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Risk influencing factors in maritime accidents

An exploratory statistical analysis of the Norwegian Maritime Authority incident database

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Studio Apertura

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Studio Apertura, NTNU Social Research

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ABSTRACT

This report is an exploratory statistical analysis of the Norwegian Maritime Authority's database, using data on groundings, collisions, allisions fires/explosions and some data on capsizings in Norwegian waters from 1981 through 2014. The analysis is part of the Norwegian Ship Risk Model project. The statistical analysis is divided into two parts.

The first part is a descriptive analysis, which identifies common traits in accidents. Vessel types are broken down into 12 categories. Fires/explosions are most common on small fishing vessels in outer coastal waters in Northern regions, with a notable proportion happening in dock. Groundings are most common on cargo vessels in narrow coastal waters in Northern regions, and in the dark. Capsizings typically involve small fishing and cargo vessels in outer coastal waters, and feature strong winds and higher seas. Collisions are most frequent among fishing and break bulk vessels in outer coastal waters. Allisions are common among medium sized passenger vessels in the harbour area.

The second part of the analysis uses multinomic regression to describe variation between accidents. Accident types vary modestly between vessel types, gross tonnages and length, but substantially between waters. Groundings are associated with narrow coastal waters, collisions with outer coastal, allisions with port areas, and fires/explosions are associated with vessels in dock. Weather has limited effect, although collisions are ten times more likely than other accidents under no visibility. High vessel damage severity was primarily associated with shorter vessels. We were not able to explain much variation in injuries and fatalities.

The results indicate a strong need to connect accident data with normalized traffic data to identify risk influencing factors with more certainty.

KEYWORDS	Risk influencing factors, maritime accidents, relative probabilities, multinomic regression, fires/explosions, groundings, collisions, allisions, vessel types, waters, visibility, common accident scenario.

1 Preface

This report was written in January-March 2015 on commission from Studio Apertura, NTNU Social Research, as part of the National Ship Risk Model project. The author would like to thank the entire staff at Studio Apertura for helping me out with all my needs in this period. In particular, I would like to thank Trond Kongsvik and Petter Almklov for valuable comments and support in the work on this report. In addition, I would like to thank Rolf Bye, Stein Haugen and Elisabeth Blix at Safetec Trondheim for their input in the research process. Special thanks goes to the Norwegian Maritime Authority, and their representative Vegar Berntsen in particular, for assistance in supplying data and information.

Trondheim, May 18, 2015,

Per Stornes

2 Contents

3 Abstract

This research report is an exploratory statistical analysis of the Norwegian Maritime Authority's (NMA) incident database, with the objective of exploring possible Risk Influencing Factors (RIFs) in Norwegian maritime traffic for the National Ship Risk Model project. I use data on vessel accident reported from 1981 through 2014 on groundings, collisions, allisions and fires/explosions. Capsizings are also included in part 1 of the analysis. The analysis divides vessels into 12 categories.

The analysis consists of two main parts. The *first part* is a descriptive analysis where I describe common traits of accidents.

Fires and explosions are most common on small fishing vessels in outer coastal waters in the Northern regions. They usually happen in good weather. A notable proportion of fires and explosions happen while the vessel is in dock.

Groundings are most common among cargo vessels, however small fishing vessels in coastal fishing are also notable. Narrow coastal waters are typical, as is the northernmost region of the coastline. Groundings are most common in the dark and at night, while the ship is underway.

Capsizings typically involve smaller fishing and cargo vessels in outer coastal waters. The northernmost region of the coastline is once again notable for capsizings. Capsizings are characterized by strong winds, and more frequent in moderate and high seas than other types of accidents.

Collisions are most common among fishing vessels and break bulk vessels. They are most frequent in outer coastal waters, but narrow coastal waters and harbour areas also feature notably in collisions. Once again, the northernmost coastal region reports most collisions. Collisions tend to happen in good weather conditions.

Allisions are most common among medium sized passenger vessels, in particular ferries. They tend to feature vessels certified for trafficking protected waters. Half of all allisions are reported in narrow coastal waters, which in practice usually means striking the quay. Most allisions happen in the two regions between Lindesnes and Trondheim. They tend to happen in good weather, but a larger proportion happens in in strong winds compared to other accidents.

The *second part* of the analysis is an advanced statistical analysis. I perform a multinomic regression on accidents, and compare the relative influence on vessel types and qualities, geographical qualities and weather qualities in an integrated model. In addition, I perform multinomic analyses of certification, operational states and time variation. I perform logistic regressions on damage severity, injuries and fatalities using variables from the integrated model. In addition, I predict conditional probabilities for results from these analyses.

The main results are as follows. For **vessel types**, I find significant but modest differences in accident qualities for ferries, passenger/cruise vessels, high speed craft, work & service vessels and break bulk vessels. Foreign vessels are more likely to experience groundings than other accidents. Higher gross tonnages are associated with decreased probabilities of groundings.

Accidents vary substantially between **waters**. Groundings are most likely in narrow coastal waters, collisions most likely in outer coastal waters, and allisions most likely in port areas. Fires/explosions are more probable along quay than in other waters.

Weather has a limited effect on accident probabilities. Collisions are ten times more likely under conditions of no visibility.

Variations in **time** were modest. Groundings are more likely by night than by day, and collisions less likely. Vessels certified for coastal fishing had the highest probability of fires/explosions. Allisions appear more likely on arrival of port than on departure.

Vessel **damage severity** was primarily associated with vessel length. The shorter the vessel, the higher the odds of severe damage, particularly in allisions. I were not able to explain much of the variation on **injuries** and **fatalities**. High seas increase the risk of injury substantially in fires/explosions, whereas high speed craft have around five times higher probability of injuries than large fishing vessels. Groundings in short vessels increase the probability of fatalities by over 30 times.

I propose the following **main risk influencing factors**.

For **fires/explosions**, fishing vessels appear at high risk. Large gross tonnages increase risk of fires, as well as longer vessels. The risk of fires is high at the quayside, while weather appears to be little influential.

For **groundings**, cargo vessels (work and service vessels in particular) appear at higher risk. Vessels of low gross tonnage and longer length appear at higher risk. Narrow coastal waters increase the relative risk of groundings substantially.

For **collisions**, small break bulk vessels appear at higher risk. Travelling in no visibility increases the relative risk of a collision considerably. Outer coastal waters increases the risk of a collision considerably.

For **allisions**, high speed craft of medium gross tonnage and longer lengths appear at higher risk of allisions. Allisions are closely tied to the harbour area.

4 Introduction

This research report is an exploratory statistical analysis of the Norwegian Maritime Authority's (NMA) incident database, with the objective of identifying Risk Influencing Factors (RIFs) in Norwegian maritime traffic. The following chapter gives a brief description of the National Ship Risk Model project, the objectives of the second work package in the project, and an overview of the contents of this report.

4.1 The «National ship risk model» project

The National Ship Risk Model (NSRM) is a joint research project with the ultimate objective of developing a risk model for traffic in Norwegian waters. The research group consists of Studio Apertura at NTNU Social Research, Safetec Nordic AS and NTNU. The project is funded by the Norwegian Maritime Authority, the Norwegian Coastal Administration and the Norwegian Research Council (NTNU Social Research 2014).

The NSRM will be used to better monitor and communicate the risk picture of maritime activities in Norwegian waters. It will be used by the NMA to monitor changes in the risk picture, prioritize inspection activities (risk based inspections), and support decisions regarding development of regulations and safety improving measures. Furthermore, the risk model will be used as a tool by the NCA to improve the quality of their risk analysis preceding major interventions and modifications of fairways and ports, as well as in the daily risk assessments performed by the Vessel Traffic Service (VTS) Centres. It will also be used in the decision processes related to the pre-deployment of the governmental tugboat contingency service as well as oil spill response measures.

4.2 Goals of Work Package 3.

The objective of this work package is to generate knowledge regarding causes and conditional factors associated with different types of marine accidents. This knowledge will be generated by conducting statistical exploratory analysis of accident data. The data will be analysed by using explorative methods of logistic and multinomic regression analysis. The dependent variables will be accident types and accident qualities such as damage severity, injuries and fatalities. Parameters for the independent variables in the explorative analysis will be qualities of vessels, geography and weather. The results of these analyses will improve the knowledge regarding causes of marine accidents. The conceptualization of RIFs is based on the assumption that the risk (in terms of a quantitative measure) can be controlled by changing/managing/controlling the Risk influencing factors. The identification of RIFs will be used as input in work package 5 (the development of risk models).The deliverables of this work package are:

a) Research report presenting findings

b) One publication in scientific journal

4.3 Layout of the report.

The report is laid out as follows: Chapter 5 deals with some theoretical perspectives on risk influencing factors in maritime accidents. Chapter 6 describes the data in the NMA database and the operationalization of these data for the present analysis.

Chapter 7 and 8 together form part 1 of the analysis, and focuses on common traits in accidents. Chapter 7 presents descriptive statistics focusing on traits *within* accidents. Chapter 8 summarizes the descriptive statistics in the form of common traits of each accident type.

Chapters 9 and 10 form part 2 of the analysis, where accident traits are compared *between* accidents in advanced statistical models. (Take note that this is not directly compatible with the descriptive statistics presented in chapter 7, so a separate set of descriptive statistics is found in the appendix, chapter 13.) Chapter 9 presents the logistic and multinomic regression techniques applied in the analysis, with examples from the current dataset. Chapter 10 presents the statistical models. The analysis is laid out in the following way: First, I test the vessel, geographical and weather qualities in individual models in chapters 10.1-10.2. The significant variables from each model are then put together in an integrated model, which is the main item of interest in this report. Results from this model are presented in chapters 10.3-10.7.

Additionally, a few separate analyses are presented on additional qualities of accidents. These include separate analyses of time variables, operational states vessel damage severity. This is covered in chapters 10.8-10.10. Variables from the integrated model are also applied on two analyses of factors influencing injuries and fatalities in vessel accidents. This is found in chapters 10.11-10.13.

Chapter 11 brings an integrated discussion on risk influencing factors in vessel accidents.

5 Theoretical perspectives

The term "risk influencing factor" (RIF) is derived from Bayesian network analysis, and means any factor that affects an undesired event (Rausand & Utne 2011:187). The undesired events here are the *accidents*. A particular challenge in analysing data from an accident database is that we do not have access to non-accidents. For example, it may well be that most groundings take place in broad daylight under good weather conditions. What we cannot tell without access to regular traffic data is whether these conditions are substantially different between accidents and non-accidents. The NSRM research project plans to analyse regular traffic data retrieved from the AIS system. The findings from this report will be used as input into that analysis.

The present analysis uses accident data from 1981 forward, and I have not been able to retrieve regular traffic data for this period. The main reason for using data from back to 1981 is that it yields more statistical power. I work under the assumption that risk influencing factors have a partly static nature. For example, I assume that the effects of strong winds and high seas have not changed substantially since 1981. Any findings from the analysis therefore present an average of effects since the inception of the database.

Another challenge in the present analysis is that the accident database mainly quantifies technical data, such as vessel quality, geography and weather conditions. The database does contain some qualitative data on events surrounding the accident, but this analysis limits itself to the quantitative data that is readily available in the dataset. I can assume that these data only cover a limited range of causes of accidents.

At the current stage, I have not been able to retrieve normalized maritime traffic data. This analysis therefore limits itself to analysing only the accident data. It follows that there are serious limitations to the potential generalization of the findings. This has two major implications. First, a large part of the report will therefore be descriptive in nature, and aim to *summarize the most common traits of maritime accidents*. Second, as a consequence of not having access to information on non-accidents, the analysis will instead be forced to *compare different traits of accidents*.

As for the first part, it is our view that knowing the most common traits of accidents is useful in for example prioritizing inspections based on risk. Following a section of descriptive statistics, I will therefore devote a section to summarizing the most common traits for each type of accident. This is not a statistical analysis per se, but rather a qualitative description of singular traits of accidents.

As for the second part, it poses somewhat of a challenge, as accidents are not directly comparable. For example, it is impossible to know whether a decrease in accidents is due to a decrease in traffic, or a true decrease due to improved security measures. What we can do, however, is compare the relative influence of parameters against accident types. To achieve this, I will apply the technique of *multinomic regression*, which allows us to compare all different types of accidents against each other in a single model. We can, for example, investigate whether there are significant differences in vessel qualities between for example groundings and collisions. Or we can see whether strong winds or high seas are significantly different between types of accidents, while simultaneously comparing vessel types and different types of waters. This is presented in the section on regression analysis. First, there will be a multinomic regression comparing different accident types according to vessel, geographical and weather qualities. Then, there will be separate analyses for a smaller number of items. Accident severity, injuries and fatalities will be analysed using a combination of logistic and multinomic regression. Logistic regression will for example be used to compare fatal accidents against non-fatal ones.

Following each statistical analysis, there will be a presentation of the most important results. In Chapter 11, there will be a discussion on the most important findings.

The NSRM research group proposed the use of correspondence analysis in internal research project documents. I demonstrate this technique in the appendix, chapter 14.6, but it was judged not to be suitable for further use in this statistical analysis.

5.1 Risk models

As this is an exploratory statistical analysis, the purpose of the analysis is on contributing to building a risk model. I have taken inspiration from Balmat et al. (2011) in selecting items for analysis, see figure 5.1.1 below.

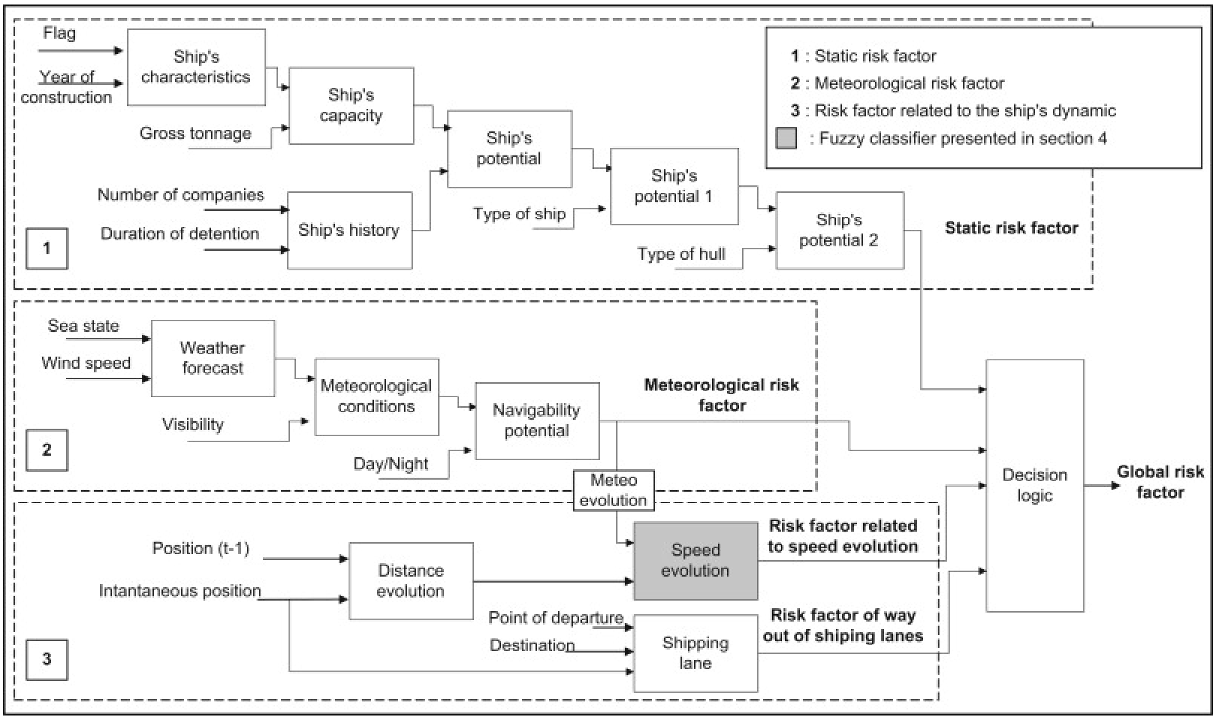

Figure 5.1.1: Maritime risk assessment architecture (from Balmat et al. 2011).

Adapting this architecture posed a challenge. I had to select items on the basis of availability. The technical nature of the database tells quite a lot about what Balmat refers to as *static risk factors*. I did not have data on ship history. Data on hull material was available, but only for a small number of cases. In terms of *meteorological risk factors*, I did not have access to data on weather forecasts. For the third risk factor, *speed evolution and shipping lanes*, I had some data on waters that was analogous.

I opted for a slightly different architecture, based on the available data.

First, there was a lot of data available on *vessel qualities*. This includes information on vessel type, nationality, technical information such as length and gross tonnage, and regulatory information such as vessel register.

Second, there was data available on *geographical qualities* such as the location and the type of waters of the accident.

Third, there was data available on *weather qualities* such as sea state, wind force, visibility and lighting.

Additionally, I looked at *time qualities* of the accidents such as year, seasons and hours. Finally I identified two complex variables for separate analysis: *certification* and *operational state*. Details on these items are found in chapter 6.

The database also contains information on some additional accident qualities regarding the consequences of accidents. I selected *damage severity* of the vessels, as well as *injuries and fatalities* as items for further study. I consider this useful information in building a risk model.

An overview of the issues covered in this report are summarized in figure 5.1.2 below.

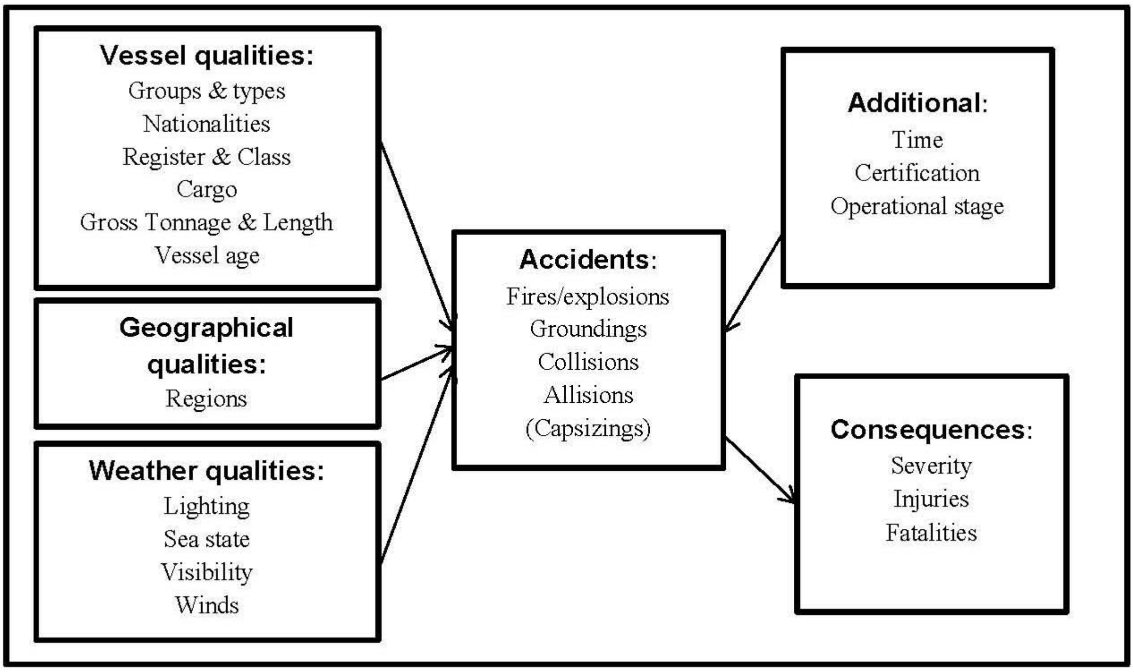

Figure 5.1.2: Potential risk influencing factors in maritime accidents, with consequences.

5.2 Research questions

On the basis of the preceding discussion, the research questions can be summarized as:

1. *How do vessel qualities, geographical and weather data affect the relative risk of maritime accidents?*
2. *How does time, certification and operational state influence the relative risk of maritime accidents?*
3. *What factors contribute to severity of vessel damage, injuries and fatalities in maritime accidents?*

Question 1 is covered in chapters 10.1-10.7, question 2 is covered in 10.8-10.10, and question 3 is covered in 10.11-10.13. I now proceed to describing the data and its operationalization.

6 The NMA incident database.

In the following chapter, I will briefly describe the history of the database, accident types and other qualities of accidents, as well as a qualitative description of the variables used in the analysis. Every variable is operationalized for use in this study at the end of each description.

6.1 History of the database.

The following is a brief outline of the history of the database, largely based on internal documentation supplied by the NMA. The database was created in 1981, under the acronym DAMA (Norwegian: "Databank til sikring av maritime operasjoner", English "Databank for securing maritime operations") (our translation). The criterion for inclusion was that the incident was under investigation by the NMA inspectors. The original database contained vessel incidents and *serious* personnel accidents, such as fatalities. By 1986, the NMA required *any* accident-related injury to be reported. In 1986, the NIS ship register was initiated, after massive relocation of nationally registered ships. In 1989, a separate database for personnel accidents was created. In 2006, the NMA itself was reorganized and relocated from Oslo to Haugesund. In 2008, the term *work accident* was redefined as any incident that results in injury during shipping operation. Additionally, all incident reporting was gathered on a single form, instead of using multiple forms for different types of events. In 2012, the Norwegian Maritime Code was updated to correspond with EU directive 2009/18. In 2013, all registering of accidents was reorganized to be done by a single unit.

Consequences for the analysis.

In terms of the current analysis, the main focus herein lies on the vessel accidents. None of the changes in regulation and reporting through the years appear to have fundamentally changed the reporting of accidents such as groundings, collisions and fires/explosions. As such, the entire database appears to be valid for analysis. In terms of personnel accidents, we limit ourselves to personnel accidents co-occurring with vessel accidents. The main difference here appears to be the change in 1986 from reporting only *serious* accidents to *any* accident. The fact that reporting, and personnel accident reporting in particular, has been organized in different ways through the years might also have an effect.

Another fundamental change is the introduction of the NIS register in 1986. However, in the context of the current analysis, this change might not affect the analysis much, as the

NIS ships are not licensed to carry cargo or passengers between Norwegian harbours, or be in regular traffic between Norwegian and international ports (Lovdata 1987).

The statistical analysis will therefore be an analysis of *average* effects of risk influencing factors from 1981 until 2014.

6.2 Validity of the data

6.2.1 Reporting of maritime accidents.

The present analysis rests on the assumption that the database is trustworthy. Still, there are several possible sources of error in reporting. The first and perhaps most crucial issue is whether all relevant accidents are in fact reported to the NMA. This is covered in the section on reliability. Second, there is also the issue of whether all relevant information is actually reported. At present, the NMA uses a publicly available form for reporting incidents and registering them. There have been several changes in regulation regimes through the years. For example, the NIS regime was not instituted until 1987. Some historical comparisons are thus limited.

Another type of related reporting issue is very relevant here, as it goes towards the severity of accidents. Presently, for example, the NMA requires all collisions to be reported, regardless of damage. There is plausible reason to believe that this might not always be adhered to, as there may little to be gained for captain, crew or shipping companies in reporting accidents. In fact, reporting may have undesirable effects, as it costs time, money and possibly reputation.

Thirdly, some of the reporting relies on a qualitative assessment on the part of the reportee, as well as the NMA caseworker. For example, the criteria for assessing an accident as “severe” or “less severe” might be open to interpretation, and might also change over time.

