robert Megyery:	Noske-Kaeser GmbH + Service GmbH & Co. KG robert.megyery@noske-kaeser.com
Mr. Hauke Klehn:	Noske-Kaeser GmbH + Service GmbH & Co. KG hauke.klehn@noske-kaeser.com
Mr. Bernd Sehrer:	Noske-Kaeser GmbH + Service GmbH & Co. KG bernd.sehrer@noske-kaeser.com

Sworn declaration

I hereby declare that I authored this dissertation myself and without the assistance of any third party and that I used no aids other than those specified.
I have explicitly identified all literal citations or glosses from other works as such.

Bremen, 1st September 2016 Helge Rath