6.2.2 Reliability of vessel accident data

Research on the accountability of accident databases in general, and road and aviation databases in particular, suggests that accidents in general are substantially underreported (Psarros et al. 2010). With regards to maritime accident databases, Psarros et al. focused on the tanker vessel segment in the years 1997-2007, comparing data from the same NMA database as the present study with data from Lloyd’s Register FairPlay (LRFP). Their study suggests that only around 30% of all fires and explosions in this segment were actually reported.

The present study limits itself to accidents in Norwegian waters. A relevant question in this case is whether there are substantial differences in the reporting between Norwegian vessels and international vessels. Nævestad et al. (2014) suggest that even for serious accidents, there is a possibility that international ships might report the accident to their national maritime authorities and not to the NMA. At present, there is no open international database of accidents, which makes true reporting of maritime accidents even harder to calculate.

Concluding, then, it is safe to assume that the NMA database does not report all accidents in Norwegian waters, and that the degree of underreporting might be larger for non-Norwegian ships. It is generally assumed that less severe accidents are more under-reported than severe ones, although there is not strong empirical proof for such a claim.

6.3 Accident types.

Incidents vs accidents: The database is formally called an *incident* database. In this context, the term refers to any event that is reported to the NMA, fulfilling the criteria at the time of the event. The events are either *accidents*, described below, or *near accidents/misses,* described in Chapter 6.4.2.

The database contains information on various types of accidents. At an overall level, the database distinguishes between *personnel accidents* and *vessel accidents*. The majority of accidents are personnel only, numbering in excess of 20.000 events where one or more persons were injured or killed. The second overall category is vessel accidents, which are the accidents analysed herein. The database contains around 9500 such events in total. However, personnel injuries and fatalities are reported for vessel accidents as well.

Within the category of vessel accidents, the database distinguishes between 12 different accident types. They are, in order of frequencies: groundings, collisions, fires and explosions, allisions, other accidents, environmental damage and pollution, leakage, capsizing, weather damage, stability failure without capsizing, vessel missing and machine breakdown.

I have selected the four most common types of accidents for inclusion in the analysis. In addition, capsizings have been included in the section on common traits in accidents, due to the severe nature of this accident type. Capsizings were too small for inclusion in the advanced statistical analysis, however.

The database itself does not contain a qualitative description of accident types. However, the NMA has published guidelines for incident reporting (Sjøfartsdirektoratet 2013), which can be summarised as follows:

Grounding: Any incident where the vessel touches ground. This is in line with Jin et al's (2001) definition: "vessel is in contact with the sea bottom or a bottom obstacle, struck object on the sea floor, or struck or touched the bottom". Note that the NMA does not require the occurrence of damage to report groundings (Sjøfartsdirektoratet 2013).

Collision: A collision, as strictly defined by the NMA, is any incident of two (or more) vessels striking each other on the water surface, independent of the amount of damage. It is noteworthy that any such incident is reported as *two separate cases* in the database, as the database uses the ship as the primary unit of analysis (Sjøfartsdirektoratet 2014a). Note that unlike Jin et al. (2001), the NMA categorizes incidents involving only one vessel as a separate category, see allisions below.

Fires and explosions: The incident itself is self-explanatory. I consider the event as it is recorded in the database, without regard to whether the fire itself is a consequence of some other event, in contrast with Jin et al. (2001), who define fire and/or explosion as the initiating event reported.

Allisions: Strictly defined, an allision (Norwegian: kontaktskade) is the striking of a stationary object, other than another vessel. The database only reports allisions for incidents causing damage to the vessel or stationary object (Sjøfartsdirektoratet 2013). Thus, the separation between collisions and allisions are not only quantitative, but also qualitative.

Capsizing is when a boat or ship is turned on its side or it is upside down.

There have been numerous changes in the reporting scheme since the database's inception in 1981. However, it appears that the classification of vessel accident types has been consistent throughout.

6.4 Other qualities of accidents

6.4.1 Accident severity

The main part of this analysis deals with accident types as dependent variables. In addition, as pointed out in the introduction, accident severity is applied here as a measure of risk. Around three fourths of the database contains information on accident severity, measured by the degree of damage to the ship. The categories are, in assumed order of severity: Total shipwrecking/sinking, total shipwreck/no sinking, severe damage, less severe damage and no damage. The notion that shipwrecking with sinking is more severe than shipwrecking without sinking is debatable. I therefore split severity in two groups. *Less severe accidents* include the original categories less severe damage and no damage. All the other types are included in the *more severe accidents*.

As pointed out in the next chapter, there are other qualities of accidents that can be seen as measures of severity. These include near accidents, as well as the number of deaths and injuries associated with the accident. I cover these in the next sections.

6.4.2 Near accidents, injuries and fatalities

Near accidents (Near misses) are unplanned events that did not result in injury, illness, or damage. The NMA uses the criteria of danger of life, major material damage or serious pollution (Sjøfartsdirektoratet, n.d.). In the context of this study, a near accident could be used as a measure of severity, and be used to identify risk influencing factors. However, data on near accidents were not found to be sufficient for statistical analysis.

Injuries. The database contains an item on vessel accidents involving personnel injuries. As for fatalities, the database lists the number of injuries per incident. Thus, the larger amount of incidents is limited to single person injuries, whereas the most severe accident reported 75 injuries. As with severity and fatalities, I have chosen to divide injuries into two categories for the analysis: Accidents with no injuries, and accidents with one or more injury.

Fatalities or missing personnel. The database contains a shared variable for vessel accidents involving fatalities or missing persons. It is important to note that the database does not list these events individually. Rather, it reports the number of fatalities for each incident. Thus, the larger amount of cases involves a single fatality, whereas the largest number of fatalities for a single incident is 20. In the context of this study, this could be seen as a measure of the severity of an accident. To simplify, in this analysis I have opted to split the analysis in two groups: accidents with no dead or missing personnel, and accidents with one or more fatalities or missing persons.

6.5 Vessel groups in the database

The database categorizes vessels in five general groups, they will henceforth be referred to as “vessel groups”. It is important to differentiate this from the term “vessel types”, which refers to more specific subcategories of vessels within each group, and is covered in the next section. In order of frequencies, the groups are cargo, fishing, passenger and recreational vessels and finally, what is referred to as “mobile offshore units”. The current analysis limits itself to cargo, fishing and passenger vessels, as the number of incidents for the last two types is extremely small in comparison, and thus does not meet statistical requirements for inclusion.

Vessel groups in the database are based on the SOLAS agreement, “International Convention for the Safety of Life at Sea”, as maintained by the International Maritime Organization (IMO) (IMO 2015b).

Definitions:

A cargo vessel is a ship whose primary function is to carry cargo. The IMO (2015b) does not define this term precisely, but refers to specific types of cargo ships instead, such as bulk carriers and oil tankers. Thus, this category can be seen to be the broadest type of category in the dataset. The database contains many sub-categories of cargo vessels, which will be reviewed in the next section.

A fishing vessel is a vessel that is used in commercial fishing. Regulations divide these vessels into three subtypes according to length: 6 – 10.67 m, 10.67-15 m and more than 15 m (Sjøfartsdirektoratet 2014b).

A passenger vessel is usually defined as a merchant ship whose primary function is to carry passengers. The database does not define the category specifically. The NMA defines this as a ship that can carry more than 12 passenger or which needs a public permit to carry passengers (NMA 2012).

6.6 Vessel types in the database.

Vessel type is a complex categorization. In the database, vessel type is identified using a two or three character code, for example 1B, which is the code for an oil tanker. The first code is a number from 0 to 9 identifying a main type of vessel, where the second character is a number referring to a sub group of vessel types, sometimes adding a third character in the form of a number, referring to a subgroup of the subgroup. The database contains around 130 vessel types in total. There is a big challenge in reducing this number to a manageable and meaningful number of vessel types. The complete list of vessel codes is listed in the appendix in Norwegian. I provide a provisional translation of the cargo vessel types.

The most important distinction is the first number. An overview of the 10 main types is given in table 6.6 below.

Code	Vessel type
Type 0	A broad category of tankers, including chlorine and gas tankers.
Type 1	Tankers, ranging from oil to water and chemicals.
Type 2	2A: Break Bulk/Bulk/Container 2B: Tank/Ore
Type 3	Bulk ships
Type 4	Break bulk
Type 5	Passenger ships and ferries
Type 6	Fishing and other sea catching vessels.
Type 7	Specialty ships
Type 8	Expedition vessels
Type 9	Various ships

Table 6.6: Vessel types in the database

6.7 Vessel categories in the present analysis.

Based on work by the NSRM research group (Safetec 2014), I propose a risk structure for vessel types as follows:

6.7.1 Fishing vessels

Fishing vessels were split into two categories above and below 15 meters of length, as current regulations mainly differentiate between these two sizes (NMA 2013).

6.7.2 Passenger vessels

Five categories as described below, based on codes in the accident database, given in parentheses.

Passenger vessel type 1: **Inland ferries**. This category includes two types of car ferries (5C and 5C1) and ro-ro passenger ferries (5C2), with the assumption that inland ferries are below 8000 GT.

Passenger vessel type 2: **International car ferries**. This category includes the same ferries as type 1, with the assumption that ferries in international traffic are above 8000 GT. Note: The two preceding categories had to be collapsed into one group for statistical reasons. This is noted under the analysis section.

Passenger vessel type 3: **Passenger/cruiseships**. This includes the general category of passenger ships and ferries (code 5), various subtypes of passenger ships (5B, 5B1, 5B2), combined passenger/break bulk (general) cargo ships (5F) and indeterminate passenger vessels and ferries (5G).

Passenger vessel type 4: High-speed craft. This includes hovercraft (5H), catamarans/trimarans/hydrofoils (5I), general catamarans (5I1), passenger catamarans (5I4) and catamarans with combined passenger and break bulk cargo (5I5).

Passenger vessel type 5: Other passenger vessels. This category includes other small passenger/ferry/medical/shuttle vessels (5K), vessels with limited passenger carriage, medical/shuttle vessels (5K2), railway vessels (5D), hotel/lodging/hospital/missionary/exposition vessels (5E) and governmental passenger and patrol vessels.

6.7.3 Cargo vessels

Cargo vessels are the most diverse category. The NSRM research group has divided the vessels into 6 subtypes (Safetec 2014). I briefly summarize the qualities of the vessel types here. A full listing of all the separate vessel types is given in the appendix.

Bulk vessels carry cargo in bulk, meaning commodity cargo that is transported unpackaged in large quantities. The most common type of bulk vessel in the database is “common bulk” (3B), but cement (3F) and sand (3G) are also fairly common types of bulk. All the bulk ships included here belong to code 2 and 3 in the accident database vessel type categorization.

Break Bulk Cargo Vessels (general cargo, Norwegian: godsfartøy) carry goods that must be loaded individually. All the vessels in this category correspond to the NMA code 4. The most common types registered are “general cargo” and “pallet cargo”.

Offshore service vessels are ships specially designed to supply and serve offshore oil platforms. They correspond to codes 7D, 7D1 and 7D2 in the database. Work processes differ substantially from other bulk vessels, and regulations involve additional authorities, such as the Petroleum Safety Authority of Norway.

Tanker vessels are merchant vessels designed to transport liquids or gases in bulk. This includes most of the vessels coded 0 or 1 in the database, with oil (1B) and chemicals (1D) being the most common types.

Well boats are live fish carriers, derived exclusively from code 3H in the database. Work processes differ substantially from other bulk vessels, and regulations involve additional authorities, such as the Norwegian Food Safety Authority.

Work and service vessels are a diverse group of vessels that operationally have little in common with the other cargo categories. The most common types recorded in the database are tugboats and rescue ships (7A), research and supervision ships (7C) and pilot boats and fire rescue ships (7F).

Vessels which did not satisfy these criteria were excluded from the analysis. This meant that a few very small vessel types such as training ships were excluded from the analysis.

6.8 Vessel properties

In addition to the vessel types listed in chapter 6.7, I investigated some further vessel properties, detailed below.

Nationalities. The analysis divides nationalities into three groups based on the Paris MOU (2014a) port state control, which classifies ships on how they meet international safety, security and environmental standards, and whether crew members have adequate living and working conditions. The "White List" represents quality flags with a consistently low detention record, flags with an average performance are shown on the "Grey List", and the "Black List" shows flags with a poor performance that are considered high or very high risk (Paris MOU 2014b). Individual countries are listed in the descriptive statistics.

Ship registers: The database contains a record of the two Norwegian ship registers, NOR and NIS. As a main rule, inclusion in either the regular Norwegian register (NOR) or the Norwegian International Register (NIS) is mandatory for ships longer than 15 meters, independent of use (Sjøfartsdirektoratet 2014c). Some ships may be voluntarily registered in NOR, if they are at least 7 meters, or are used for commercial purposes. NIS was founded in 1987, with the main purpose of ensuring that Norwegian ships were registered under Norwegian flags, to improve the competitivity of Norwegian ships in international shipping, and to maintain the employment of Norwegian seamen. Ships in NIS are under Norwegian jurisdiction.

NIS was not introduced until 1987, which means that there is some skew to the analysis. The parameters for NIS vessels are average parameters for the period 1987-2014, as opposed to NOR vessels, where the parameters are average parameters for the entire period.

Class: A classification society is a non-governmental organization that establishes and maintains technical standards for the construction and operation of ships and offshore structures. The largest known classification society for vessels in the database is DNV, which as of 2013 merged with another major society, Germanischer Lloyd. I have retained DNV as a separate category in the database. Other known classification societies made up a separate category, which includes American Bureau of Shipping, Bureau Veritas, Germanischer Lloyd and Lloyd's Register. Other, unknown and unclassified vessels made up the last category.

Cargo. Around three fourths of the records contain information on cargo. Cargo in this context does not exclusively mean commercial cargo on merchant ships. Fish catches on fishing vessels and ballast is also recorded, as are passengers on all types of ships. These categories are also some of the most common types of cargo registered in the database.

The present analysis divides cargo into nine categories: Ballast, fish, passengers, dry/bulk/container, bulk/ore/grain/coal, oil/chemicals/gas, other known, empty and finally unknown cargo. (Take note that although the database lists “other known”, it does not actually say actually what this known cargo is.)

Gross tonnage (GT) (Norwegian: *bruttotonn*) is a measure related to a ship's overall internal volume. Gross tonnage is calculated based on "the moulded volume of all enclosed spaces of the ship" and is used to determine things such as a ship's manning regulations, safety rules, registration fees, and port dues. The measure was introduced in the International Convention on Tonnage Measurement of Ships, which came into force in 1982 (IMO n.d. a). The general rule for Norwegian ships is that ships of at least 15 meters should be measured according to GT (Lovdata 2009). The database records a continuous measure of GT, which includes around 90% of all incidents. Additionally, the database breaks GT down into three categories, below 500, between 500 and 3000, and above 3000. The reasoning behind these groupings appears to be the application of different safety regulations. For example, one regulation requires AIS to be fitted aboard all cargo ships of 500 gross tonnage and upwards not engaged on international voyages, and all passenger ships irrespective of size (IMO n.d. b). Another example is that there are different requirements in training according to these size limitations.

Thus, gross tonnage contributes to differences in risk based both on differences in physical properties in ships, and differences in regulation. For example, a smaller ship would respond differently to weather conditions such as high seas than a larger ship, all other things kept equal. In terms of regulation, the question is whether the increased degree of training required to steer a larger ship accurately reflects the increased degree of risk associated with increased size.

The present analysis divides gross tonnage into three categories: below 500, between 500 and 3000, above 3000 and finally unknown GT.

Length. The database records the length of the ship according to the same criteria as gross tonnage (Lovdata 2009). Thus, there is both a continuous measure in meters, as well as a grouping of ships shorter than 10.67 m, between 10.67 and 15m, 15 to 24 m, and longer than 24 m. Length is also associated with how GT is measured, as the formulas for GT differ with the length of the ship. The 10.67 limit applies to fishing vessels as described above, while 15 m is the lower limit required for measurement of GT. Almost all records contain information on length.

The present analysis divides length into five groups: vessels shorter than 10.67 m, between 10.67-15, between 15-24, above 24m and finally of unknown length.

Vessel age. The database records the year of build for around nine tenths of all ships. This information is used to calculate age of ship at the time of accident by subtracting the year of build from the year of the accident.

The statistical analysis divides year of build into five categories: 0-5, 6-15, 16-25, 25 and older and finally unknown age.

Operational state. The database contains information on operational state, meaning the stage at which the accident happened. There are no less than 17 categories originally. The five largest categories are underway, on arrival at port, along the quay, during fishing and on departure port. These categories by themselves imply that docking is an inherently risky activity. Due to the complexity of the category, a separate analysis was performed on this variable.

The statistical analysis breaks operational stage into 7 categories: the five given above, in addition to other known and unknown operational stage. The "other known" category consists of numerically very small categories such as in drilling position, in storage, anchored, on dynamic positioning, in security state, in towage, on installation and at buoy.

6.9 Geographical properties

The database records all known maritime accidents in Norwegian waters. This includes actual or potential spills in the territorial waters of Svalbard, Jan Mayen, and in the Norwegian economic zone. Thus, incidents involving both Norwegian and international ships are found in the database. Additionally, the database contains incidents of Norwegian vessels in non-Norwegian waters. This analysis limits the selection to all *incidents in Norwegian waters*, as defined by the Norwegian Map Authority (Kartverket 2014). To our knowledge, the territory covered in the database has not changed since its inception. For practical purposes, it is noteworthy that the grand majority of incidents happen near the Norwegian coastline, more on this in in the next section, and in the section on waters.

Longitude and latitude: The database contains positional data for around 80% of the incidents reported. This data was useful in selecting relevant cases, as cases reported for coordinates outside Norwegian waters could relatively easy be filtered out. The data was also used to visualize the positions and density of accidents. Data on longitude and latitude was however not ultimately used in the statistical analysis. A scatter plot of the selected positional items is given in figure 6.9.1 below.

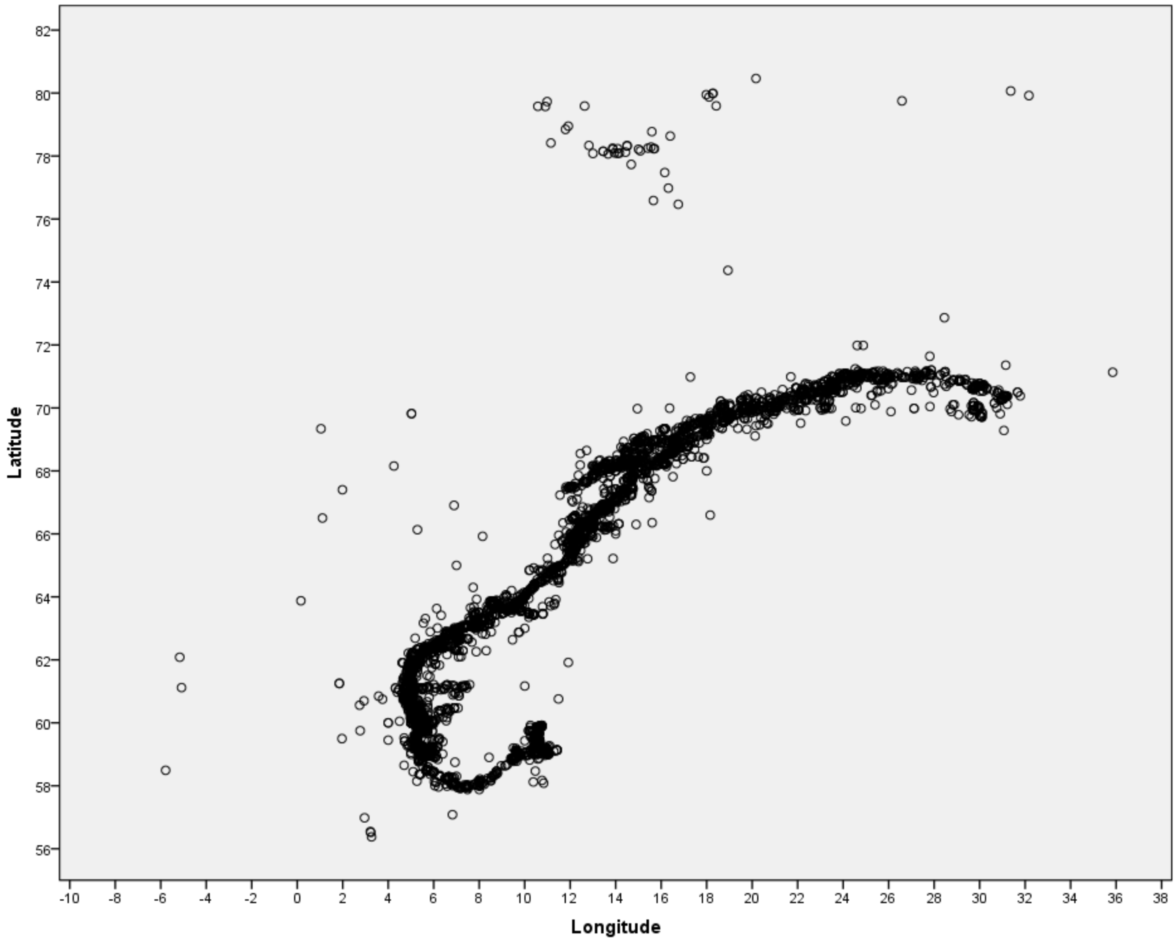

Figure 6.9.1: Scatterplot of longitude and latitude

We can clearly see the outline of the Norwegian coastline. A few events appear questionable. Some accidents appear to have taken place inlands. This could potentially be accidents in rivers and lakes, although these accident waters were initially filtered out. The results could be due to error in reporting correct positioning, or else it could be due to error in reporting accident waters. I have used multiple criteria to filter events, such as data on regions (covered in the next section). The results illustrate the potential scope of errors in database records.

Regions: The original database contains over 100 pre-defined geographical areas. Most of these are located along the Norwegian coastline, and refer to specific areas such as Stavanger, or to standardized shipping routes or waterways. For example, the database identifies Stadt to Ålesund as one such route. International routes are not included in this analysis.

The analysis breaks geographical areas into 8 initial categories: Swedish border-Lindesnes, Lindesnes-Bergen, Bergen-Trondheim, Trondheim-Tromsø, Tromsø-Russian border, Svalbard/Jan Mayen/Bjørnøya, Norwegian Continental Shelf/Arctics and finally other/unknown regions in Norwegian waters. Take note that for statistical reasons, a few of these categories were ultimately collapsed into the other/unknown category in the analysis. This is noted for each separate analysis.

Waters: The database contains information on 12 categories of waters. These are, in descending order of frequencies: Narrow coastal waters, outer coastal waters, port areas, open seas, canals/rivers, wharfside/dockside, oil field, separation/cautionary area, other and unknown waters, and finally lakes and archipelagic waters. There are relatively few missing cases. A brief review of the descriptive statistics gave cause to believe there were systematic differences in accidents between types of waters.

The statistical analysis collapsed the categories into seven initial categories: narrow coastal, outer coastal, dockside, oil field, separation area and finally others/unknown. Note that for statistical reasons, oil field and separation are were ultimately collapsed into the *other* category in the analysis. The most important categories are therefore narrow and outer coastal waters, port/harbour areas and dockside.

The NMA does not have a strict legal definition of outer and narrow coastal waters. This is somewhat surprising as it used as a set category in the accident report. The categories are based on qualitative assessments made by the NMA inspectors, according to information supplied by the NMA. A tentative description is that *outer coastal waters* are areas on the outer side and in relatively close proximity of the Norwegian coastline, not far enough from the coastline to qualify as open seas. In some cases, outer coastal might be areas between islands and reefs in the outer archipelagos of mainland Norway. *Narrow coastal waters* are waters between islands and reefs and the mainland, and fairways where vessels meet and must observe each other closely for safe passage. The terms *harbour area* and *dockside* are considered to be self-explanatory.

6.10 Weather properties

Lighting conditions are reported in three categories, light, twilight and dark. Data is available for around three fourths of all incidents. I used the three categories in addition to a separate category of unknown.

Sea state was measured in 9 categories, in accordance with World Meteorological Organization *sea state code* (WMO, n.d.). The original categories were calm (glassy), calm (rippled), smooth (wavelets), slight, moderate, rough, very rough, high, very high, phenomenal.

For the present analysis, I divided sea state into three categories: calm/smooth, slight/moderate and rough/high/phenomenal, as well as a category of unknown wind force.

Visibility is measured in 5 categories, based on visibility in nautical miles: Poor (0.5-2 miles), good (over 5), moderate (2.1 to 5), below 0.25 and tight fog/snowfall (0-0.5). Data is available for around three fourths of all acccidents. I used these categories in the analysis, in addition to a separate category of unknown visibility.

Wind direction and speed. The database records wind direction in 8 categories in the form of north, north-east etc for about three fourths of all incidents. Wind speeds are measured according to the Beaufort scale, which means there were 13 ordinal categories.

For the present analysis, I opted to exclude wind direction from further analysis. Wind force was coded into three categories: Calm, light air and light breeze was coded as *weak winds.* Moderate and fresh breeze was coded as *moderate winds*, on the basis that the Norwegian Meteorological Institute issues weather warnings from moderate breeze and upwards. Strong breeze, high wind, gales, storms and hurricanes were coded as *strong winds*. In addition, there was a category of unknown and unregistered winds.

6.11 Date and time properties

The database contains exact data on the date of the accident, which was used to extract three categories of eleven years each and a variable on four quarters. A separate variable for exact time of accident was also present, but a lot of missing data and doubts about the precision of this data led us to construct four categories of hours: night time (01-06), morning (7-12), afternoon (13-18) and evening (19-23) as well as a category of unknown hours.

Take note that all cases recorded as happening at midnight were coded as unknown, as I could not ascertain which ones actually happened at midnight. Midnight is therefore not included in the analytical categories.

6.12 Certification properties

The certification area is a designated type of water a vessel can traffic (Lovdata 1981). It has a direct impact on construction, equipment, crew and operation of the vessel. Both ship and crew must be certified to operate in the designated area. Due to its complexity, it was subjected to a separate statistical test. The main division in certification is between national and international traffic. The different certifications are listed below.

National traffic: Traffic on rivers and lakes and along the Norwegian coastline, with the exception of Svalbard and Jan Mayen.

Traffic in enclosed waters (Area 1): Traffic on Norwegian lakes and rivers, as well as inner parts of fjords and other waters that can usually be considered smooth.

Traffic in protected waters (Area 2): Traffic on Norwegian waters which are protected against waves and wind from the open seas, as well as any waters within these areas.

Inshore traffic within open seas of 5 nautical miles (Area 3): Traffic along the Norwegian coastline which does not pass any stretch of more than 5 nautical miles, not protected against waves and winds of the open seas, as well as any waters within.

Inshore traffic within open seas of 25 nautical miles (area 4): Traffic along the Norwegian coastline which does not pass any stretch of more than 25 nautical miles, not protected against waves and winds of the open seas, as well as any waters within.

Minor coastal traffic: Traffic along the Norwegian coast line which passes more than 25 nautical miles which is not protected against waves and winds of the open seas, as well as any waters within, with the added proviso that the ship is never further than 20 nautimal miles beyond the baseline (the line from which the seaward limits of a state's territorial sea and certain other maritime zones of jurisdiction are measured). The waters around Stadtlandet are considered minor coastal traffic.

International traffic: Any traffic beyond national traffic.

*Major coastal traffic***:** Minor coastal traffic, plus traffic on Swedish, Danish and German waters east of Lindesnes-Limfjord, and west of Karlskrona-Svinemünde.

Northern and Eastern Sea traffic: Minor coastal traffic, as well as traffic in Skagerrak, Kattegat, Eastern Sea (including the Botnic and Finnish bay), and the North Sea up to 61 degrees north. Traffic to Great Britain, Ireland east of 8 degrees west, and the English canal limited to Brest-Cork.

European traffic: Any travel within the following outer limits: The White Seas, Svalbard, Jan Mayen, Iceland, Madeira, Azores, Canaries, the African west coast north of 30 degrees, the Mediterranean and the Black Sea.

Minor international travel: International traffic where the vessel is not beyond 200 nautical miles from port, or where passengers and crew can be brought to safety, or where the distance between the latest port of arrival begins and the last destination does not exceed 600 nautical miles.

International traffic: Traffic from a country which has ratified the SOLAS treaty to a harbour beyond this country, or the other way around.

Overseas traffic: Traffic from one continent to another across one of the oceans.

Unlimited traffic: Traffic on any waters.

The categories were initially retained for use in the statistical analysis. Some of the smaller categories had to be collapsed into an unknown category for statistical reasons, this is noted in the analysis.

6.13 Vessel identity

I include a summarised account of the way vessels and accidents are identified in the database, although I do not use this data in the analysis. This section might be useful for later work on normalization of traffic data using AIS.

ID. All incidents in the database are linked to an ID. As pointed out in connection with collisions, these ID's pose somewhat of a challenge in analysing the database, as a collision involves two ships, the ships are used as cases in the database, and both cases thus share the same ID.

Vessel names: The database records the name, callsign and and IMO number of all ships where available. Interestingly, around one third of all **name cases** are duplicate, meaning that a ship of the same name was involved in more than one accident. **Callsigns** are supposed to be unique identifiers of ships. They report even more duplicates, around half of all callsigns occur more than once in the data.

International Maritime Organization (IMO) numbers are a unique reference for ships and for registered ship owners and management companies. They were introduced under the SOLAS Convention to improve maritime safety and security and to reduce maritime fraud. For ships, the IMO number remains linked to the hull for its lifetime, regardless of a change in name, flag, or owner. (IMO, n.d. b) However, IMO numbers were not made mandatory until 1994, and then not covering all ship types. Thus, only around half of the incidents feature IMO numbers. Interestingly, only around one fourth of all IMO numbers are unique to the database.

Taken together, the data on accident and vessel IDs strongly suggests that many ships are involved in multiple accidents. These ships can be seen as having higher risk, and it would therefore be interesting to investigate these cases further. There was, however, not enough space to cover this in the current report.

6.14 A note on missing data

The database in many ways resembles a Swiss cheese: There are many categories with large shares of missing data. The reasons for missing data can be many. First, there have been a few changes through the years on reporting. For example, there exists some data on current speeds, but this was not introduced before the early 00s (and was therefore found not suitable for inclusion in the analysis). Second, not all information may have been considered relevant at the time of reporting the accident. For example, if the accident happened while the ship was in dock, there might reason to believe that sea state was not recorded.

Some of these data could have been imputed, using for example mean values of vessel length for the given vessel type. The present analysis uses only data which is categorized. I have therefore opted for a strategy of categorizing missing data as unknown or unregistered. Significant results for these categories could imply that there are systematic differences between the known and the unknown categories. In the present analysis, I do not delve into the influence of unknown and unregistered data, and as such, significant results on these categories will not be discussed further. The reader is free to hypothesize on his own on the meaning of such results.

This concludes the descriptions of the categories in the database. In the next two chapters, I will present descriptive statistics and a summary on the most common accident traits in Norwegian waters.

7 Analysis Part 1: Common traits in accidents - descriptive statistics.

In the following two chapter (7 and 8), I will do a descriptive analysis of common traits in accidents. Chapter 7 contains descriptive statistics for each accident trait. Therefore, the variables are summated in columns. Looking at table 7.1.1 below, we can for example see that fires and explosions are most common on fishing vessels, while groundings are most common on cargo vessels. These traits are summarized in chapter 8.

Take note that this format is different from the format used in the advanced statistical analysis used in chapters 9 and onwards. The regression analysis requires the tables to be summated in rows instead of columns. Descriptive statistics for the regression analysis is found in the appendix.

Take note that this section includes data on capsizings, whereas the more advanced statistical analysis in chapters 9 an onwards exclude this accident type due to the small number of accidents, which makes capsizings unfit for advanced statistical analysis.

I would also like to point out that although crosstables like these are informative, they should be read with care. It could very well be that the variation we find between vessel types, for example, has more to do with differences in gross tonnage and length of the vessel, than with the vessel types as such. To know what creates the variation between accident types, the advanced technique of regression analysis has to be conducted. This is done in chapter 9 onwards.

7.1 Vessel qualities

Vessel group	**Accident type**					
	Fire/expl.	*Grounding*	*Capsizing*	*Collision*	*Allision*	*Total*
Fishing vessel	64,8%	37,7%	46,0%	43,8%	8,7%	37,8%
Cargo vessel	20,2%	40,1%	48,9%	34,0%	25,4%	35,5%
Passenger vessel	15,0%	22,2%	5,0%	22,2%	65,9%	26,7%
	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%
Total N	**614**	**3607**	**139**	**865**	**772**	**5997**

Table 7.1.1: Distribution of vessel groups within accident types.

Vessel type	Accident type					
	Fire/expl.	*Grounding*	*Capsizing*	*Collision*	*Allision*	*Total*
Fishing <15m	39,9%	15,8%	31,7%	25,0%	2,8%	18,3%
Fishing >15m	24,9%	21,8%	14,4%	18,8%	5,8%	19,5%
Ferries	4,4%	11,6%	2,9%	9,2%	48,8%	15,1%
Passenger/cruise	5,2%	5,9%	1,4%	7,7%	8,9%	6,4%
High-speed	1,5%	2,1%	0,0%	2,3%	7,0%	2,6%
Other passenger	3,9%	2,6%	0,7%	2,9%	1,2%	2,6%
Work and service	4,2%	4,8%	23,0%	3,5%	3,1%	4,7%
Offshore service	2,0%	1,2%	0,0%	1,4%	3,6%	1,6%
Wellboats	0,7%	2,4%	0,0%	0,8%	0,6%	1,7%
Tanker	1,3%	2,7%	1,4%	2,3%	2,2%	2,4%
Bulk	1,6%	3,9%	2,9%	3,5%	3,2%	3,5%
Goods (Godsfartøy)	10,4%	25,2%	21,6%	22,5%	12,6%	21,6%
	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%
Total N	**614**	**3607**	**139**	**865**	**772**	**5997**

Table 7.1.2: Distribution of vessel types within accident types.

Nationalities	Accident type					
	Fire/expl.	*Grounding*	*Capsizing*	*Collision*	*Allision*	*Total*
Norwegian	97,4%	92,4%	97,1%	92,3%	92,5%	93,0%
PMOU White List	2,4%	6,5%	2,2%	6,5%	6,3%	6,0%
PMOU Grey, Black & Others	0,2%	1,1%	0,7%	1,3%	1,2%	1,0%
	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%
Total N	**614**	**3607**	**139**	**865**	**772**	**5997**

Table 7.1.3: Distribution of vessel national groups within accident types.

Register	Accident type					
	Fire/expl.	*Grounding*	*Capsizing*	*Collision*	*Allision*	*Total*
NOR ships	87,5%	87,7%	82,7%	83,0%	89,9%	87,2%
NIS ships	1,3%	4,4%	1,4%	4,7%	4,4%	4,1%
Foreign ships	0,8%	0,4%	1,4%	0,0%	0,4%	0,4%
Unregistered & unknown	10,4%	7,4%	14,4%	12,3%	5,3%	8,3%
	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%
Total N	**614**	**3607**	**139**	**865**	**772**	**5997**

Table 7.1.4: Distribution of vessel registers within accident types.

Class	Accident type					
	Fire/expl.	*Grounding*	*Capsizing*	*Collision*	*Allision*	*Total*
Class DNV	16,3%	28,4%	10,1%	23,5%	27,2%	25,9%
Class ABS/BV/GL/LR	3,7%	10,1%	5,8%	9,7%	5,7%	8,8%
Class other, unknown, unregistered	80,0%	61,5%	84,2%	66,8%	67,1%	65,4%
	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%
Total N	**614**	**3607**	**139**	**865**	**772**	**5997**

Table 7.1.5: Distribution of classification societies within accident types.

Cargo	Accident type					
	Fire/expl.	*Grounding*	*Capsizing*	*Collision*	*Allision*	*Total*
Ballast	29,5%	21,1%	8,6%	19,8%	8,4%	19,9%
Passengers	8,8%	15,4%	2,2%	16,8%	50,3%	19,1%
Fish and fish produce	16,3%	19,8%	26,6%	17,9%	3,5%	17,2%
Dry/Bulk/Container	3,4%	11,4%	17,3%	9,8%	5,4%	9,8%
Bulk (Ore, coal, grains etc)	2,3%	6,8%	11,5%	4,3%	2,3%	5,5%
Other known cargo	0,8%	1,7%	9,4%	0,8%	1,8%	1,7%
Oil and oil produce	0,3%	1,1%	0,0%	0,9%	1,2%	1,0%
Chemicals and gas	0,3%	0,4%	0,0%	0,0%	0,3%	0,3%
Empty	13,7%	5,4%	3,6%	5,7%	4,7%	6,2%
Not registered/unknown	24,6%	16,9%	20,9%	24,0%	22,2%	19,5%
	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%
Total N	**614**	**3607**	**139**	**865**	**772**	**5997**

Table 7.1.6: Distribution of registered cargo within accident types.

Gross Tonnage	Accident type					
	Fire/expl.	*Grounding*	*Capsizing*	*Collision*	*Allision*	*Total*
< 500	79,3%	67,5%	82,0%	69,9%	37,6%	65,5%
500-3000	11,1%	24,3%	5,0%	18,5%	47,3%	24,6%
>3000	5,2%	5,2%	1,4%	6,2%	14,6%	6,5%
Unknown	4,4%	2,9%	11,5%	5,3%	0,5%	3,3%
	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%
Total N	**614**	**3607**	**139**	**865**	**772**	**5997**

Table 7.1.7: Distribution of gross tonnages within accident types.

Length	Accident type					
	Fire/expl.	*Grounding*	*Capsizing*	*Collision*	*Allision*	*Total*
< 10.67 m	28,8%	9,6%	33,1%	19,4%	1,8%	12,5%
10.67 to 15 m	14,2%	8,4%	15,1%	8,4%	1,3%	8,2%
15 to 24 m	21,3%	13,3%	13,7%	16,5%	5,1%	13,5%
> 24 m	34,5%	67,4%	36,7%	52,9%	90,0%	64,1%
Unknown	1,1%	1,4%	1,4%	2,7%	1,8%	1,6%
	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%
Total N	**614**	**3607**	**139**	**865**	**772**	**5997**

Table 7.1.8: Distribution of vessel length within accident types.

Ship Age: Continuous

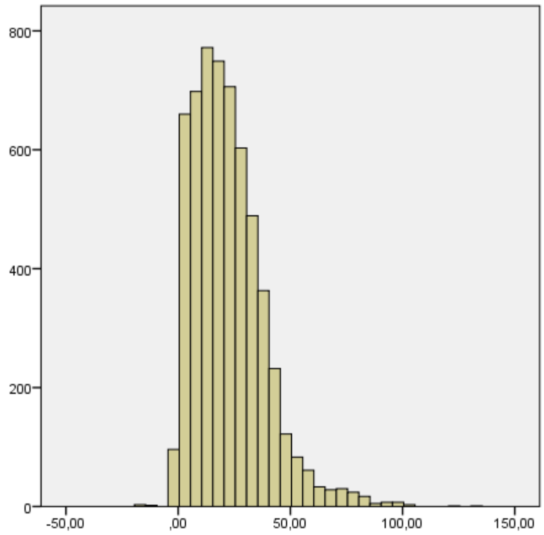

Figure 7.1.1: Vessel age in years.

Ship Age: In categories

Ship Age	Accident type					
	Fire/expl.	*Grounding*	*Capsizing*	*Collision*	*Allision*	*Total*
0-5	12,2%	12,1%	7,9%	11,0%	17,7%	12,6%
6-15	23,3%	24,2%	24,5%	26,9%	24,1%	24,5%
16-25	20,8%	24,3%	25,9%	27,5%	22,8%	24,3%
25+	41,0%	36,2%	37,4%	30,9%	30,2%	35,2%
Unknown	2,6%	3,2%	4,3%	3,7%	5,2%	3,5%
	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%
Total N	**614**	**3607**	**139**	**865**	**772**	**5997**

Table 7.1.9: Distribution of vessel age within accident types.

7.2 Geographical qualities

Region	Accident type					
	Fire/expl.	*Grounding*	*Capsizing*	*Collision*	*Allision*	*Total*
Swedish border - Lindesnes	7,7%	7,9%	11,5%	12,9%	10,2%	9,0%
Lindesnes - Bergen	15,8%	16,8%	14,4%	22,7%	28,5%	19,0%
Bergen - Trondheim	13,7%	23,2%	23,0%	16,8%	27,1%	21,8%
Trondheim - Tromsø	30,5%	36,3%	36,0%	27,7%	21,2%	32,5%
Tromsø - Russian border	30,5%	13,6%	14,4%	18,2%	8,4%	15,3%
Svalbard/Jan M./Bj.	0,0%	1,2%	0,0%	0,5%	0,3%	0,8%
Norwegian Continental Shelf/Arctics	0,3%	0,0%	0,0%	0,9%	2,8%	0,5%
Other/Unknown regions	1,6%	0,9%	0,7%	0,3%	1,4%	1,0%
	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%
Total N	**614**	**3607**	**139**	**865**	**772**	**5997**

Table 7.2.1: Distribution of regions within accident types.

Waters	Accident type					
	Fire/expl.	*Grounding*	*Capsizing*	*Collision*	*Allision*	*Total*
Narrow coastal	16,9%	58,4%	18,7%	28,4%	14,4%	43,3%
In harbour area	24,3%	16,0%	25,2%	27,7%	64,0%	24,9%
Outer coastal	35,3%	21,8%	43,9%	37,2%	4,0%	23,6%
Along quay	20,4%	0,5%	7,9%	2,9%	11,4%	4,5%
Oil field	0,2%	0,0%	0,0%	0,8%	2,7%	0,5%
Separation area	0,0%	0,0%	0,0%	0,6%	0,0%	0,1%
Other/unknown	2,9%	3,2%	4,3%	2,3%	3,5%	3,1%
	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%
Total N	**614**	**3607**	**139**	**865**	**772**	**5997**

Table 7.2.2: Distribution of waters within accident types.

7.3 Weather qualities.

Lighting	Accident type					
	Fire/expl.	*Grounding*	*Capsizing*	*Collision*	*Allision*	*Total*
Light	48,2%	35,5%	48,2%	56,8%	53,2%	42,5%
Twilight	7,3%	7,3%	5,0%	8,6%	7,6%	7,5%
Dark	25,6%	48,5%	23,7%	28,2%	25,1%	39,6%
Unreg./unknown	18,9%	8,7%	23,0%	6,5%	14,0%	10,5%
	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%
Total N	**614**	**3607**	**139**	**865**	**772**	**5997**

Table 7.3.1: Distribution of lighting conditions within accident types.

Sea state	Accident type					
	Fire/expl.	*Grounding*	*Capsizing*	*Collision*	*Allision*	*Total*
Calm seas	43,8%	56,0%	29,5%	62,7%	52,6%	54,6%
Slight/moderate seas	11,2%	14,4%	22,3%	12,3%	5,3%	12,8%
High seas	0,8%	2,8%	12,2%	1,4%	1,6%	2,5%
Unknown	44,1%	26,8%	36,0%	23,7%	40,5%	30,1%
	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%
Total N	**614**	**3607**	**139**	**865**	**772**	**5997**

Table 7.3.2: Distribution of sea states within accident types.

Visibility	Accident type					
	Fire/expl.	*Grounding*	*Capsizing*	*Collision*	*Allision*	*Total*
Good (>5 nm)	52,8%	56,9%	46,8%	63,4%	64,1%	58,1%
Moderate (2.1.-5 nm)	6,0%	11,6%	10,8%	8,6%	9,8%	10,4%
Poor (0.5-2 nm)	2,0%	7,4%	6,5%	3,8%	2,6%	5,7%
None (>0.25 nm)	0,2%	4,9%	0,0%	8,0%	1,6%	4,3%
Tight fog, snowfall (<0.5 nm)	1,0%	4,8%	0,7%	4,4%	1,2%	3,8%
Unknown	38,1%	14,4%	35,3%	11,9%	20,7%	17,8%
	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%
Total N	**614**	**3607**	**139**	**865**	**772**	**5997**

Table 7.3.3: Distribution of visibility within accident types.

Wind force	**Accident type**					
	Fire/expl.	*Grounding*	*Capsizing*	*Collision*	*Allision*	*Total*
Winds Weak	24,1%	31,3%	20,9%	40,2%	29,0%	31,3%
Winds Moderate	17,3%	22,2%	13,7%	21,4%	14,4%	20,4%
Winds Strong	5,4%	18,1%	29,5%	6,9%	18,7%	15,5%
Winds Unknown	53,3%	28,4%	36,0%	31,4%	38,0%	32,8%
	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%
Total N	**614**	**3607**	**139**	**865**	**772**	**5997**

Table 7.3.5: Distribution of wind force within accident types.

7.4 Time qualities

Accident year	**Accident type**					
	Fire/expl.	Grounding	Capsizing	Collision	Allision	Total
1981-1991	51,0%	39,1%	41,0%	47,2%	21,6%	39,3%
1992-2002	21,2%	32,7%	28,8%	35,0%	25,4%	30,8%
2003-2014	27,9%	28,2%	30,2%	17,8%	53,0%	29,9%
	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%
Total N	**614**	**3607**	**139**	**865**	**772**	**5997**

Table 7.4.1: Distribution of accident years within accident types.

Seasons	**Accident type**					
	Fire/expl.	*Grounding*	*Capsizing*	*Collision*	*Allision*	*Total*
Jan-Mar	27,0%	28,1%	38,1%	24,7%	27,3%	27,6%
Apr-Jun	23,3%	19,2%	18,7%	26,5%	22,2%	21,1%
Jul-Sep	25,1%	22,2%	15,8%	26,1%	23,6%	23,1%
Oct-Dec	24,6%	30,5%	27,3%	22,7%	26,9%	28,2%
	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%
Total N	**614**	**3607**	**139**	**865**	**772**	**5997**

Table 7.4.2: Distribution of seasons within accident types

Time data:

Data for time have been approximated to the nearest hour, and then split into five categories. A large number of accidents in the database were timed to midnight. There is good reason to believe that this is due to the exact accident time being unknown. The histogram below in figure 7.4.1 shows this very clearly graphically. I have therefore timed all accidents reported as happening at midnight as “unknown”.

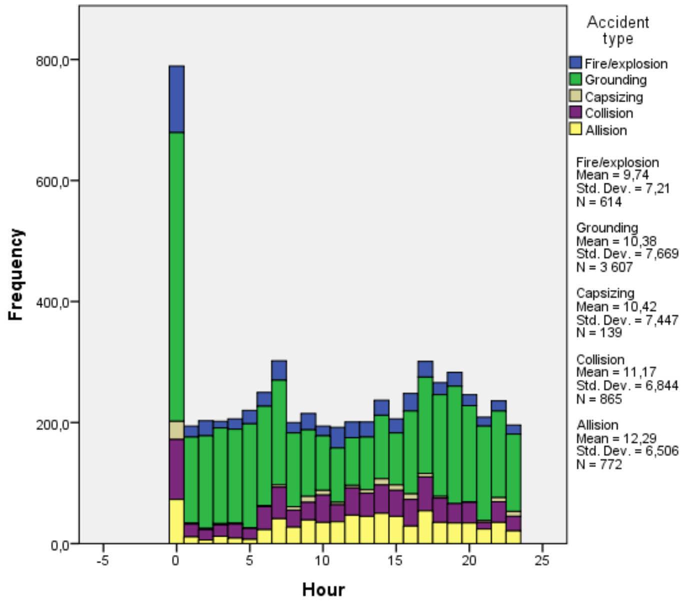

Figure 7.4.1: Distribution of accidents by hour.

Time	**Accident type**					
	Fire/expl.	*Grounding*	*Capsizing*	*Collision*	*Allision*	*Total*
01-06	18,9%	26,2%	7,9%	15,7%	8,8%	21,3%
07-12	24,8%	18,4%	25,9%	26,2%	29,1%	21,7%
13-18	24,1%	20,6%	30,9%	31,0%	33,4%	24,3%
19-23	14,3%	21,6%	13,7%	15,6%	19,2%	19,5%
Unknown	17,9%	13,2%	21,6%	11,4%	9,5%	13,2%
	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%
Total N	**614**	**3607**	**139**	**865**	**772**	**5997**

Table 7.4.3: Distribution of accident time within accident types.

7.5 Other notable qualities

Certification	**Accident type**					
	Fire/expl.	*Grounding*	*Capsizing*	*Collision*	*Allision*	*Total*
Enclosed waters	1,5%	2,5%	3,6%	4,5%	4,5%	3,0%
Protected waters	3,1%	6,4%	2,2%	5,1%	30,4%	8,9%
Inshore <5 n.m.	3,7%	5,7%	2,9%	5,0%	9,5%	5,8%
Inshore <25 n.m.	4,6%	4,8%	5,0%	4,2%	4,8%	4,7%
Minor coastal traffic	5,0%	11,1%	13,7%	7,6%	6,7%	9,5%
Major coastal traffic	1,1%	2,9%	3,6%	3,2%	0,5%	2,5%
Northern & Eastern Sea	2,9%	8,6%	1,4%	6,2%	2,5%	6,7%
European traffic	1,8%	4,7%	1,4%	2,3%	3,8%	3,9%
International & Overseas	1,0%	0,5%	0,0%	1,4%	0,9%	0,7%
Unlimited traffic	2,4%	3,9%	2,2%	3,6%	4,0%	3,7%
Fjord fishing	0,7%	0,5%	2,2%	1,3%	0,0%	0,6%
Coastal fishing	12,7%	6,2%	7,9%	8,7%	1,3%	6,7%
Bank fishing	9,0%	7,8%	5,8%	5,5%	1,8%	6,8%
Sea fishing	8,5%	11,5%	3,6%	8,2%	2,3%	9,4%
Others/unknown	40,4%	21,4%	44,6%	32,9%	19,2%	25,2%
Certificate B/C/D	1,6%	1,4%	0,0%	0,2%	7,8%	2,1%
	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%
Total N	**614**	**3607**	**139**	**865**	**772**	**5997**

Table 7.5.1: Distribution of vessel certification within accident types.

Operational stage	**Accident type**					
	Fire/expl.	*Grounding*	*Capsizing*	*Collision*	*Allision*	*Total*
Underway	35,5%	75,7%	43,9%	64,2%	11,9%	61,0%
On arrival port	2,3%	8,6%	3,6%	8,4%	65,2%	15,1%
Along quay	28,8%	0,5%	12,9%	4,5%	4,3%	4,8%
On departure port	1,8%	3,7%	2,9%	7,4%	6,5%	4,4%
Fishing	11,6%	1,8%	14,4%	6,7%	0,0%	3,6%
Other known	7,5%	1,5%	5,0%	1,5%	6,3%	2,8%
Unknown/others	12,5%	8,1%	17,3%	7,3%	5,8%	8,4%
	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%
Total N	**614**	**3607**	**139**	**865**	**772**	**5997**

Table 7.5.2: Distribution of operational stages within accident types.

Severity	**Accident type**					
	Fire/expl.	*Grounding*	*Capsizing*	*Collision*	*Allision*	*Total*
No damage	0,9%	1,7%	0,0%	4,7%	8,2%	2,4%
Less damage	38,5%	65,5%	4,5%	61,8%	78,6%	61,6%
Severe damage	24,5%	25,7%	19,7%	16,0%	11,8%	23,5%
Shipwreck, no sinking	7,3%	0,9%	3,8%	1,1%	0,0%	1,7%
Total shipwreck	28,8%	6,2%	72,0%	16,4%	1,3%	10,9%
	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%
Total N	**587**	**3380**	**132**	**275**	**449**	**4823**

Table 7.5.3: Distribution of severity within accident types.

Injuries	**Accident type**					
	Fire/expl.	*Grounding*	*Capsizing*	*Collision*	*Allision*	*Total*
No injuries	94,3%	98,1%	92,1%	95,8%	89,6%	96,2%
One person injured	4,2%	1,2%	7,2%	3,5%	6,1%	2,6%
Two or more injured	1,5%	0,6%	0,7%	0,7%	4,3%	1,2%
	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%
Total N	**614**	**3607**	**139**	**865**	**772**	**5997**

Table 7.5.4: Distribution of injuries within accident types.

Fatalities	**Accident type**					
	Fire/expl.	*Grounding*	*Capsizing*	*Collision*	*Allision*	*Total*
No fatalities	99,0%	99,3%	80,6%	97,9%	99,9%	98,7%
One fatality	0,7%	0,4%	10,1%	1,6%	0,1%	0,8%
Two or more fatalities	0,3%	0,2%	9,4%	0,5%	0,0%	0,5%
	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%
Total N	**614**	**3607**	**139**	**865**	**772**	**5997**

Table 7.5.5: Distribution of fatalities within accident types.

8 Analysis Part 1: Common traits in accidents

This section summarizes the descriptive statistics given in the previous section for each accident type. A summary of common traits across accident types is given in the last part of this section.

8.1 Common traits in fires and explosions

Fires and explosions account for 614 (10,2%) of 5997 accidents.

8.1.1 Vessel qualities in fires and explosions.

Both when looking at the general vessel groups and the more specific vessel types, we can see that fires and explosions are most common on fishing vessels, and vessels under 15 m in particular. Most of the vessels involved are over 25 years old. As most fires happen on small vessels, it follows that most fires happen on ships below 500 GT. The largest known certification category is vessels registered for coastal fishing. Most of the vessels involved in fires and explosions are registered in the NOR database. The largest known class is DNV. The most common cargo held on a vessel involved in a fire is ballast followed by fish. Most fires happen on ships below 15 m in total, while fires on longer vessels are also quite common. Almost all fires and explosions happen on Norwegian ships.

8.1.2 Geographical qualities in fires and explosions.

Most fires happen in outer coastal waters, however, the distribution is relatively equal among categories: In the harbour area, along the quay and narrow coastal waters all accounting for substantial portions among waters. When it comes to geographical regions, the two northernmost regions (Trondheim-Tromsø and Tromsø-Russia) account for around 30% each of all fires.

8.1.3 Weather qualities in fires and explosions.

When it comes to sea state, the largest known category is calm and glassy seas. The same pattern holds for wind forces, where weak winds are the largest known category. Good lighting conditions are the most common in fires, followed by dark conditions. Most fires happen in good visibility.

8.1.4 Time qualities in fires and explosions.

Most fires and explosions happen in the first quarter of the year, although there is only a few percent variation between seasons. Most of these accidents happen during daytime and in the afternoon, although there is also relatively little variation here.

8.1.5 Other notable qualities in fires and explosions.

Most fires happen while the ship is underway or in dock, as is also reflected in the geographical qualities. A relatively small proportion of injuries happen in fires and explosions, and a small proportion of fatalities. Fires and explosions tend to have somewhat severe consequences, with a large amount of shipwrecks and severe damage.

8.2 Common traits in groundings

8.2.1 Vessel qualities in groundings.

For the general category of vessel groups, we see that most of the groundings are reported on cargo vessels. For the more specific vessels types, most of the groundings occur in the category godsfartøy (break bulk). However, this is a more general category than most of the other categories. The more specific categories of short and long fishing vessels are also commonly featured in groundings. Groundings are most common among older ships, although this might reflect the relatively high ship age in the database. Most groundings occur on vessels of less than 500 GT, and the most common certification is for coastal fishing. A large majority of vessels are in the NOR register, and most commonly classed by DNV, although there are a lot of vessels of unknown class. Most vessels involved in groundings are above 24 m.

8.2.2 Geographical qualities in groundings.

Most groundings happen in narrow coastal waters, and in the region north of Tromsø.

8.2.3 Weather qualities in groundings.

Most groundings happen in a calm sea state, with weak winds. However, groundings are most frequent in the dark. This is slightly at odds with the fact that most groundings are reported in good visibility.

8.2.4 Time qualities in groundings

Most groundings happen in quarters 1 and 4, and most happen at night.

8.2.5 Other notable qualities in groundings

Most groundings happen while the ship is underway. Groundings involve the least of all injuries and rather few fatalities. They tend to involve less severe damage to the ship.

8.3 Common traits in capsizings

Capsizings account for 139 of all accidents. This small number gives reason for caution in reading too much into the descriptions, as the basis for statistical generalization is much smaller than for the other categories. Capsizings were therefore not included in the advanced statistical analysis in chapters 9 and 10.

8.3.1 Vessel qualities in capsizings.

For the general vessel groups, cargo and fishing vessels account for 95% of all capsizings. The largest vessel type involved in capsizing is small fishing vessels. Work and service vessels as well as goods vessels and large fishing vessels also contribute substantially. Most of the vessels are old, and below 500 GT. The largest known certification is minor coastal traffic. The large majority of vessels belong to the NOR register, and are of unknown class, while DNV is the largest known class. Most capsizings are reported on vessels longer than 24 meters, although vessel below 10.7 m rank a close second, presumably due to the large number of small fishing vessels.

8.3.2 Geographical qualities in capsizings.

Most capsizings are reported in outer coastal waters, and in the region north of Tromsø.

8.3.3 Weather qualities in capsizings.

Most capsizings are reported in calm seas. However, capsizings have the largest share of accidents happening in slight/moderate and high seas. Most capsizings are reported when the wind is strong, which sets these accidents apart from other accident types, where weak winds are most common. Around half of all capsizings are reported in good lighting conditions and in good visibility.

8.3.4 Time qualities in capsizings.

Most capsizings are reported in the first quarter, and in the afternoon.

8.3.5 Other notable qualities in capsizings

Most capsizings are reported while the ship is underway. Capsizings have the largest share of injuries and fatalities among accident types, and are also associated with total shipwrecking and severe damage. These qualities suggest that although capsizings are relatively rare, much can be gained from reducing the number further.

8.4 Common traits in collisions

Once again, it should be noted that one collision is reported as at least two events, as the database lists collisions per ship.

8.4.1 Vessel qualities in collisions.

Looking at the general vessel groups, most vessels reported are fishing vessels. Both types of fishing vessels as well as break bulk vessels account for the three largest types of vessels. Most of the ships are more than 25 years old, with a gross tonnage below 500. Certifications are relatively evenly distributed, but coastal fishing, sea fishing and minor coastal traffic are the most common. A large majority is registered in NOR, and are of unknown class, with DNV being the largest known class. More than half of all ships reported in collisions are longer than 24 meters.

8.4.2 Geographical qualities in collisions.

Around a third of all collisions happen in outer coastal waters, with narrow coastal and in the harbour area following closely behind. The region north of Tromsø reports most collisions, followed by Lindesnes-Bergen.

8.4.3 Weather qualities in collisions.

Most collisions are reported in calm seas and weak winds. More than half are reported in light conditions, and a quarter in dark. Visibility is reported to be good in most cases.

8.4.4 Time qualities in collisions

Most collisions are reported in quarters 2 and 3, and in the afternoon.

8.4.5 Other notable qualities in collisions

Most collisions are reported while the ship is underway. When it comes to injuries and fatalities, collisions are about average. Collisions are associated with less severe damage in most cases.

8.5 Common traits in allisions

8.5.1 Vessel qualities in allisions.

In terms of the general vessel groups, allisions are by far most frequent in passenger vessels. When it comes to vessel types, this is reflected in the large share of ferries involved in allisions. Break bulk vessels follow a rather distant second. Most ships are more than 25 years old. When it comes to gross tonnage, allisions differ somewhat from other accidents, in that they primarily are associated with tonnages of 500-3000, although tonnage below 500 follows a rather close second. Allisions are also different in that most accidents are reported for vessels certified to traffic protected waters. They are primarily registered in NOR, and with a large category of unclassed vessels, with DNV following second. Around 90% of allisions happen on ships above 24 m length.

8.5.2 Geographical qualities in allisions.

Almost half of all allisions are reported in narrow coastal waters, and the Lindesnes-Bergen region is the largest, closely followed by Bergen-Trondheim.

8.5.3 Weather qualities in allisions.

Allisions are associated with calm sea states and weak winds, although allisions are relatively more common in strong winds than for most other types of accidents. Half are reported in light conditions, and with good visibility.

8.5.4 Time qualities in allisions.

Allisions are relatively evenly spread through the year, although they are marginally more common in the first quarter. Most allisions happen in the afternoon.

8.5.5 Other notable qualities in allisions.

Not unexpectedly, as allisions are highly associated with ferries in narrow waters, most allisions are reported on arriving port. Somewhat more surprising is the fact that allisions have the second highest share of injuries, but only a fraction of fatalities. Most allisions report less severe damage, with severe damage following a rather distant second.

8.6 Common traits in accidents: A summary and comparison.

In the following section, I briefly summarize notable traits of accidents, and make a comparison between accident types, to lay the ground for the analysis ahead.

Fires and explosions are most common on small fishing vessels in outer coastal waters in the Northern regions. They usually happen in good weather. A notable proportion of fires and explosions happen while the vessel is in dock.

Groundings are most common among cargo vessels, however small fishing vessels in coastal fishing are also notable. Narrow coastal waters are typical, as is the northernmost region of the coastline. Groundings are most common in the dark and at night, while the ship is underway.

Capsizings typically involve smaller fishing and cargo vessels in outer coastal waters. The northernmost region of the coastline is once again notable for capsizings. Capsizings are characterized by strong winds, and more frequent in moderate and high seas than other types of accidents. Capsizings tend to be the most severe accidents in terms of damage, injuries and fatalities. Fortunately, they are rare.

Collisions are most common among fishing vessels and break bulk vessels. They are most frequent in outer coastal waters, but narrow coastal waters and harbour areas also feature notably in collisions. Once again, the northernmost coastal region reports most collisions. Collisions tend to happen in good weather conditions.

Allisions are most common among medium sized passenger vessels, in particular ferries. They tend to feature vessels certified for trafficking protected waters. This goes together with the fact that half of all allisions are reported in narrow coastal waters, which in practice usually means striking the quay. In contrast with other accident types, most happen in the two regions between Lindesnes and Trondheim. Most happen in good weather, but a larger proportion happens in in strong winds compared to other accidents. Allisions come second in the number of cases involving injuries.

The following table summarizes these traits:

	Fires/explosions	**Groundings**	**Capsizings**	**Collisions**	**Allisions**
Vessel	Small fishing	Cargo and small fishing	Cargo and small fishing	Fishing, break bulk	Medium sized passenger, ferries
Weather	Good	In the dark	Strong winds, higher seas	Good	Good, stronger winds
Waters	Outer coastal	Narrow coastal	Outer coastal	Outer coastal	Narrow coastal
Other	Notable proportion in dock	Underway	Severe	Notable proportion in narrow coastal waters and harbour areas	Notable proportion of injuries

Table 8.6.1: Common traits in accidents summarized.

As we can see, accidents vary between vessel types. Fishing and cargo vessels feature most in the first four accident types, whereas passenger vessels feature most in allisions. Most accidents are reported in good weather, but allisions feature somewhat harsher conditions. We see that groundings and allisions are more typical in narrow coastal waters, where the other types are typical in outer coastal. As we can see from the last row in the table, each accident type has some additional particular qualities.

8.7 Risk influencing factors based on common traits

Based on the previous description, I propose the following candidates for risk influencing factors in these types of accidents:

Fires/explosions: Small fishing vessels appear to be at higher risk of fires and explosions. Weather does not appear to influence the risk of fires substantially. Waters emerges as a risk influencing factor. Most fires happen in outer coastal waters, but a notable proportion happens in dock.

Groundings: Cargo and small fishing vessels appear at higher risk of groundings. Darkness emerges as a RIF in groundings, as does narrow coastal waters.

Capsizings: Cargo and small fishing vessel appear as exposed to higher risk of capsizing. Severe weather is more common in capsizings.

Collisions: Fishing and break bulk vessels appear at higher risk of collisions, with outer coastal waters increasing the risk of collisions.

Allisions: Passenger vessels and ferries appear at higher risk of allisions. Stronger winds emerges as a possible risk influencing factor. Narrow coastal waters appears to increase the risk of allisions.

I now move on to see whether these purely descriptive points will hold up to be statistically significant when all variables are ultimately entered simultaneously into an advanced statistical analysis. Conditional probabilities for the common traits scenarios are calculated in chapter 10.6.

9 Analysis part 2: Logistic and multinomic regression methods

This chapter is strictly methodological, and therefore quite technical in nature. Readers who are not familiar with regression techniques are advised to read the whole chapter. You do not need to understand the reasoning behind the logarithmic transformation technique that is used, but the chapter will tell you how to interpret the output of the regression analysis, how I arrive at the probabilities I present in the results section, and enable the reader to calculate probabilities on his or her own, if so desired. Readers familiar with logistic regression can skip to the section on multinomic regression.

The following analysis will apply the methods of logistic and multinomic regression. Multinomic regression is an expansion on logistic, so I will cover the logistic model first, and the multinomic model second, illustrating the concepts with examples from the current data set.

9.1 The logistic regression model.

Regression analysis is a method of predicting the variability of a dependent variable, such as an accident, using information on one or more independent variables, such as vessel, weather and geographical properties. The method attempts to find out what values in the dependent variable we can expect, given certain values of the independent variables (Vogt 2005:69). In this case, the dependent variables are primarily accidents, and secondarily qualities of accidents.

In the case of accidents, they either happen or they don't happen. In this case, I only have data on different types of accidents. For the current dataset, that means that an accident is either for example a fire/explosion or it is not, in which case it is another type of accident. I express this mathematically by assigning fires the value 1, and all other accidents 0.

Logistic regression uses what is technically referred to as maximum likelihood estimation, which selects coefficients that make the observed value the most likely to have occurred (Vogt 2005:188). For technical reasons, data is transformed by using natural logarithms. See for example Field (2009:264-315) for a detailed introduction to this method.

Logistic models are assessed by what is technically referred to as changes in -2 Log Likelihood or -2LL. The log likelihood is a measure of unexplained variance in the model. We wish to reduce unexplained variance, and therefore the size of -2LL. As I add explanatory variables, log likelihood should therefore decrease. Initial models are compared to a theoretical null model, which contains no explanatory variables.

I do not report -2LL values here, as they are not very intuitive in their interpretation. Instead, I report pseudo R squares, which have an intuitive interpretation, as they report the percentage of the variation we are able to explain. A model which explained all the variation would thus have a R square of 100%. For technical reasons, logistic regression is not able to produce a true R square, and there are a number of approximations. I have selected the Cox & Snell measure. All pseudo R squares have technical issues that demand that they be treated with some caution. A shortcoming of the Cox & Snell measure is that its maximum value can be less than 100%, which means that we actually underestimate the explained variance. In this instance, we are primarily interested in how pseudo R squares change between models, and an increase in the figure is interpreted as an improvement of the model. For more on this topic, see for example Field (2009) or Eikemo & Claussen (2012).

I also assess the statistical significance of the model. This tells us whether a model with explanatory variables explains the variation in accidents better than a model without explanatory variables. Each variable is also tested using an LR test. This tells us whether a single variable adds significant explanatory power to the model. As we are using variable categories as parameters in the model, we might experience that a variable, such as wind force, is significant as a whole, whereas a single category, such as medium winds, might not be. As long as the variable as a whole is significant, it makes statistical sense to retain it in the analysis.

More on significance in the example below.

A simple example.

Using a simple example to illustrate, I ask how fires vary among vessel groups. In this case, I simply compare fires to *all other types of accidents*. For the dependent variables, I compare the effects of the vessel group against a reference category; in this case I use fishing vessels. Running a logistic regression in SPSS yields the following result:

	B	SE	Wald	p	OR
Cargo Vessels	-1.237	.108	131.322	.000	.290
Passenger Vessels	-1.281	.121	112.362	.000	.278
Constant	-1.512	.055	745.369	.000	.220

Table 9.1.1: Logistic regression of fires by vessel groups.

Statistical tests of the model

The model is *statistically significant* at the 0.000 level, meaning that there is only an extremely small probability that the results could be due to chance. By extension, it is highly likely that fires and explosions vary systematically between vessel groups.

The model has a Cox & Snell *pseudo R square* of 0.035. This is a somewhat unreliable measure, but shows that we can explain only approximately 3.5% of the variation in fires from vessel groups.

Interpreting the results of the analysis

Now I move on the most interesting part of the analysis, namely interpretation of the coefficients in the model.

Interpreting the B-coefficient, standard error, Wald and p.

The B-coefficient shows the change in the *predicted logit* when there is a change of one in values on the independent variable (Eikemo & Claussen 2012:122). The predicted logit is a technical measure, which is only a preliminary step in the analysis. In this case, the independent variables can change from either being a cargo or a passenger vessel (1) or not being one (0). The only thing we can read from the B-coefficient is that since it is negative for cargo vessels, they are *less likely* to be involved in fires than fishing vessels. It is important to keep in mind that this is conditional upon an accident happening. Put in another way, if an accident happens, it is less likely that it is a fire if we are travelling on a cargo vessel.

SE stands for standard error, and is technically defined as the standard deviation of the sampling distribution of a statistic (Vogt 2005). In layman's terms, it tells us the margin of error in the B-coefficient.

The Wald statistic is a technical measure for assessing the significance of individual coefficients (Vogt 2005: 341), which is given in the next column. These values are called p-values, and technically they are defined as the probability that a statistic could occur by sampling error, if the null hypothesis were true (Vogt 2005:252). The commonly accepted p-value is below 0.05, meaning that values below are considered statistically significant, and values above 0.05 are considered statistically insignificant. In layman's terms, a value above 0.05 implies too much of a probability that the results could be due to chance, although this is a simplistic interpretation of the p value.

Interpreting the odds ratio in the odds scale

Technically, the odds ratio (OR) is the *antilogarithm of the B-coefficient* (Eikemo & Claussen 2012:123). Another slightly simpler way of describing it is as the relationship between two odds. In this case, the OR tells us of the odds of an accident involving a cargo or passenger vessel compared to the odds of involving a fishing vessel. The OR is not totally straightforward in its interpretation, but with a little effort it can tell us a lot. Odds are briefly defined as the ratio of success to failure in probability calculations (Vogt 2005:219).

Odds of 1:1=1 implies that there's an equal chance of success and failure in an event. It follows that an odds ratio of 1:1=1 implies that two events have the same odds. An OR higher than one implies that the odds *increases* when the value of the variable changes by one, and an OR below one implies that the odds *decreases*.

Using the results from the simple regression model given above, we see that cargo vessels have an OR of -1.237. This means that given that an accident happens, the odds of it being a fire happening with a cargo vessel is 1.237 times or 23.7% lower than the odds of it being a fire with a fishing vessel. If the odds ratio was higher than 1, that would mean the odds increased. Take note that percentage changes in odds are not the same as changes in probability, which I will cover in the section on calculating L.

It is still hard to have an intuitive understanding of how odds ratios affect probabilities, but it tells us something of the relative influence, in this case it tells us that fishing vessels are more likely to be involved in fires than other vessels. I will review probabilities next, after explaining how to calculate the regression equation to find L.

Calculating L: The regression equation and predicting probability.

Odds ratios can be transformed to probabilities by using the formula $P=(1/1+e^{-L)}$, where P is the probability, and L the predicted B coefficient. To calculate probabilities in the given model, we first need to calculate the regression equation. Here, we only have one independent variable, which yields the following equation: $L = B_0 + B_1X_1$, or, in more practical terms, L = Constant + Vessel type. (In more complex equations, additional independent variables are added together in the same way as vessel types.)

We have three different possibilities, depending on vessels group. In table 9.1.2 below, we find the calculated probabilities of an accident being a fire. For clarity, I have also calculated the probability of the accident not being a fire by using the formula P(Not fire) = 100 – P(Fire).

Vessel group	L	P (Fire)	P (Not fire)
Fishing	-1.512 + 0 (since it is the reference category) = -1.512.	18,1 %	81,9 %
Cargo	-1.512 - 1.237 = -2,749	6,0 %	94,0 %
Passenger	-1.512 - 1.281 = -2,793	5,8 %	94,2 %

Table 9.1.2: Predicted vessel groups in fires/explosions.

How do we interpret these numbers? First and foremost, the reader must always keep in mind that given that we are analysing an accident database, it is 100% certain that an accident is going to happen. (Take note that we summarize probabilities in rows, which always are 100%.) What we are trying to find out here, is what the probability is of this accident being a fire, as opposed to a grounding, collision or allision. Note that by this method, we can only tell whether other accidents are non-fires. Next, we have to keep in mind that we are using fishing vessels as the reference category. Say we are on board a fishing vessel, and we know that there's going to be an accident. Then, there's around a 18% chance that this accident is going to be a fire.

What happens if we travel by a cargo vessel instead of a fishing vessel? Then, the probability that the accident will be a fire decreases to 6%. Cargo vessels are thus less likely to report fires than fishing vessels are. The results are very similar for passenger vessels. In absolute terms, the probability decreases from around 18 to around 6. In relative terms, you could say that it is around three times more likely that an accident will be a fire on a fishing vessel as opposed to other vessel. The logistic regression technique will be applied to analyses of vessel damage severity, injuries and fatalities.

The logistic technique is not satisfactory in that we only are able to compare fires to non-fires. I will therefore move on to an extension of the logistic regression model. All aspects of interpretation of the logistic model are carried forward into the multinomic regression model. The multinomic technique will be applied to analysis of vessel qualities, geography and weather.

9.2 The multinomic regression model

Multinomic regression (Tufte 2012) is based on logistic regression with an important addition. Where logistic regression only permits a dichotomous outcome, such as fires versus non-fires, multinomic regression allows a number of categorical outcomes on the dependent variable. In this way, we can compare how an independent variable influences several outcomes at once. The differences between the logistic and multinomic methods are illustrated in the figures below.

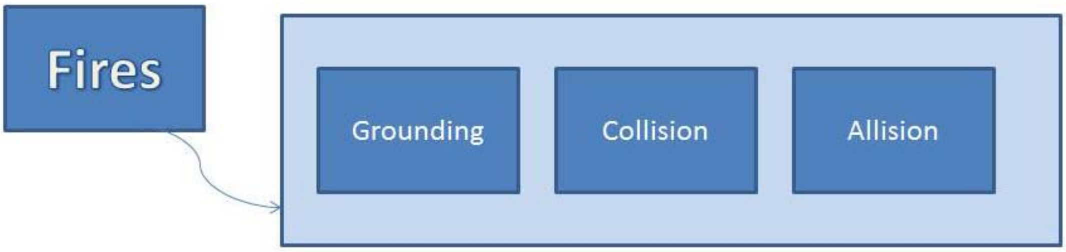

Figure 9.2.1: Illustration of logistic approach: Fires vs non-fires.

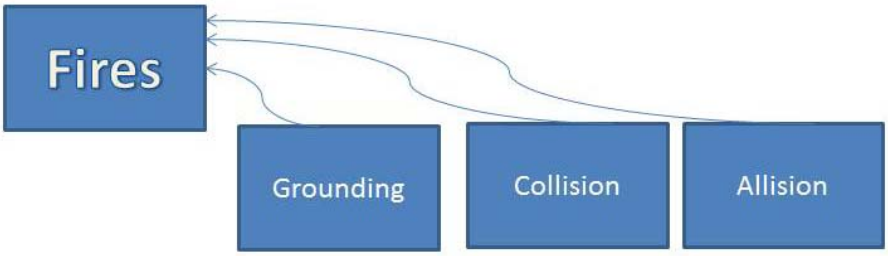

Figure 9.2.2: Illustration of multinomic approach: Grounding, collision and allision vs fires.

I will continue by using the same example as in the previous section, only this time by comparing each accident type against one reference category. All other types of accidents will be compared to fires/explosions. The reference category for vessels will remain fishing vessels.

Running a multinomic analysis yields the following results. Only B, significance and OR is reported here:

Vessel type	**Accident type**								
	Grounding			*Collision*			*Allision*		
	B	p	OR	B	p	OR	B	p	OR
Intercept	1.228	.000		-.049	.496		-1.782	.000	
Cargo Vessel	1.229	.000	3.418	.912	.000	2.490	2.240	.000	9.390
Passenger Vessel	.936	.000	2.550	.785	.000	2.192	3.492	.000	32.865

Table 9.2.1: Multinomic regression of accidents by vessel groups.

9.2.1 Interpreting the model

The model can be interpreted in the following way: The previous logistic model compared fires against non-fires. Here, we split the non-fires into three distinct accident types. The model can be described as having three logistic regressions in one. Each model can be read in the same way as a logistic model. We compare groundings with fires, collisions with fires and allisions with fires. The B's, p's and OR's are read exactly in the same way as a logistic model: For groundings, the odds are around 3.4 times higher that an accident on a cargo vessel will be a grounding as opposed to a fire. For passenger vessels, the odds are over 32 times higher that an accident will be an allision as opposed to a fire.

The advantage this has over the logistic model is that now we are able to separate the variation between all types of accidents. An additional advantage is that we are able to do this in one model, which means that we can compare figures. The odds of an allision on a passenger vessel are 32 times higher than for a fire, while the odds of a grounding is just 2.5 times higher.

9.2.2 Statistical tests of the model

The model as a whole is significant at the .000 level, with a Cox and Snell pseudo R square of 13.3%, which implies that the model explains a lot more of the variation than the logistic model. This is a statistical argument in favour of using multinomic regression instead of logistic. The logical extension of this argument is that we are able to see how each accident type is different from the others, instead of comparing one accident type against the rest.

The intercept is here interpreted in the same way as the constant in the previous example, as the value of L when all other values are zero. In this case, it means the values for a fishing vessel. The statistics software does not list odds ratios for the intercept, but the coefficient for groundings is positive, which means that the odds are higher for groundings on fishing vessels than for fires, and lower for collisions and allisions.

Odds ratios are listed for cargo and passenger vessels. The odds ratio for cargo vessels in groundings is 3.418. This means that cargo vessels have increased odds of groundings compared to the odds of fires/explosions. In fact, all odds ratios are larger than 1, which means that fires and explosions on fishing vessels have decreased odds of happening, compared to all other combinations of accident types and vessel groups.

The most extreme result is that passenger vessels have an odds ratio of over 32. This means that an allision on a passenger vessel is 32 times more likely to happen than an allision on a fishing vessel.

9.2.3 Calculating probabilities in multinomic regression

Take note that the following calculations summate probabilities in rows and not columns. The probabilities should therefore be compared to the descriptive statistics in the appendix.

A challenge in using multinomic regression is the calculation of probabilities, which is even more complex than in logistic regression. This has to be done in two steps. First, we have to calculate the odds for all the values of the independent variable we wish to calculate. Second, we take the odds of the value of the variable we wish to calculate, and divide it by the sum of all odds plus one. For the reference category, we divide 1 by the sum of 1 and all available odds. I will now do some predictions on probabilities for accidents in passenger vessels. The reference category is still fires/explosions.

Predictions of accidents in passenger vessels

Step one: Calculate the odds for all the values of the independent variable using the following equation: $e^{((\text{intercept accident type}) + \text{passenger})} = e^{(L)}$

Accident	L	e (L)
Grounding	1.228 + 0.936 = 2,164	8,7059
Collision	-0.049 + 0.785 = 0,736	2,0876
Allision	-1.782 + 3.492 = 1,710	5,5290

Table 9.2.1: Odds of accidents in passenger vessels.

Step two: calculate probabilities by the following formula:

P = Odds/(1+sum of all odds).

For example, the probability of a grounding in a passenger vessel is:

P = 8,7059 /(1+ 8,7059 + 2,0876 + 5,5290) = 50,3 %

The probabilities for collisions and allisions are calculated in the same way, and are presented in table 9.2.2 below.

For the reference category (here; fires in passenger vessels), the formula is:
P = 1/(1+ sum of all odds) which gives*:*

***P = 1/(1*+8,7059 + 2,0876+ 5,5290*)* = 5,8 %**

The results for accidents in passenger vessels are given in table 9.2.2 below.

P (Grd)	P (Coll)	P (All)	P (Fire)	Sum
50,3 %	12,1 %	31,9 %	5,8 %	100,0 %

Table 9.2.2: Probabilities of accidents in passenger ships.

Take note that these results are exactly the same as the first table in the descriptive statistics in table 14.1.1 in the descriptive statistics for the regression analysis in the appendix. This is because we have not yet added any explanatory variables. I turn to this issue in the next section.

Adding independent variables in multinomic regression: Analytical strategy.

The real interest in using multinomic regression analysis comes when we start adding independent variables.

I have identified three major types of potential risk-influencing factors. First we have the vessel qualities, which may be both physical and regulatory. Second, we have the geographical qualities, and third we have the weather variables. I will apply the following analytical strategy: First I will test the vessel types, then add the remaining vessel qualities, and drop any insignificant variables. Then I test geographical and weather qualities separately and discard insignificant items. Finally I test all these qualities in an integrated model.

Separate analyses will be provided on time categories, certifications and operational states. This is due to the fact that the data set was not large enough, or did not contain enough variation to expand on the integrated model in chapter 10.3.

10 Analysis part 2: Regression analyses of accidents.

This chapter utilizes both multinomic and logistic regression analysis of accidents; please take note which technique is being applied for each subchapter. I begin by building a multinomic regression model of accidents. I begin with a preliminary analysis of vessel types and accidents in chapter 10.1. Chapter 10.2 builds the regression model by testing vessel qualities, geography and weather in individual models. Significant variables from each of these models are then used in an integrated model in chapter 10.3. Chapters 10.4 through 10.7 calculate conditional probabilities for various scenarios. Take particular note of 10.6, which calculates probabilities of the common traits scenario, and 10.7, which calculates the scenarios which maximize the conditional probability of each accident type.

Chapter 10.8 contains a separate multinomic analysis of time categories, whereas chapter 10.9 contains a separate analysis of certification. Chapter 10.10 contains a multinomic analysis of operational stages. Chapter 10.11 contains a logistic regression analysis of severity, while 10.12 contains a logistic regression on injuries and 10.13 a logistic regression of fatalities.

The calculation of probabilities summates values in rows. This format is different from the format used in the section on common traits. A separate section with descriptive statistics where traits are summated in rows is found in the appendix, chapter 14.

10.1 Preliminary analysis of vessel types and accidents.

10.1.1 Analyzing the NSRM categories.

The NSRM vessel categories are theoretical constructions. Before proceeding with the full models including vessel, geographical and weather qualities, I will do a separate test of NSRM categories against accidents. A multinomic regression was performed, using accident categories as dependent variables, and NSRM types as independent. The reference categories are *fires and explosions* and *NSRM fishing vessels above 15m*. The results are shown on the next page in table 10.1.1.

	Grounding				Collision				Allision			
	B	*SE*	*p*	*OR*	*B*	*SE*	*p*	*OR*	*B*	*SE*	*p*	*OR*
Intercept	**1,64**	0,09	*0,00*		**0,06**	0,11	*0,57*		**-1,22**	0,17	*0,00*	
Fishing <15m	**-0,79**	0,12	*0,00*	0,45	**-0,19**	0,15	*0,20*	0,83	**-1,19**	0,28	*0,00*	0,31
Ferries	**1,10**	0,22	*0,00*	3,01	**1,02**	0,25	*0,00*	2,78	**3,86**	0,26	*0,00*	47,47
Pass./Cruise	**0,26**	0,21	*0,21*	1,30	**0,68**	0,24	*0,01*	1,97	**1,99**	0,27	*0,00*	7,33
High Speed	**0,48**	0,36	*0,19*	1,62	**0,74**	0,42	*0,08*	2,09	**3,02**	0,40	*0,00*	20,40
Other Pass.	**-0,27**	0,25	*0,26*	0,76	**-0,02**	0,31	*0,94*	0,98	**0,24**	0,43	*0,57*	1,28
Work/Service	**0,25**	0,23	*0,27*	1,28	**0,08**	0,29	*0,78*	1,08	**1,14**	0,33	*0,00*	3,14
OffshoreServ	**-0,36**	0,34	*0,28*	0,70	**-0,06**	0,42	*0,88*	0,94	**2,07**	0,38	*0,00*	7,93
Well Boats	**1,42**	0,52	*0,01*	4,13	**0,50**	0,64	*0,44*	1,64	**1,45**	0,69	*0,04*	4,25
Tankers	**0,85**	0,38	*0,03*	2,33	**0,85**	0,43	*0,05*	2,35	**1,98**	0,46	*0,00*	7,23
Bulk	**1,01**	0,34	*0,00*	2,74	**1,04**	0,38	*0,01*	2,82	**2,14**	0,41	*0,00*	8,50
Break bulk	**1,02**	0,16	*0,00*	2,76	**1,05**	0,18	*0,00*	2,86	**1,64**	0,23	*0,00*	5,15

Table 10.1.1: Multinomic regression model 1, vessel types (N=5858).

The model is statistically significant at the 0.000 level. The Cox and Nell pseudo R square shows that we explain approximately 17.7% of the variation in accidents. This suggests that the NSRM vessel types are a slight improvement on the generic vessel groups presented in the introduction to this chapter, which had a Cox and Snell of 13.3%.

A Likelihood Ratio test reveals that all of the variables have significant effects at the 0.01 level in the model as a whole, except for other passenger vessels. This finding is reflected in the table, where we see that this category proves insignificant across accident types. All the other vessel categories produce significant results in at least one accident category. The NSRM vessel types are thus maintained in the further analysis.

I will refrain from further discussion of the actual results in this model, as it is a preliminary stage before introducing the remaining independent variables.

10.2 Multinomic analysis of vessels, geography and weather.

10.2.1 Choosing reference categories

The present analysis rests almost entirely on categorical analysis. To some extent, the categories are ordered, but the main strategy has been to dummy code relevant categories to measure the potential influence of each category. This entails choosing the best reference categories for comparison. Theoretically, any category can be chosen to be a reference category, as it does not influence the statistical tests so long as the category has a sufficient size. However, the reference category should also be meaningful. Fishing vessels are, in our view, the most homogenous vessels. I chose Norwegian medium sized vessels of above 15 meters as our reference vessel type. There were 1169 accidents involving such vessels registered in the database overall. As for additional vessel qualities, I chose 500-3000 GT, length of above 24 meter and ballast cargo as reference categories. This reduced the number of real cases to 42. This means that for additional qualities, it is very unlikely that there are actual cases in the database that covers all the reference categories. However, it still makes sense to envision these vessels to be of different age, certification, traveling in different waters, and under different lighting conditions. I thus chose vessels of 0-5 years of age, traveling in outer coastal waters in the Sweden to Lindesnes region, under good weather conditions, in the third season and in daytime, as our reference categories for the remaining variables.

NB! *For the accident types, fires and explosions was chosen as the reference*, as it was seen as qualitatively most different from the other types of accidents. Groundings, collisions and allisions all share the quality of hitting an obstruction, be it the sea floor, another ship or a quay.

The details of the reference categories are given in table 10.2.1 below.

Reference categories: Accident type	
Fires/explosions	
Reference categories: Vessel qualities	**Value**
NSRM type 2	Fishing vessels >15m
Nationality type 1	Norway
Vessel register type 1	NOR
Class type 1	DNV
GT type 2	500-3000
Length type 4	>24 m
Cargo type 1	Ballast
Ship Age type 1	0-5 years
Reference categories: Geographical qualities	**Value**
Region type 4	Tromsø-Russia
Waters type 1	Narrow coastal
Reference categories: Weather qualities	**Value**
Lighting conditions type 1	Light
Sea State type 1	Calm
Visibility type 1	Good
Wind Force type 1	Weak

Table 10.2.1: reference categories for multinomic analysis.

10.2.2 Model with vessel qualities

Vessel qualities such as nationality, register, classification society, gross tonnage, length, cargo type and ship age were added to the model of vessel types. Some problems were found with the register variables. The solution was to collapse the *unknown* and *foreign* categories into one.

Statistical tests of the model.

The model as a whole was significant at the .000 level. The model had a Cox and Snell pseudo R square approximate explained variation of 23.6%. LR tests showed that ferries, passenger & cruise ships, offshore service, well boats and break bulk vessels were significant as a whole. Only PMOU White Lists nations were significant, as was unknown class societies. Vessels carrying passengers, fish, empty and unknown cargo were significant, as were all gross tonnages and lengths. Ship age was also significant for all ages.

Even though one category of class society was shown as significant as a whole, none of the individual coefficients were significant. It was thus decided to drop the class societies from further analysis.

Individual results from the model will not be discussed further here, as the primary interest lies in presenting a full model featuring vessel, geographical and weather qualities. Some of the changes from this model will be compared with the results from the final model. Results are given in the table below.

	Grounding				**Collision**				**Allision**			
	B	SE	p	OR	B	SE	p	OR	B	SE	p	OR
Intercept	**2,002**	0,23	*0,00*		**-0,152**	0,28	*0,59*		**-0,136**	0,31	*0,67*	
NSRM vessel types												
Fishing <15m	**-0,225**	0,32	*0,48*	0,80	**-0,299**	0,38	*0,43*	0,74	**0,510**	0,59	*0,39*	1,67
Ferries	**0,991**	0,28	*0,00*	2,69	**0,761**	0,33	*0,02*	2,14	**2,414**	0,34	*0,00*	11,17
PassCruise	**0,369**	0,26	*0,15*	1,45	**0,414**	0,30	*0,17*	1,51	**1,174**	0,33	*0,00*	3,24
HighSpeed	**0,163**	0,40	*0,68*	1,18	**0,122**	0,46	*0,79*	1,13	**1,938**	0,45	*0,00*	6,94
OtherPass	**-0,002**	0,32	*1,00*	1,00	**-0,451**	0,40	*0,26*	0,64	**0,344**	0,50	*0,49*	1,41
WorkService	**0,354**	0,25	*0,16*	1,42	**0,076**	0,32	*0,81*	1,08	**0,771**	0,36	*0,03*	2,16
OffshoreServ	**-0,311**	0,38	*0,42*	0,73	**0,126**	0,47	*0,79*	1,13	**1,083**	0,44	*0,01*	2,95
Well Boats	**1,104**	0,53	*0,04*	3,02	**0,400**	0,65	*0,54*	1,49	**0,718**	0,71	*0,31*	2,05
Tankers	**0,498**	0,45	*0,27*	1,65	**0,820**	0,51	*0,11*	2,27	**0,877**	0,55	*0,11*	2,41
Bulk	**0,383**	0,40	*0,34*	1,47	**0,558**	0,45	*0,22*	1,75	**0,807**	0,48	*0,10*	2,24
Goods	**0,389**	0,21	*0,07*	1,48	**0,653**	0,25	*0,01*	1,92	**0,695**	0,30	*0,02*	2,00
Nationality												
PMOU White	**1,003**	0,36	*0,01*	2,73	**0,733**	0,39	*0,06*	2,08	**0,617**	0,42	*0,14*	1,85
PMOU G/B/O	**1,837**	1,04	*0,08*	6,28	**1,700**	1,08	*0,11*	5,47	**1,684**	1,10	*0,13*	5,39
Register												
NIS	**0,723**	0,40	*0,07*	2,06	**0,827**	0,43	*0,05*	2,29	**0,958**	0,44	*0,03*	2,61
Foreign & unknown	**0,063**	0,18	*0,73*	1,07	**0,282**	0,20	*0,16*	1,33	**-0,095**	0,30	*0,75*	0,91
Class												
Other Known*	**0,210**	0,26	*0,41*	1,23	**0,325**	0,28	*0,25*	1,38	**0,286**	0,31	*0,36*	1,33
Unknown	**-0,071**	0,16	*0,66*	0,93	**-0,145**	0,19	*0,45*	0,87	**0,351**	0,19	*0,07*	1,42
Registered Cargo												
Fish	**0,629**	0,14	*0,00*	1,88	**0,590**	0,17	*0,00*	1,80	**0,210**	0,28	*0,45*	1,23
Passengers	**0,236**	0,23	*0,31*	1,27	**0,824**	0,28	*0,00*	2,28	**1,024**	0,29	*0,00*	2,78
Dry/Bulk/Cont	**0,693**	0,28	*0,01*	2,00	**0,677**	0,31	*0,03*	1,97	**0,623**	0,34	*0,07*	1,87
Bulk/Ore/Grain/Coal	**0,579**	0,32	*0,07*	1,78	**0,298**	0,37	*0,42*	1,35	**0,151**	0,42	*0,72*	1,16
Oil/Chemicals/Gas	**0,474**	0,59	*0,42*	1,61	**0,029**	0,70	*0,97*	1,03	**0,707**	0,68	*0,30*	2,03
Other Known*	**0,686**	0,49	*0,16*	1,99	**0,319**	0,61	*0,60*	1,38	**1,156**	0,57	*0,04*	3,18
Empty	**-0,576**	0,16	*0,00*	0,56	**-0,435**	0,22	*0,04*	0,65	**0,085**	0,28	*0,76*	1,09
Unknown	**-0,308**	0,13	*0,02*	0,74	**0,177**	0,16	*0,27*	1,19	**0,331**	0,21	*0,11*	1,39
Gross Tonnage												
<500	**0,187**	0,17	*0,28*	1,21	**0,324**	0,20	*0,11*	1,38	**-0,538**	0,20	*0,01*	0,58
>3000	**-1,176**	0,26	*0,00*	0,31	**-0,811**	0,30	*0,01*	0,44	**-0,552**	0,28	*0,05*	0,58
Unknown	**0,863**	0,29	*0,00*	2,37	**0,974**	0,33	*0,00*	2,65	**-0,520**	0,61	*0,40*	0,59
Length												
<10.67 m	**-1,268**	0,33	*0,00*	0,28	**-0,176**	0,39	*0,65*	0,84	**-2,537**	0,61	*0,00*	0,08
10-15 m	**-0,601**	0,32	*0,06*	0,55	**-0,133**	0,38	*0,72*	0,88	**-2,172**	0,58	*0,00*	0,11
15-24 m	**-0,719**	0,17	*0,00*	0,49	**-0,132**	0,20	*0,51*	0,88	**-1,250**	0,25	*0,00*	0,29
Unknown	**-0,883**	0,47	*0,06*	0,41	**0,015**	0,51	*0,98*	1,02	**-0,892**	0,56	*0,11*	0,41
Vessel Age												
6-15	**-0,074**	0,16	*0,65*	0,93	**0,168**	0,19	*0,38*	1,18	**-0,381**	0,20	*0,06*	0,68
16-25	**-0,132**	0,17	*0,43*	0,88	**0,177**	0,20	*0,37*	1,19	**-0,461**	0,21	*0,03*	0,63
26+	**-0,415**	0,16	*0,01*	0,66	**-0,372**	0,19	*0,05*	0,69	**-0,715**	0,20	*0,00*	0,49
Unknown	**0,053**	0,32	*0,87*	1,06	**0,040**	0,37	*0,91*	1,04	**0,284**	0,38	*0,45*	1,33

Table 10.2.2: Multinomic model 3: Vessel qualities (N=5858).

10.2.3 Model with geographical variables

A model was tested using only the geographical variables. The analysis revealed that there were problems with the categories *oil field* and *separation area* due to the low number of cases. These categories were collapsed into the *other* category. *Region 7, Norwegian Continental Shelf & Arctics* and *Region 8, Svalbard/Jan Mayen and Bjørnøya* were also problematic, and collapsed into the *other waters* category.

Statistical tests of the model:

The model as a whole was significant at the .000 level. The Cox and Snell pseudo R square approximate explained variation is 28.3%. All entered variables were significant as a whole. All items were thus retained. As with the vessel qualities, these results will not be discussed further individually. Results are given in the table below.

	Grounding				**Collision**				**Allision**			
	B	SE	p	OR	B	SE	p	OR	B	SE	p	OR
Intercept	**3,07**	0,12	*0,00*		**0,66**	0,14	*0,00*		**-0,31**	0,17	*0,06*	
Region												
Sweden-Lindesnes	**-0,15**	0,19	*0,42*	0,86	**0,68**	0,21	*0,00*	1,97	**0,43**	0,22	*0,05*	1,53
Lindesnes-Bergen	**-0,07**	0,15	*0,64*	0,94	**0,53**	0,16	*0,00*	1,69	**0,71**	0,17	*0,00*	2,04
Bergen-Trondheim	**0,24**	0,15	*0,10*	1,27	**0,27**	0,17	*0,12*	1,31	**0,88**	0,17	*0,00*	2,41
Trondheim-Tromsø	**-0,73**	0,13	*0,00*	0,48	**-0,45**	0,15	*0,00*	0,64	**-0,76**	0,19	*0,00*	0,47
Region Others & Unknown	**0,04**	0,34	*0,90*	1,04	**-0,10**	0,41	*0,81*	0,90	**1,20**	0,38	*0,00*	3,30
Waters												
Harbour Area	**-1,59**	0,14	*0,00*	0,20	**-0,36**	0,16	*0,02*	0,70	**1,19**	0,17	*0,00*	3,29
Outer Coastal	**-1,53**	0,13	*0,00*	0,22	**-0,23**	0,15	*0,13*	0,79	**-1,70**	0,24	*0,00*	0,18
Along Quay	**-4,83**	0,27	*0,00*	0,01	**-2,45**	0,25	*0,00*	0,09	**-0,34**	0,20	*0,09*	0,71
Other Waters	**-1,20**	0,28	*0,00*	0,30	**-0,27**	0,32	*0,40*	0,76	**0,67**	0,32	*0,04*	1,95

Table 10.2.3: Multinomic model 4: Geographical Qualities (N=5858).

10.2.4 Model with weather variables

A separate model was tested using only weather data.

Statistical tests of the model:

The model as a whole was significant at the .000 level. The Cox and Snell pseudo R square approximate explained variation is 13.3%. LR tests showed that items were significant as a whole, except twilight, high seas, moderate visibility and moderate winds. As these were parts of dummy sets, they were all retained for further analysis. As with the vessel and geographical qualities, these results will not be discussed further individually. Results are given in the table below.

	Grounding				**Collision**				**Allision**			
	B	SE	p	OR	B	SE	p	OR	B	SE	p	OR
Intercept	**1.69**	0.10	*0.00*		**0.78**	0.11	*0.00*		**0.49**	0.12	*0.00*	
Lighting												
Twilight	**0.21**	0.18	*0.25*	1.23	**-0.06**	0.21	*0.77*	0.94	**-0.06**	0.22	*0.78*	0.94
Dark	**0.81**	0.11	*0.00*	2.24	**-0.09**	0.13	*0.50*	0.91	**-0.18**	0.14	*0.19*	0.83
Unknown	**0.76**	0.16	*0.00*	2.14	**0.03**	0.23	*0.90*	1.03	**0.56**	0.21	*0.01*	1.75
Sea State												
Moderate	**-0.58**	0.17	*0.00*	0.56	**-0.34**	0.20	*0.08*	0.71	**-1.55**	0.24	*0.00*	0.21
High	**-0.09**	0.49	*0.85*	0.91	**0.18**	0.57	*0.75*	1.20	**-0.64**	0.57	*0.26*	0.53
Unknown	**0.05**	0.14	*0.72*	1.05	**-0.09**	0.16	*0.57*	0.91	**0.43**	0.16	*0.01*	1.54
Visibility												
Moderate	**0.27**	0.19	*0.16*	1.30	**0.25**	0.22	*0.25*	1.29	**0.13**	0.23	*0.56*	1.14
Poor	**0.81**	0.31	*0.01*	2.25	**0.58**	0.35	*0.10*	1.78	**-0.21**	0.39	*0.59*	0.81
None	**3.04**	1.01	*0.00*	20.83	**3.69**	1.01	*0.00*	40.08	**1.91**	1.05	*0.07*	6.75
Fog/Snow	**1.17**	0.42	*0.01*	3.21	**1.35**	0.45	*0.00*	3.86	**-0.12**	0.54	*0.83*	0.89
Unknown	**-1.15**	0.15	*0.00*	0.32	**-1.14**	0.19	*0.00*	0.32	**-1.31**	0.19	*0.00*	0.27
Winds												
Moderate	**0.02**	0.15	*0.88*	1.02	**-0.13**	0.17	*0.44*	0.88	**-0.02**	0.18	*0.92*	0.98
Strong	**0.85**	0.23	*0.00*	2.35	**-0.17**	0.27	*0.53*	0.84	**1.68**	0.25	*0.00*	5.38
Unknown	**-0.51**	0.13	*0.00*	0.60	**-0.43**	0.16	*0.01*	0.65	**-0.35**	0.16	*0.03*	0.70

Table 10.2.4: Multinomic model 5: Weather qualities (N=5858).

10.3 Integrated model of vessel, geography and weather.

Statistical tests of the model.

This model integrates significant items from the previous models on vessel, geography and weather. It will be used as the basis for the calculation of probabilities in chapters 10.4 through 10.7.

The model as a whole was significant at the .000 level. The Cox and Snell pseudo R square approximate explained variation is 43.8%. Taken together, this suggests that this model is better than each model individually. It also shows that we have been able to explain a fair amount of the variation in the data set.

Likelihood ratio tests revealed that only the following variables were significant for the model as a whole: For vessel types, *ferries* and *high speed craft*. For nationalities, only ships on the *PMOU White List.* For type of cargo, only vessels carrying *passengers, fish and unknown cargo* were significant. *All gross tonnages* were significant, as were *all lengths*, except the unknowns. Ship age was only significant for *ages 16-25*. All regions were significant, except the "others" category. All types of *waters* were significant. Only *dark and unknown lighting* conditions were significant, and no sea states except the unknown. *All categories of visibility* were significant, except the moderate. *Only strong winds* were significant as a whole. As all of the categories were parts of dummy sets, we could not exclude any single category from the analysis.

Individual results are given in table 10.3.1 below, and will be used as a basis for discussion and predictions. This model will be referred to as the *integrated* model. Following the table, on the next page, is an edited version, containing only significant B-coefficients and odds ratios, to clarify results.

	Grounding				Collision				Allision			
	B	SE	p	OR	B	SE	p	OR	B	SE	p	OR
Intercept	**2,465**	0,31	*0,00*		**0,026**	0,36	*0,94*		**-0,250**	0,41	*0,55*	
Vessel types												
Fishing <15m	**-0,186**	0,37	*0,62*	0,830	**-0,551**	0,42	*0,19*	0,576	**0,373**	0,60	*0,53*	1,453
Ferries	**1,314**	0,31	*0,00*	3,721	**0,605**	0,36	*0,09*	1,830	**2,361**	0,36	*0,00*	10,603
PassCruise	**0,820**	0,30	*0,01*	2,271	**0,601**	0,34	*0,08*	1,825	**1,208**	0,36	*0,00*	3,348
HighSpeed	**0,550**	0,43	*0,21*	1,734	**0,282**	0,48	*0,56*	1,326	**1,975**	0,47	*0,00*	7,208
OtherPass	**-0,191**	0,37	*0,60*	0,826	**-0,732**	0,43	*0,09*	0,481	**0,208**	0,52	*0,69*	1,232
WorkService	**0,579**	0,30	*0,05*	1,784	**0,043**	0,35	*0,90*	1,044	**0,758**	0,39	*0,05*	2,133
OffshoreServ	**-0,449**	0,42	*0,29*	0,638	**-0,268**	0,50	*0,59*	0,765	**0,399**	0,48	*0,40*	1,490
Well Boats	**1,093**	0,61	*0,07*	2,984	**0,462**	0,71	*0,51*	1,588	**1,015**	0,74	*0,17*	2,761
Tankers	**0,532**	0,51	*0,30*	1,702	**0,840**	0,57	*0,14*	2,317	**0,763**	0,60	*0,20*	2,145
Bulk	**0,525**	0,44	*0,23*	1,690	**0,520**	0,48	*0,28*	1,682	**0,856**	0,51	*0,09*	2,354
Goods	**0,378**	0,24	*0,11*	1,459	**0,574**	0,27	*0,03*	1,776	**0,671**	0,31	*0,03*	1,957
Nationality												
PMOU White	**1,333**	0,39	*0,00*	3,791	**1,077**	0,42	*0,01*	2,936	**0,862**	0,44	*0,05*	2,367
PMOU G/B/O	**1,985**	1,09	*0,07*	7,276	**1,975**	1,11	*0,08*	7,208	**1,993**	1,13	*0,08*	7,336
Register												
NIS	**0,902**	0,42	*0,03*	2,464	**0,792**	0,44	*0,07*	2,208	**0,961**	0,45	*0,03*	2,615
Foreign & unknown	**0,126**	0,20	*0,53*	1,134	**0,512**	0,22	*0,02*	1,668	**-0,016**	0,32	*0,96*	0,984
Registered Cargo												
Fish	**0,623**	0,16	*0,00*	1,865	**0,587**	0,18	*0,00*	1,799	**0,274**	0,29	*0,34*	1,315
Passengers	**-0,027**	0,26	*0,92*	0,974	**0,501**	0,30	*0,09*	1,650	**0,706**	0,31	*0,02*	2,026
Dry/Bulk/Cont	**0,287**	0,29	*0,33*	1,333	**0,342**	0,32	*0,29*	1,408	**0,238**	0,36	*0,51*	1,269
Bulk/Ore/Grain/Coal	**0,400**	0,36	*0,26*	1,492	**0,175**	0,40	*0,66*	1,191	**0,146**	0,44	*0,74*	1,157
Oil/Chemicals/Gas	**0,509**	0,67	*0,45*	1,663	**-0,142**	0,77	*0,85*	0,867	**0,529**	0,75	*0,48*	1,697
Other Known*	**0,497**	0,53	*0,35*	1,644	**0,248**	0,64	*0,70*	1,281	**0,836**	0,61	*0,17*	2,308
Empty	**-0,337**	0,20	*0,09*	0,714	**-0,179**	0,24	*0,45*	0,837	**-0,043**	0,30	*0,88*	0,958
Unknown	**0,366**	0,18	*0,04*	1,441	**1,075**	0,20	*0,00*	2,930	**0,553**	0,25	*0,03*	1,738
Gross Tonnage												
<500	**0,242**	0,19	*0,20*	1,274	**0,352**	0,21	*0,10*	1,421	**-0,410**	0,21	*0,05*	0,663
>3000	**-1,221**	0,28	*0,00*	0,295	**-1,007**	0,32	*0,00*	0,365	**-0,770**	0,29	*0,01*	0,463
Unknown	**0,807**	0,32	*0,01*	2,242	**1,021**	0,36	*0,00*	2,775	**-0,454**	0,63	*0,47*	0,635
Length												
<10.67 m	**-1,347**	0,38	*0,00*	0,260	**-0,268**	0,42	*0,53*	0,765	**-2,024**	0,61	*0,00*	0,132
10-15 m	**-0,694**	0,36	*0,06*	0,499	**-0,121**	0,41	*0,77*	0,886	**-1,605**	0,58	*0,01*	0,201
15-24 m	**-0,812**	0,18	*0,00*	0,444	**-0,270**	0,21	*0,19*	0,764	**-1,002**	0,25	*0,00*	0,367
Unknown	**-0,908**	0,52	*0,08*	0,403	**-0,236**	0,56	*0,67*	0,790	**-0,722**	0,59	*0,22*	0,486
Vessel Age												
6-15	**-0,047**	0,18	*0,79*	0,954	**0,217**	0,20	*0,29*	1,242	**-0,249**	0,22	*0,25*	0,779
16-25	**-0,124**	0,18	*0,50*	0,883	**0,212**	0,21	*0,31*	1,237	**-0,317**	0,23	*0,16*	0,729
26+	**-0,327**	0,17	*0,06*	0,721	**-0,258**	0,20	*0,20*	0,773	**-0,436**	0,22	*0,04*	0,647
Unknown	**0,273**	0,35	*0,44*	1,313	**0,274**	0,39	*0,49*	1,315	**0,635**	0,40	*0,11*	1,887
Region												
Sweden-Lindesnes	**0,129**	0,23	*0,58*	1,137	**0,739**	0,26	*0,00*	2,093	**0,273**	0,30	*0,36*	1,313
Lindesnes-Bergen	**0,125**	0,19	*0,50*	1,134	**0,729**	0,21	*0,00*	2,074	**0,120**	0,25	*0,63*	1,127
Bergen-Trondheim	**0,343**	0,18	*0,06*	1,409	**0,536**	0,21	*0,01*	1,709	**0,297**	0,25	*0,23*	1,346
Trondheim-Tromsø	**0,600**	0,14	*0,00*	1,822	**0,445**	0,17	*0,01*	1,560	**0,175**	0,22	*0,43*	1,191
Region Others/Unkn.	**0,483**	0,40	*0,23*	1,621	**0,266**	0,47	*0,57*	1,305	**1,015**	0,47	*0,03*	2,759
Waters												
Harbour Area	**-1,522**	0,15	*0,00*	0,218	**-0,204**	0,17	*0,23*	0,815	**0,761**	0,18	*0,00*	2,140
Outer Coastal	**-1,323**	0,14	*0,00*	0,266	**-0,084**	0,16	*0,60*	0,920	**-1,306**	0,25	*0,00*	0,271
Along Quay	**-4,617**	0,29	*0,00*	0,010	**-1,987**	0,27	*0,00*	0,137	**-0,521**	0,24	*0,03*	0,594
Other Waters	**-0,415**	0,31	*0,18*	0,660	**0,615**	0,36	*0,09*	1,849	**1,233**	0,37	*0,00*	3,430
Lighting												
Twilight	**0,427**	0,20	*0,04*	1,532	**0,218**	0,22	*0,33*	1,244	**0,498**	0,26	*0,06*	1,646
Dark	**0,665**	0,13	*0,00*	1,945	**-0,070**	0,15	*0,63*	0,933	**0,091**	0,16	*0,58*	1,095
Unknown	**0,291**	0,20	*0,15*	1,338	**-0,642**	0,26	*0,01*	0,526	**0,276**	0,26	*0,29*	1,318
Sea State												
Moderate	**-0,315**	0,18	*0,09*	0,730	**-0,247**	0,21	*0,23*	0,781	**-0,745**	0,28	*0,01*	0,475
High	**0,141**	0,51	*0,78*	1,151	**0,229**	0,58	*0,69*	1,257	**0,360**	0,63	*0,57*	1,433
Unknown	**-0,117**	0,16	*0,47*	0,890	**-0,352**	0,18	*0,06*	0,703	**0,093**	0,19	*0,63*	1,098
Visibility												
Moderate	**0,062**	0,21	*0,77*	1,064	**0,112**	0,23	*0,63*	1,118	**-0,005**	0,26	*0,99*	0,995
Poor	**0,586**	0,33	*0,07*	1,797	**0,371**	0,36	*0,31*	1,449	**-0,410**	0,43	*0,34*	0,664
None	**2,453**	1,01	*0,02*	11,623	**3,310**	1,02	*0,00*	27,386	**1,265**	1,06	*0,23*	3,541
Fog/Snow	**0,914**	0,45	*0,04*	2,494	**1,182**	0,47	*0,01*	3,262	**-0,249**	0,57	*0,66*	0,780
Unknown	**-0,903**	0,18	*0,00*	0,405	**-1,201**	0,21	*0,00*	0,301	**-1,236**	0,23	*0,00*	0,291
Winds												
Moderate	**-0,069**	0,16	*0,67*	0,933	**-0,177**	0,18	*0,32*	0,837	**-0,023**	0,21	*0,91*	0,978
Strong	**0,872**	0,25	*0,00*	2,393	**-0,111**	0,29	*0,70*	0,895	**1,401**	0,28	*0,00*	4,059
Unknown	**-0,349**	0,15	*0,02*	0,706	**-0,343**	0,17	*0,04*	0,710	**-0,152**	0,19	*0,43*	0,859

Table 10.3.1: Multinomic regression 6: Integrated model (N=5 858).

10.3.1 Highlighting significant results

To simplify interpreting the results, I have deleted all insignificant results from the previous table. This table only lists B-coefficients and odds ratios for the significant categories.

	Grounding		Collision		Allision	
	B	OR	B	OR	B	OR
Vessel types			-	-		
Ferries	1,314	3,721	-	-	2,361	10,603
Passenger & Cruise ships	0,820	2,271	-	-	1,208	3,348
High Speed Craft	0,550	1,734	-	-	1,975	7,208
Work Service Vessels	0,579	1,784	-	-	0,758	2,133
Break Bulk	-	-	0,574	1,776	0,671	1,957
Nationality						
PMOU White	1,333	3,791	1,077	2,936	0,862	2,367
Register						
NIS	0,902	2,464	-	-	0,961	2,615
Foreign & unknown	-	-	0,512	1,668	-	-
Registered Cargo						
Fish	0,623	1,865	0,587	1,799	-	-
Passengers	-	-	-	-	0,706	2,026
Unknown	0,366	1,441	1,075	2,930	0,553	1,738
Gross Tonnage						
<500	-	-	-	-	-0,410	0,663
>3000	-1,221	0,295	-1,007	0,365	-0,770	0,463
Unknown	0,807	2,242	1,021	2,775	-	-
Length						
<10.67 m	-1,347	0,260	-0,268	0,765	-2,024	0,132
10-15 m	-	-	-	-	-1,605	0,201
15-24 m	-0,812	0,444	-	-	-1,002	0,367
Vessel Age						
26+	-	-	-	-	-0,436	0,647
Region						
Sweden-Lindesnes	-	-	0,739	2,093	-	-
Lindesnes-Bergen	-	-	0,729	2,074	-	-
Bergen-Trondheim	-	-	0,536	1,709	-	-
Trondheim-Tromsø	0,600	1,822	0,445	1,560	-	-
Region Others/Unkn.	-	-	-	-	1,015	2,759
Waters						
Harbour Area	-1,522	0,218	-	-	0,761	2,140
Outer Coastal	-1,323	0,266	-	-	-1,306	0,271
Along Quay	-4,617	0,010	-1,987	0,137	-0,521	0,594
Other Waters	-	-	-	-	1,233	3,430
Lighting						
Twilight	0,427	1,532	-	-	-	-
Dark	0,665	1,945	-	-	-	-
Unknown	-	-	-0,642	0,526	-	-
Sea State						
Moderate	-	-	-	-	-0,745	0,475
Visibility						
None	2,453	11,623	3,310	27,386	-	-
Fog/Snow	0,914	2,494	1,182	3,262	-	-
Unknown	-0,903	0,405	-1,201	0,301	-1,236	0,291
Winds						
Strong	0,872	2,393	-	-	1,401	4,059
Unknown	-0,349	0,706	-0,343	0,710	-	-

Table 10.3.1.1: Multinomic regression 6: Significant results (N=5 858).

10.3.2 Results of the integrated model

In the following section, I will only present some highlights of the results as basis for further discussion and as a basis for doing some predictions of probabilities.

Vessel types: Only three types of passenger ships and two types of cargo vessels showed significantly different results compared to the reference category, and then mainly in the grounding and allision accidents. Looking at the odds ratios, we see that given that an accident happens, ferries have 3.7 times higher odds than large fishing vessels of being involved in a grounding as opposed to a fire/explosion. This is the largest difference in ORs for groundings vs fires. When it comes to collisions, only break bulk vessels have higher odds than large fishing vessels. The biggest differences are found in the allision category, where ferries and high speed craft have the largest differences in odds compared to large fishing vessels.

Nationality: Perhaps due to the low number of accidents featuring other nationalities, the only category that proved significant was the PMOU White list. The PMOU normally lists Norway as belonging to the White List as well. For all types of accidents, the odds are two to three times higher of White List vessels to be involved in other accidents than fires. Or, put the other way, the odds are significantly lower of a White List vessel to be involved in a fire as opposed to other types of accidents.

Register: We see that NIS ships have slightly lower odds of being involved in fires and explosions than NOR ships, as opposed to other types of accidents.

Cargo: The type of cargo a ship carries does not on the whole seem to affect accident type a lot, as only vessels carrying fish and passengers have significantly different results than vessel carrying ballast. By extension, a fishing vessel carrying fish has higher odds of a grounding or collision as opposed to fishing vessel carrying ballast. Or put the other way: A fishing vessel carrying ballast has higher odds of being involved in a fire/explosion compared to groundings and collisions. For vessels carrying passengers, the odds of allisions are higher as opposed to vessels carrying ballast.

Gross tonnage: Vessels of small and large tonnages have lower odds of being in groundings and allisions than in fires and explosions opposed to tonnages of 500-3000.

Length: Vessel shorter than 24 meter all have lower odds of being in groundings and allisions as opposed to vessels longer than 24 meters.

Vessel age: Vessel age turned out to be significant only for allisions in older ship, where the odds are lower than for fires and explosions.

In terms of **regions**, most of the differences were in the collision category. All known regions have higher odds of collisions than fires/explosions compared to the region Tromsø-Russia.

Waters: All known waters have lower odds than fires/explosions, except allisions in the harbour area, which has around two times higher odds. It is reasonable to link this to the higher odds of allisions among passenger vessels.

Lighting: Lighting seems to have a modest effect, as only twilight and dark increases the odds of groundings, with dark conditions being most influential.

Sea state has very little influence, where moderate seas actually decrease the odds of allisions.

Visibility proves to be one of the most influential factors. In particular, traffic in no visibility increases the odds of groundings and collisions. The odds ratios of 11 and 27 are the largest in the entire model. This means that travelling in no visibility increases the odds of an accident being a collision 27 times as opposed to it being a fire/explosion. The same figure for groundings is around 11. Improving visibility in traffic thus has the potential to reduce the number of groundings and collisions considerably. Interestingly, no known visibility has effect on the odds of allisions. It is noteworthy that while no visibility proves highly influential, dark lighting conditions have relatively little influence, and only on groundings.

Winds have relatively little influence. Strong winds increase the odds of groundings and allisions, and are most influential on allisions.

10.4 Predicted probabilities from the integrated model

Take note that the following calculations summate probabilities in rows and not columns. The probabilities should therefore be compared to the descriptive statistics in the appendix.

The following table lists predicted probabilities of accidents for fully and partially significant items from the integrated regression model. Probabilities based on significant items are marked with an asterisk (*). Note that as fires/explosions are the reference category, they are all marked as significant. This means that other items marked with an asterisk are significantly different from fires/explosions. The remaining insignificant items are thus subject to type II errors. This means the incorrect rejection of a true null hypothesis, or, in layman's terms, failing to detect an effect that is present.

	P(Fire)	P(Grd)	P(Coll)	P(All)
Reference	**6,86***	**80,75***	**7,04***	**5,35***
Vessel types				
Ferries	1,82*	79,72*	3,42	15,04*
Passenger/Cruise	3,11*	82,98 *	5,82	8,10*
High Speed	3,53*	71,89 *	4,80	19,79*
Work & Service	4,04*	84,90 *	4,33	6,72*
Break Bulk	4,65*	79,80	8,47 *	7,08*
Nationality				
PMOU White	1,98*	88,39*	5,97*	3,65*
Register				
NIS	2,92*	84,54*	6,61	5,94
Registered Cargo				
Fish	3,88*	85,00*	7,15*	3,97*
Passengers	6,36*	72,83	10,77	10,04
Empty	9,09*	76,33*	7,80	6,78
Gross Tonnage				
<500	5,57*	83,43	8,13	2,88*
>3000	19,21*	66,66*	7,20*	6,93*
Length				
<10.67 m	20,22*	61,83*	15,87*	2,08*
10-15 m	12,59*	73,99	11,45	1,97*
15-24 m	13,71*	71,62*	10,74	3,92*
Vessel Age				
26+	9,28*	78,69	7,36	4,67*

	P(Fire)	P(Grd)	P(Coll)	P(All)
Region				
Sweden-Lindesnes	5,70*	76,23	12,24*	5,83
Lindesnes-Bergen	5,77*	76,89	12,27*	5,07
Bergen-Trondheim	4,91*	81,34	8,61*	5,14
Trondheim-Tromsø	4,01*	85,86*	6,42*	3,72
Waters				
Harbour Area	16,47*	42,29*	13,78	27,46*
Outer Coastal	18,91*	59,25*	17,85	3,99*
Along Quay	58,16*	6,76*	8,18*	26,90*
Lighting				
Twilight	4,63*	83,52*	5,91	5,94
Dark	3,89*	89,06*	3,73	3,32
Sea State				
Moderate	9,30*	79,81	7,45	3,44*
Visibility				
None	0,59*	81,10*	16,67*	1,64
Fog/Snow	2,92*	85,56*	9,76*	1,77
Winds				
Strong	3,01*	84,71*	2,77	9,52*

Table 10.4.1: Predicted probabilities from the multinomic regression.

These predictions are all based on a theoretical comparison case. For example, the probability of an allision is around ten percent points higher on a ferry than on a large fishing vessel. We also know that the probability of an allision is higher in strong winds. The prediction does not tell us the probability of an allision on a ferry in strong winds. To do this, we must calculate the regression equation and repeat the previous step. There are twelve variables in the regression table, with between 3 and 12 categories in each, which yields over one billion possible combinations. I will therefore manipulate one parameter at the time, and then focus on those parameters which maximize the probabilities of accidents.

10.4.1 Baseline probabilities

The multinomic regression produced significant differences between only a few vessel types. These differences will be used as a basis for calculating probabilities between a few types of situations. First, the selected vessel types are large fishing vessels, ferries, passenger/cruise ships, high speed craft and break bulk vessels. This means that each of the main vessel groups is represented. First, we look at the baseline probabilities for these vessel types, given in the table below:

Vessel type	Probabilities in percent				
	Fire	*Grd.*	*Coll.*	*All.*	*Sum*
Large Fishing	6,9	80,7	7,0	5,3	100
Ferries	1,8	79,7	3,4	15,0	100
Passenger/Cruise	3,1	83,0	5,8	8,1	100
High Speed	3,5	71,9	4,8	19,8	100
Break Bulk	4,6	79,8	8,5	7,1	100

Table 10.4.1.1: Baseline probabilities of accidents for vessel types.

Interpreting the table: Probabilities are summated in rows. The results should be read as follows: *Given that an accident happens with a particular vessel type, what are the probabilities of the accident being of a particular type?* The table shows that given that an accident happens with a large fishing vessel, there's around an 80% chance that it will be a grounding. This is under the theoretical assumption that the vessel belongs to the reference group: it is Norwegian, belongs to NOR, carries only ballast, is of 500-300 GT, is above 24 m, is 1-5 years old, travels in the Tromsø-Russia coastal region, in narrow coastal waters, under good weather conditions. (I shall expand on these assumptions below.) Take note that this probability is considerably higher than what the descriptive statistics say: Groundings account for only slightly more than 60% of all accidents overall. This tells us that there are considerable differences in accident likelihood according to vessel qualities. Also, keep in mind that these probabilities exclude variation in the other parameters. For example, since we are assuming that the accident happens in narrow coastal waters, variation between waters is excluded.

We can also compare probabilities across vessel types. We see that the probability of a grounding is the highest for all vessel types. High speed craft have 10% less probability of being involved in a *grounding* compared to a passenger/cruise ship, but on the whole, probabilities of groundings are all in the 70-80% range. Large fishing vessels have higher probability of being involved in *collisions* than ferries, but the probabilities are all in the 4-8% range. *Allisions* are notable in larger differences across vessel groups. Here, high speed craft has ten percent higher probability of being involved in allisions than passenger/cruise vessels.

For fires, it is notable that large fishing vessels have the highest risk of around 7%, whereas ferries have only around 2%.

10.5 Conditional probabilities

I now turn to exploring the parameters of the model. To avoid extreme degrees of complexity, I will keep the vessel types constant, and only vary one parameter at a time. I begin by exploring nationality. The multinomic regression showed that there were significant differences between Norway and nations on the PMOU White List. The table below shows the same type of probabilities given in the first table, with the added parameter of nationality. Simplified, we can express this as: probability of accident = baseline probability + probability of nationality.

Vessel type	**Probabilities in percent**			
	Fire	*Grd.*	*Coll.*	*All.*
Large Fishing White List	2,0	88,4	6,0	3,7
Ferries White List	0,5	86,4	2,9	10,2
Passenger/Cruise White List	0,9	88,9	4,8	5,4
High Speed White List	1,0	80,9	4,2	13,9
Break Bulk White List	1,3	86,7	7,1	4,8

Table 10.5.1: Probabilities of accidents for White List vessels.

We see that the probabilities change somewhat. The probability of groundings increases for all White List vessels. However, it is reduced for fires/explosions, and does not change considerably for collisions and allisions. Thus we can assume that White List vessels are at relatively higher risk of groundings than Norwegian vessels. Take note that we cannot say whether foreign ships in general have higher probabilities of being involved in accidents based on these predictions.

I will now turn to exploring probabilities by adding one parameter to the reference category. I will do this in two different ways. Alternative 1 explores probabilities by vessel type, and for each vessel type, we see how changing a single parameter affects probability. Alternative 2 does the opposite, and keeps parameters constant while changing vessel type. These two alternative strategies yield two different types of insight. The first tells us how vessel types are affected by changing parameters, while the other tells us the relative influence parameters has on each vessel type.

10.5.1 Conditional probabilities by vessel type

Here, I list probabilities of parameters by vessel type. For example, *how does it affect accident probability if a vessel changes from being a Norwegian vessel to a vessel on the PMOU White List?* The answer, taken from table 10.5.1.1 below, is that White List vessels have higher probabilities of groundings than Norwegian ones, 88.4 versus 80.7, but lower probabilities of other accident types.

The baseline vessel is Norwegian, carrying ballast, 500-3000 GT, Tromsø-Russia region, in narrow coastal waters, in good visibility and no winds.

Probability of accidents in large fishing vessels

	Fire	*Grd.*	*Coll.*	*All.*
Large Fishing Vessel	7,0	80,7	7,0	5,3
PMOU White List	1,9	88,4	6,0	3,7
Cargo: Fish	6,4	72,8	10,8	10,0
Cargo: Empty	9,1	76,3	7,8	6,8
>3000 GT	19,2	66,7	7,2	6,9
Sweden-Lindesnes	5,8	76,2	12,2	5,8
Lindesnes-Bergen	5,7	76,9	12,3	5,1
Bergen-Trondheim	5,0	81,3	8,6	5,1
Trondheim-Tromsø	4,0	85,9	6,4	3,7
Harbour Area	16,4	42,3	13,8	27,5
Outer Coastal Waters	18,9	59,3	17,8	4,0
Along Quay	58,1	6,8	8,2	26,9
No Visibility	0,6	81,1	16,7	1,6
Strong Wind	3,0	84,7	2,8	9,5

Table 10.5.1.1: Probabilities of accidents for large fishing vessels.

The baseline relative probability of a grounding in a large fishing vessel is around 80%. We see that changing parameters has a relatively modest effect. For example, *White List* vessels have somewhat higher probabilities, whereas vessels *above 3000 GT* have somewhat lower. The most notable changes, however, are to do with waters. The relative probability of a grounding with a fishing vessels decreases progressively in *outer coastal waters*, in the *harbour area* and *along quay*. On the other hand, probabilities of allisions increase substantially in the same waters. Particularly notable is the fact that fires and explosions are much more likely to occur along quay than in any other water.

Probability of accidents in ferries

	Fire	*Grd.*	*Coll.*	*All.*
Ferry	1,9	79,7	3,4	15,0
PMOU White List	0,5	86,4	2,9	10,2
Cargo: Passenger	1,5	67,2	4,9	26,4
Cargo: Empty	2,3	74,9	3,8	19,0
>3000 GT	5,4	70,1	3,7	20,8
Length 15-24	4,0	78,0	5,8	12,2
Sweden-Lindesnes	1,6	75,9	6,0	16,5
Lindesnes-Bergen	1,6	77,7	6,1	14,6
Bergen-Trondheim	1,3	80,1	4,2	14,4
Trondheim-Tromsø	1,1	85,3	3,1	10,5
Harbour Area	3,3	32,1	5,2	59,4
Outer Coastal Waters	6,0	70,1	10,4	13,5
Along Quay	15,1	6,6	3,9	74,4
No Visibility	0,7	32,8	38,0	28,5
Strong Wind	0,7	74,3	1,2	23,8

Table 10.5.1.2: Probabilities of accidents for ferries.

Ferries are similar to fishing vessels in that they have a high probability of groundings, but the most notable change is an increase in allisions. We can note that allisions are more likely to happen when the vessel is carrying passengers as opposed to when it is empty. The greatest changes in probabilities are due to waters. Ferries have the highest probabilities of allisions along quay, followed by fires and explosions.

Probability of accidents in Break Bulk vessels

	Fire	*Grd.*	*Coll.*	*All.*
Break Bulk Vessel	4,6	79,8	8,5	7,1
PMOU White List	1,4	86,7	7,1	4,8
Cargo: Empty	6,1	75,5	9,4	9,0
>3000 GT	13,4	68,1	9,0	9,5
Length 15-24	9,4	72,1	13,2	5,3
Sweden-Lindesnes	3,8	74,1	14,5	7,6
Lindesnes-Bergen	3,8	75,0	14,6	6,6
Bergen-Trondheim	3,2	79,7	10,3	6,8
Trondheim-Tromsø	2,7	84,7	7,7	4,9
Harbour Area	10,5	39,5	15,7	34,3
Outer Coastal Waters	13,0	59,7	21,9	5,4
Along Quay	43,1	7,3	10,7	38,9
No Visibility	0,4	78,0	19,5	2,1
Strong Wind	2,0	82,3	3,3	12,4

Table 10.5.1.3: Probabilities of accidents for break bulk vessels.

Break bulk vessels are notable for increased probabilities of collisions. Here, vessels of 15-24 m are more likely to enter into collisions than vessels above 24m. Also, outer coastal waters are associated with higher probability of collisions. Once again, fires are most likely to occur along quay, and the same goes for allisions.

Probability of accidents in passenger/cruise vessels

	Fire	*Grd.*	*Coll.*	*All.*
Passenger/cruise vessel	3,1	83,0	5,8	8,1
PMOU White List	0,9	88,9	4,8	5,4
Cargo: Passengers	2,9	73,5	8,7	14,9
Cargo: Empty	4,2	79,0	6,5	10,3
>3000 GT	9,2	73,2	6,4	11,2
Length 15-24m	6,5	77,8	9,4	6,3
Sweden-Lindesnes	2,6	78,5	10,1	8,8
Lindesnes-Bergen	2,6	79,5	10,2	7,7
Bergen-Trondheim	2,2	83,0	7,1	7,7
Trondheim-Tromsø	1,8	87,4	5,2	5,6
Harbour Area	7,2	41,8	11,0	40,0
Outer Coastal Waters	9,5	67,5	16,3	6,7
Along Quay	32,6	8,6	8,4	50,4
No Visibility	1,1	29,6	56,0	13,3
Strong Wind	1,3	82,8	2,2	13,7

Table 10.5.1.4: Probabilities of accidents for passenger/cruise vessels.

Passenger vessels are notable due to the qualities of visibility. It is almost ten times more likely that a passenger vessel is involved in collision under no visibility as opposed to good visibility.

Probability of accidents in High Speed Craft

	Fire	*Grd.*	*Coll.*	*All.*
High Speed Craft	3,5	71,9	4,8	19,8
PMOU White List	1,0	80,9	4,2	13,9
Cargo: Passengers	2,9	57,6	6,5	33,0
Cargo: Empty	4,4	66,0	5,2	24,4
>3000 GT	9,9	59,5	4,9	25,7
Length 15-24m	7,6	68,8	7,9	15,7
Sweden-Lindesnes	2,9	67,4	8,3	21,4
Lindesnes-Bergen	3,0	69,5	8,5	19,0
Bergen-Trondheim	2,5	72,5	5,9	19,1
Trondheim-Tromsø	2,2	79,1	4,5	14,2
Harbour Area	5,3	24,0	6,0	64,7
Outer Coastal Waters	10,9	59,0	13,6	16,5
Along Quay	21,1	4,3	4,0	70,6
No Visibility	1,1	24,3	43,8	30,8
Strong Wind	1,3	66,1	1,7	30,9

Table 10.5.1.5: Probabilities of accidents for large fishing vessels.

High speed craft are similar to other passenger vessels in that groundings are most likely, followed by allisions. Visibility has a big impact on the probability of collisions.

10.5.2 Conditional probabilities by parameter.

Here, I list probabilities by parameter type. We can ask, for example, which parameter affects accident probability the most among vessel types? One possible answer, taken from the table below, is that all White List vessel types have higher probabilities of groundings than Norwegian ones, whereas all White List vessels have lower probabilities of fires and explosions.

Probability of accidents by vessels and nationality

	Fire	*Grd.*	*Coll.*	*All.*
Norwegian				
Large fish	7,0	80,7	7,0	5,3
Ferries	1,9	79,7	3,4	15,0
Passenger/Cruise	3,1	83,0	5,8	8,1
High Speed	3,5	71,9	4,8	19,8
Break Bulk	4,6	79,8	8,5	7,1
White List				
Large fish	1,9	88,4	6,0	3,7
Ferries	0,5	86,4	2,9	10,2
Passenger/Cruise	0,9	88,9	4,8	5,4
High Speed	1,0	80,9	4,2	13,9
Break Bulk	1,4	86,7	7,1	4,8

Table 10.5.2.1: Probabilities of accidents by nationalities.

Here, we see that white list vessels have higher relative probabilities of groundings than Norwegian vessels, and similarly lower probabilities of fires. It is tempting to assume that this is due to differences in reporting more so than substantial differences in probabilities between Norwegian and foreign ships.

Probability of accidents by vessels and gross tonnage

	Fire	*Grd.*	*Coll.*	*All.*
GT 500-3000				
Large fish	7,0	80,7	7,0	5,3
Ferries	1,9	79,7	3,4	15,0
Passenger/Cruise	3,1	83,0	5,8	8,1
High Speed	3,5	71,9	4,8	19,8
Break Bulk	4,6	79,8	8,5	7,1
GT >3000				
LargeFish>3k	19,2	66,7	7,2	6,9
Ferries>3k	5,4	70,1	3,7	20,8
Passenger/Cruise>3k	9,2	73,2	6,4	11,2
HiSpeed>3k	9,9	59,5	4,9	25,7
BreakBulk>3k	13,4	68,1	9,0	9,5

Table 10.5.2.2: Probabilities of accidents by gross tonnage.

The general pattern appears to be that higher tonnages are associated with somewhat decreased probabilities of groundings, and increased probability of allisions and fires.

Probability of accidents by vessels and cargo

	Fire	*Grd.*	*Coll.*	*All.*
Cargo: Ballast				
Large fish	7,0	80,7	7,0	5,3
Ferries	1,9	79,7	3,4	15,0
Passenger/Cruise	3,1	83,0	5,8	8,1
High Speed	3,5	71,9	4,8	19,8
Break Bulk	4,6	79,8	8,5	7,1
Cargo: Fish				
Large Fish	6,4	72,8	10,8	10,0
Cargo: Passenger				
Passenger/Cruise	2,9	73,5	8,7	14,9
Ferries	1,5	67,2	4,9	26,4
High Speed	2,9	57,6	6,5	33,0
Cargo: Empty				
Large fish	9,1	76,3	7,8	6,8
Passenger/Cruise	4,2	79,0	6,5	10,3
Ferries	2,3	74,9	3,8	19,0
High Speed	4,4	66,0	5,2	24,4
Break Bulk	6,1	75,5	9,4	9,0

Table 10.5.2.3: Probabilities of accidents by cargo.

Some of the theoretically possible combinations are not logically meaningful. For example, there is no reason to estimate the probability of a grounding for a passenger vessel carrying fish. It is noteworthy, though, that the relative probability of a grounding decreases when a fishing vessel carries fish instead of ballast. It is also noteworthy that the probabilities for the various passenger vessel types change according to whether they carry passengers or are empty. Groundings are more likely to happen when the vessels are empty, whereas allisions are more likely when they carry passengers.

Probability of accidents by vessels and length

	Fire	Grd.	Coll.	All.
Length >24				
Ferries	1,9	79,7	3,4	15,0
Passenger/Cruise	3,1	83,0	5,8	8,1
High Speed	3,5	71,9	4,8	19,8
Break Bulk	4,6	79,8	8,5	7,1
Length 15-24				
Ferries	4,0	78,0	5,8	12,2
Passenger/Cruise	6,5	77,8	9,4	6,3
High Speed	7,6	68,8	7,9	15,7
Break Bulk	9,4	72,1	13,2	5,3

Table 10.5.2.4: Probabilities of accidents by length.

Length has not been used for calculations involving fishing vessels, as they are already categorized according to whether they are above or below 15 m. I therefore limit the analysis to passenger and cargo type vessels. Here, we see that the greatest change comes for collisions with break bulk vessels, which are more likely to collide if they are shorter. Longer vessels are more likely in allisions and fires than shorter ones.

Probability of accidents by vessels and region.

	Fire	Grd.	Coll.	All.
Tromsø-Russia				
Large fish	7,0	80,7	7,0	5,3
Ferries	1,9	79,7	3,4	15,0
Passenger/Cruise	3,1	83,0	5,8	8,1
High Speed	3,5	71,9	4,8	19,8
Break Bulk	4,6	79,8	8,5	7,1
Sweden-Lindesnes				
Large fish	5,8	76,2	12,2	5,8
Ferries	1,6	75,9	6,0	16,5
Passenger/Cruise	2,6	78,5	10,1	8,8
High Speed	2,9	67,4	8,3	21,4
Break Bulk	3,8	74,1	14,5	7,6
Lindesnes-Bergen				
Large fish	5,7	76,9	12,3	5,1
Ferries	2,6	79,5	10,2	7,7
Passenger/Cruise	1,6	77,7	6,1	14,6
High Speed	3,0	69,5	8,5	19,0
Break Bulk	3,8	75,0	14,6	6,6
Bergen-Trondheim				
Large fish	5,0	81,3	8,6	5,1
Ferries	1,3	80,1	4,2	14,4
Passenger/Cruise	2,2	83,0	7,1	7,7
High Speed	2,5	72,5	5,9	19,1
Break Bulk	3,2	79,7	10,3	6,8

Trondheim-Tromsø				
Large fish	4,0	85,9	6,4	3,7
Ferries	1,1	85,3	3,1	10,5
Passenger/Cruise	1,8	87,4	5,2	5,6
High Speed	2,2	79,1	4,5	14,2
Break Bulk	2,7	84,7	7,7	4,9

Table 10.5.2.5: Probabilities of accidents by region.

We can note that there are no radical differences in groundings between regions. Break bulk vessels are more likely to collide in the southern regions. Apart from this, variation in vessel types and regions does not add all that much new information.

Probability of accidents by vessels and waters.

	Fire	*Grd.*	*Coll.*	*All.*
Narrow Coastal				
Large fish	7,0	80,7	7,0	5,3
Ferries	1,9	79,7	3,4	15,0
Passenger/Cruise	3,1	83,0	5,8	8,1
High Speed	3,5	71,9	4,8	19,8
Break Bulk	4,6	79,8	8,5	7,1
Harbour Area				
Large fish	16,4	42,3	13,8	27,5
Ferries	3,3	32,1	5,2	59,4
Passenger/Cruise	7,2	41,8	11,0	40,0
High Speed	5,3	24,0	6,0	64,7
Break Bulk	10,5	39,5	15,7	34,3
Outer Coastal				
Large fish	18,9	59,3	17,8	4,0
Ferries	6,0	70,1	10,4	13,5
Passenger/Cruise	9,5	67,5	16,3	6,7
High Speed	13,0	59,7	21,9	5,4
Break Bulk	10,9	59,0	13,6	16,5
Along Quay				
Large fish	58,1	6,8	8,2	26,9
Ferries	15,1	6,6	3,9	74,4
Passenger/Cruise	32,6	8,6	8,4	50,4
High Speed	21,1	4,3	4,0	70,6
Break Bulk	43,1	7,3	10,7	38,9

Table 10.5.2.6: Probabilities of accidents by waters.

Waters prove to influence probabilities a lot. As we have already seen, groundings are most likely in narrow coastal waters, followed by outer coastal and the harbour area. Collisions are most probable in outer coastal waters, followed by the harbour area. Allisions are most likely along quay and in the harbour area. (This is very much common sense.) Somewhat more surprisingly, fires and explosions are much more probable along quay than in any other water.

Probability of accidents by vessels and visibility

	Fire	*Grd.*	*Coll.*	*All.*
Good visibility				
Large fish	7,0	80,7	7,0	5,3
Ferries	1,9	79,7	3,4	15,0
Passenger/Cruise	3,1	83,0	5,8	8,1
High Speed	3,5	71,9	4,8	19,8
Break Bulk	4,6	79,8	8,5	7,1
No visibility				
Large fish	0,6	81,1	16,7	1,6
Ferries	0,7	32,8	38,0	28,5
Passenger/Cruise	1,1	29,6	56,0	13,3
High Speed	1,1	24,3	43,8	30,8
Break Bulk	0,4	78,0	19,5	2,1

Table 10.5.2.7: Probabilities of accidents by visibility.

Visibility has rather different types of effects for different types of vessels and accidents. Notably, it is much less likely that a grounding with a passenger type vessel happens under no visibility than in good visibility. On the other hand, it is ten times more likely that a collision will happen to a passenger type vessel under no visibility. Probabilities of allisions also increase for passenger type vessels under no visibility.

Probability of accidents by vessels and winds.

	Fire	*Grd.*	*Coll.*	*All.*
No winds				
Large fish	7,0	80,7	7,0	5,3
Ferries	1,9	79,7	3,4	15,0
Passenger/Cruise	3,1	83,0	5,8	8,1
High Speed	3,5	71,9	4,8	19,8
Break Bulk	4,6	79,8	8,5	7,1
Strong Winds				
Large fish	3,0	84,7	2,8	9,5
Ferries	0,7	74,3	1,2	23,8
Passenger/Cruise	1,3	82,8	2,2	13,7
High Speed	1,3	66,1	1,7	30,9
Break Bulk	2,0	82,3	3,3	12,4

Table 10.5.2.8: Probabilities of accidents by winds.

Winds have a relatively modest effect on probabilities. Strong winds decrease the probabilities of collisions, and increase the probability of allisions.

10.6 Predicted probabilities of common traits

In chapter 8 I listed common traits of accidents. These traits were listed one by one, meaning that for example fires and explosions were most common on small fishing vessels, and that they were most common on vessels below 500GT, to use two examples. Now, I will investigate what happens if all the common traits co-occur. I will compare this to the baseline probabilities given in chapter 10.4. The reference scenario is thus a large fishing vessel, registered in NOR, with a gross tonnage of 500-3000, longer than 24 m, traveling in narrow coastal waters in the Tromsø-Russia region under good weather conditions.

For fires/explosions, this means I will calculate the relative probability of a fire on a small fishing vessel below 500 GT, with a length of 10-15 m, registered in NOR, carrying ballast, travelling in outer coastal waters in the Trondheim-Tromsø region, under good weather conditions.

For groundings, I will calculate the relative probability for a break bulk vessel, less than 500 GT, longer than 24 m, registered in NOR, carrying ballast, longer than 24 m, traveling in narrow coastal waters in the Tromsø-Russia region in good weather conditions.

For collisions, I will calculate the relative probability for large fishing vessels, below 500 GT, carrying ballast, registered in NOR, longer than 24 m, traveling in outer coastal waters in the Tromsø-Russia region under good weather conditions.

For allisions, I will calculate the relative probability for a ferry with a GT of 500-3000, registered in NOR, longer than 24 m, travelling in narrow coastal waters in the Lindesnes-Bergen region, under good weather conditions. The results are given in the table below.

	P(Fire)	P(Grd.)	P(Coll.)	P(All.)
Reference	6,9 %	80,8 %	7,0 %	5,3 %
Common traits fire	**19,5 %**	58,7 %	20,8 %	0,9 %
Common traits grounding	2,1 %	**90,4 %**	5,1 %	2,4 %
Common traits collision	15,4 %	61,7 %	**20,7 %**	2,2 %
Common traits allision	1,6 %	77,7 %	6,1 %	**14,6 %**

Table 10.6.1: Probabilities of common traits scenario.

The table shows that for fires, the common traits scenario actually increases the probability of an accident being a fire by more than 10%. Another way of seeing it is that fires are around three times more likely under the common traits scenario than the reference scenario. This suggests that the common traits scenario is a realistic scenario for fires and explosions.

For groundings, the common traits scenario increases probability by around 10%. This is a smaller change relatively of around 1.1 times the reference, but also suggests that the scenario is realistic.

For collisions, the common traits scenario increases probability by 13%. This amounts to a probability which is around three times higher than the reference. Take note that this scenario also increases the probability of a fire somewhat.

For allisions, the common traits scenario increases the probability by around 10% compared to the reference. Relatively speaking, this is three times higher than the reference.

Taken together, these findings suggest that the common traits scenario is indeed realistic, where most of the accident types are around three times more likely under their specific common traits scenario than under the reference scenario.

10.7 High risk profiles of accidents

In this section, we see what combination of traits that maximize the probabilities of each type of accident. I do this by adding one parameter at a time. A summary is given at the end of this section.

So far, I have investigated probabilities of accidents by adding the effects of one parameter only. I have also investigated the probabilities of combinations of common traits. All the combinations of common traits appear realistic, in that they tend to increase the probability of the given accident type compared to the reference category.

An interesting question in the extension of this is: What combination of traits maximizes the probability of a given type of accident? Take note that this is a slightly theoretical exercise, regarding the combinations of gross tonnages and length in particular. Some of the combinations listed below might not be very realistic; this is an issue for expert opinion.

Let's return to the baseline results from setting all variables to their reference categories. This means a Norwegian fishing vessel longer than 24 m, GT 500-3000, traveling in narrow coastal waters in good weather conditions. Other variables create very little variation, so I will disregard the effects of cargo and regions, for example. I begin by reviewing the baseline probabilities as listed below:

Parameter	*P (Grd)*	*P (Coll)*	*P (All)*	*P (Fire)*
Reference	80.7 %	7.0 %	5.3 %	6.9 %

Table 10.7.1: Baseline probabilities of accidents using reference categories.

There is no direct way of calculating which coefficients maximize the probability of any given outcome. Instead, I work iteratively, by adding one parameter at a time, to find the parameter that maximizes probability. We see that the probability of a grounding is already high, which reflects the fact that groundings are the most common accidents overall, and that the reference category realistically reflects a grounding scenario.

10.7.1 Adjusting for vessel types

I begin by manipulating vessel types. The reference category is large fishing vessels. What happens to the probabilities as we change vessel types? The table below lists the vessel type which yields the maximum probability for each accident type.

Parameters	*P (Grd)*	*P (Coll)*	*P (All)*	*P (Fire)*
Work/Service	**84,9 %**	4,3 %	6,7 %	4,0 %
Break Bulk	79,8 %	**8,5 %**	7,1 %	4,6 %
High speed	71,9 %	4,8 %	**19,8 %**	3,5 %
Large fishing	80,7 %	7,0 %	5,3 %	**6,9 %**

Table 10.7.1.1: Maximum probabilities by vessel types.

We see that when it comes to groundings, work and service vessels are somewhat more likely to enter into groundings than the other vessels. When it comes to collisions, break bulk vessels are slightly more likely to enter into collisions than the reference category. High speed craft are more likely than any other vessel type to enter into allisions, although it should be noted that they still are even more likely to be involved in groundings. An allision scenario is therefore rather similar to a groundings scenario. Large fishing vessels remain the vessels most likely to enter into fires.

10.7.2 Adjusting for gross tonnages

I now maintain the previous vessel types, and vary between gross tonnages. This means that for large fishing vessels, for example, we try to find the gross tonnage that increases the probability of a grounding, and for high speed craft we try to find the GT that increases the probability of an allision. The results are given in the table below.

Parameters	*P (Grd)*	*P (Coll)*	*P (All)*	*P (Fire)*
Work/service, GT<500	**88.1 %**	5.0 %	3.6 %	3.3 %
Break bulk, GT<500	82.6 %	**9.8 %**	3.8 %	3.8 %
High speed, GT med.	71.9 %	4.8 %	**19.8 %**	3.5 %
Large fishing, GT >3000	66.7 %	7.2 %	6.9 %	**19.2 %**

Table 10.7.2.1: Maximum probabilities by vessel type and gross tonnage.

We see that work/service vessels below 500 GT are more likely to enter into groundings than the reference category. Break bulk vessels below 500 GT are more likely to enter into collisions. High speed craft of medium GT remain most likely to enter into allisions. Large fishing vessels above 3000 GT are more likely to enter into fires. The greatest change from the reference category is for fires/explosions, where fishing vessels above 3000 GT are three times more likely to enter into fires than medium sized GTs.

10.7.3 Adjusting for length

I retain the previous combinations, and see what lengths maximize probabilities of accidents. The results are given in the table below.

Parameters	*P (Grd)*	*P (Coll)*	*P (All)*	*P (Fire)*
Work/service, GT<500, >24m	**88.1 %**	5.0 %	3.6 %	3.3 %
Break bulk, GT<500, <10.7m	64.6 %	**22.5 %**	1.5 %	11.4 %
High speed, GT med, >24m	71.9 %	4.8 %	**19.8 %**	3.5 %
Large fishing, GT >3000, 15-24m	52,1 %	9,7 %	4,5 %	**44.7 %**

Table 10.7.3.1: Maximum probabilities by vessel type, gross tonnage and length.

For groundings, the reference category of vessels longer than 24 m remains most likely. For collisions, lengths below 10.7 m are most likely. For allisions, the reference category above 24 m remains most likely. For fires, fishing vessels between 15-24 m are most likely to enter into fires. The most substantial changes are for collisions and fires. Collisions become more than twice as likely when vessels are shorter than the reference category, and fires become twice as likely when the length is reduced from above 24 m to between 15 and 24.

10.7.4 Adjusting for waters.

The reference category is narrow coastal waters. We will now see what happens when we try to find the type of waters that maximizes the probability of each type of accident. The results are given in the table below.

Parameters	*P (Grd)*	*P (Coll)*	*P (All)*	*P (Fire)*
Work/service, GT<500, >24m, narrow coastal	**88,1 %**	5,0 %	3,6 %	3,3 %
Break bulk, GT<500, <10.7m, outer coastal	34,6 %	**41,7 %**	0,8 %	22,9 %
High speed, GT med, >24m, harbour area	42,3 %	13,8 %	**27,5 %**	16,5 %
Large fishing, GT >3000, 15-24m, along quay	1,3 %	3,5 %	6,9 %	**88,3 %**

Table 10.7.4.1: Maximum probabilities by vessel type, gross tonnage, length and waters.

For groundings, the reference category of traveling in narrow coastal waters remains the most probable scenario. For collisions, the probability increases drastically, from around 20 to around 40 when traveling in outer coastal waters. Allisions become somewhat more likely in the harbour area, but take note that groundings are still more probable under this scenario. Fires become extremely likely along quay, as opposed to in narrow coastal waters, with a increase from 45 to almost 90%.

10.7.5 Adjusting for lighting and sea state

No changes in lighting conditions and sea states substantially increase the probabilities of accidents. This means that good light and calm seas are the most likely scenarios for all types of accidents.

10.7.6 Adjusting for visibility

The results showed that changing from good visibility to no visibility increased the probability of collisions. The effect of this change is shown in the table below.

Parameters	*P (Grd)*	*P (Coll)*	*P (All)*	*P (Fire)*
Work/service, GT<500, >24m, narrow coastal, good visibility.	**88,1 %**	5,0 %	3,6 %	3,3 %
Break bulk, GT<500, <10.7m, outer coastal, no visibility.	25,6 %	**72,7 %**	0,2 %	1,5 %
High speed, GT med, >24m, harbour area, good visibility.	42,3 %	13,8 %	**27,5 %**	16,5 %
Large fishing, GT >3000, 15-24m, along quay, good visibility.	1,3 %	3,5 %	6,9 %	**88,3 %**

Table 10.7.6.1: Maximum probabilities by vessel type, gross tonnage, length, waters and visibility.

We see that the probability of collisions increases quite dramatically when visibility changes from good to none, from around 40 to over 70. Other accidents do not increase their probabilities due to changes in visibility.

10.7.7 Adjusting for winds

The results showed that strong winds increased the probability of groundings somewhat. The effect of strong winds is shown in the table below.

Parameters	*P (Grd)*	*P (Coll)*	*P (All)*	*P (Fire)*
Work/service, GT<500, >24m, narrow coastal, good visibility, strong winds.	**90,3 %**	1,9 %	6,3 %	1,4 %
Break bulk, GT<500, <10.7m, outer coastal, no visibility, calm winds.	25,6 %	**72,7 %**	0,2 %	1,5 %
High speed, GT med, >24m, harbour area, good visibility, calm winds.	42,3 %	13,8 %	**27,5 %**	16,5 %
Large fishing, GT >3000, 15-24m, along quay, good visibility, calm winds.	1,3 %	3,5 %	6,9 %	**88,3 %**

Table 10.7.7.1: Maximum probabilities by vessel type, gross tonnage, length, waters ,visibility and winds.

Strong winds increase the probability of groundings slightly, but does not increase the probability of any other accident.

10.7.8 Summary

Groundings: The scenario with the highest probability of groundings is thus a work/service vessel (GT <500, length >24 m), traveling in narrow coastal waters, with good visibility and in strong winds. Under these circumstances, it is more than 90% likely that an accident will be a grounding. Most of this probability seems to come from the type of waters. Groundings are thus a phenomenon closely linked to narrow coastal waters.

Collisions: The scenario with the highest probability of collisions is a break bulk vessel (GT <500, Length <10.7 m), traveling in outer coastal waters, under no visibility in good weather. (Take note that this weather combination is not realistic. However, the effect of visibility is much stronger than any weather effect anyway.) Under these circumstances, it is more than 70% likely that an accident will be a collision. Once again, waters probably influence this more than any other factor, although visibility has a fairly strong effect. Collisions are thus a phenomenon closely linked to outer coastal waters and no visibility.

Allisions: The scenario with the highest probability of an allision is a high speed craft (GT medium, length >24 m), traveling in the harbour area under good weather conditions. Under these circumstances, it is around 27% likely that an accident will be an allision. This is the lowest maximum predicted probability for all accidents types. Additionally, a grounding is actually more likely than an allision under these circumstances. Most of the increase in probability appears to be due to type of craft. Waters are not as influential here as with other types of accidents. This is interesting, as high speed craft can be assumed to arrive and depart from dock more often than other types of vessel, due to their role in passenger traffic.

Fires and explosions: The scenario with the highest probability of a fire is a large fishing vessel (GT >3000, 15-24m) lying along quay, in good visibility and calm winds. Under these conditions, it is around 90% probable that an accident will be a fire. A lot of this comes from the fact that other types of accidents are much more unlikely while the vessel is in dock. However, there appears to be quite a lot of variation due to gross tonnage and length, which warrants further investigation.

This concludes the analysis of differences in accident traits from the integrated model. The results are discussed in chapter 11.1. Following next in chapters 10.8 through 10.10 are a few analyses of additional qualities such as time, certification and operational stage. These are discussed in chapter 11.2. Then there are analyses of severity, injuries and fatalities in chapters 10.11 through 10.13. These are discussed in chapter 11.3.

10.8 Multinomic analysis of time categories.

I performed a multinomic regression of time categories to see whether probabilities of accidents fluctuate significantly over the years. This was done individually, as I did not want to interfere with the already high complexity of the integrated model. NB! This model includes data on capsizing, as the accident type satisfied the criteria for inclusion at the time of running the model. However, this results in the model not being directly comparable to the descriptive statistics. Due to the very small size of capsizings, the substantial impact of inclusion is very small indeed. I therefore include this part of the analysis.

The analysis is laid out in the same way as the previous models. For reference categories, we set the third category of years from 2003-2014, the third quarter of the year ranging from July through September, and the afternoon hours between 13 and 18.

The model was statistically significant at the .000 level, with a Cox & Snell approximate explained variation of around 10%, which suggests that variation in time has a modest effect on accidents. The results are given below in table 10.8.1.

	Grounding				**Capsizing**				**Collision**				**Allision**			
	B	SE	p	OR	B	SE	p	OR	B	SE	p	OR	B	SE	p	OR
Intercept	**1,484**	0,14	*0,00*		**-1,619**	0,31	*0,00*		**0,174**	0,17	*0,30*		**1,094**	0,16	*0,00*	
1981-1991	**-0,281**	0,11	*0,01*	0,755	**-0,308**	0,23	*0,17*	0,735	**0,415**	0,14	*0,00*	1,515	**-1,429**	0,13	*0,00*	0,239
1992-2002	**0,381**	0,13	*0,00*	1,463	**0,267**	0,25	*0,29*	1,307	**0,931**	0,15	*0,00*	2,536	**-0,479**	0,15	*0,00*	0,619
Quarter 1	**0,148**	0,12	*0,23*	1,160	**0,786**	0,28	*0,01*	2,194	**-0,148**	0,15	*0,32*	0,863	**0,068**	0,15	*0,66*	1,070
Quarter 2	**-0,028**	0,13	*0,83*	0,972	**0,206**	0,31	*0,51*	1,229	**0,084**	0,15	*0,58*	1,088	**0,015**	0,16	*0,93*	1,015
Quarter 4	**0,339**	0,13	*0,01*	1,403	**0,543**	0,29	*0,06*	1,721	**-0,148**	0,15	*0,33*	0,863	**0,130**	0,16	*0,40*	1,139
Time 01-06	**0,505**	0,13	*0,00*	1,657	**-1,101**	0,36	*0,00*	0,333	**-0,459**	0,16	*0,01*	0,632	**-1,012**	0,19	*0,00*	0,364
Time 07-12	**-0,126**	0,13	*0,33*	0,882	**-0,205**	0,25	*0,42*	0,815	**-0,194**	0,15	*0,19*	0,824	**-0,179**	0,15	*0,23*	0,837
Time 19-23	**0,543**	0,15	*0,00*	1,721	**-0,350**	0,31	*0,26*	0,705	**-0,165**	0,17	*0,34*	0,848	**-0,063**	0,17	*0,71*	0,939
Time Unkn.	**0,002**	0,14	*0,99*	1,002	**0,050**	0,27	*0,85*	1,052	**-0,616**	0,18	*0,00*	0,540	**-0,774**	0,19	*0,00*	0,461

Table 10.8.1: Multinomic regression of accidents on time (N=5.997).

The results show that all accidents vary significantly over time compared to fires and explosions, although capsizing is only significantly different on a few categories.

For the years category: The odds of grounding and collisions and (in particular) allisions were lower in 81-91 compared to the last 11 years, whereas the odds of collisions were higher. For the years 92-02 however, the odds of groundings and collisions were higher, while the odds of allisions were lower, although not as low as for 81-91. This can be interpreted as saying that given that an accident happens, it is more likely today that it is an allision rather than a fire than in the past two periods. It is less likely in the last period that an accident was a grounding or a collision as opposed to a fire than it was in the previous period. The effects are relatively modest, though.

For the seasons, there are fewer significant results. Here, the most notable result is that the odds of a capsizing are around two times higher in the first quarter.

For the accident times, the most notable result is that the odds of groundings increase at night, while all other accidents decrease their odds at night, compared to fires and explosions.

10.8.1 Probabilities of time categories

Only the significant items from the analysis were retained. The results are given in the table below. The reference categories are the periods 2003-2014 and the hours 13-18.

	P(Fire)	P(Grd)	P(Cap)	P(Coll)	P(All)
1981-1991	14,3	47,6	2,1	25,8	10,2
1992-2002	7,9	51,3	2,1	24,0	14,7
2003-2014	10,2	45,1	2,0	12,2	30,5
Time 01-06	9,8	71,6	0,6	7,4	10,6

Table 10.8.1.1: Probabilities of accidents by time categories.

For the year categories, we see that the probabilities of groundings and fires fluctuate somewhat, collisions decrease, whereas allisions increase. The only significant difference between accident hours is between day and night, where groundings are much more likely to occur at night.

10.9 Multinomic analysis of certification.

I performed a separate multinomic regression analysis on the certification areas, see table 10.9.1 below. The reference category was set to minor coastal traffic. The model as a whole was statistically significant at the .000 level, with a Cox & Snell approximate explained variation of 15%.

	Grounding				**Collision**				**Allision**			
	B	SE	p	OR	B	SE	p	OR	B	SE	p	OR
Intercept	**2,562**	0,19	*0,00*		**0,756**	0,22	*0,00*		**0,517**	0,23	*0,02*	
Enclosed waters	**-0,260**	0,40	*0,51*	0,771	**0,711**	0,43	*0,10*	2,035	**0,841**	0,44	*0,05*	2,318
Protected waters	**-0,064**	0,30	*0,83*	0,938	**0,084**	0,35	*0,81*	1,088	**1,998**	0,33	*0,00*	7,373
Inshore u 5 nm	**-0,380**	0,29	*0,19*	0,684	**-0,130**	0,34	*0,70*	0,878	**0,638**	0,33	*0,05*	1,892
Inshore u 25 nm	**-0,741**	0,28	*0,01*	0,476	**-0,504**	0,33	*0,13*	0,604	**-0,239**	0,34	*0,48*	0,788
Major coastal	**0,155**	0,43	*0,72*	1,168	**0,631**	0,48	*0,19*	1,879	**-1,077**	0,67	*0,11*	0,341
North & Eastern Sea	**0,281**	0,31	*0,36*	1,324	**0,343**	0,35	*0,33*	1,409	**-0,463**	0,40	*0,25*	0,629
European	**0,181**	0,36	*0,62*	1,199	**-0,158**	0,43	*0,72*	0,854	**0,452**	0,42	*0,28*	1,572
International/overseas	**-1,464**	0,51	*0,00*	0,231	**-0,063**	0,55	*0,91*	0,939	**-0,363**	0,60	*0,55*	0,696
Unlimited	**-0,329**	0,33	*0,32*	0,720	**-0,030**	0,38	*0,94*	0,971	**0,209**	0,39	*0,59*	1,232
Fjord fishing	**-1,116**	0,59	*0,06*	0,328	**0,256**	0,62	*0,68*	1,292	**-20,752**	0,00	.	0,000
Coastal fishing	**-1,503**	0,23	*0,00*	0,222	**-0,795**	0,27	*0,00*	0,452	**-2,571**	0,41	*0,00*	0,076
Bank fishing	**-0,924**	0,24	*0,00*	0,397	**-0,892**	0,29	*0,00*	0,410	**-1,886**	0,38	*0,00*	0,152
Sea fishing	**-0,483**	0,24	*0,04*	0,617	**-0,444**	0,28	*0,12*	0,641	**-1,578**	0,36	*0,00*	0,206
Others	**-1,428**	0,20	*0,00*	0,240	**-0,617**	0,23	*0,01*	0,540	**-1,033**	0,25	*0,00*	0,356
Certificate B/C/D	**-0,933**	0,39	*0,02*	0,393	**-2,365**	0,81	*0,00*	0,094	**1,275**	0,41	*0,00*	3,577

Table 10.9.1: Multinomic regression of accidents on certification (N=5 858).

The results show that there are significant results for around two thirds of all the certification categories. For **groundings**, the odds are lower for most of the fishing categories, as well as for inshore under 25 n.m. and international traffic. Vessels certified for coastal fishing have the most decreased odds of groundings. For **collisions**, there are fewer significant differences, but the coastal and bank fishing certifications have decreased odds. For **allisions**, enclosed and in particular protected waters have highly increased odds. This is not surprising, knowing the strong correlation between allisions and passenger vessels. It is also noteworthy that three of the fishing categories have significantly and substantially lower odds of allisions. This could simply be an expression of these vessels being in considerably less contact with quays.

10.9.1 Predicted probabilities of certification.

The only categories consistently significant across accident types are the certifications for fishing vessels, as well as the B/C/D certificates. The probabilities for these are given in table 10.9.1.1 on the next page.

	Fire	Grd.	Coll.	All.
Minor Coastal	5,6	72,9	12,0	9,4
Coastal fishing	20,1	58,0	19,3	2,6
Bank fishing	13,8	70,7	12,0	3,5
Sea fishing	9,3	74,7	12,8	3,2
Certificate B/C/D	8,1	41,5	1,6	48,8

Table 10.9.1.1: Predicted probabilities of accidents by certification (N=5 858).

We see that probabilities of accidents vary somewhat across fishing vessels. Fishing vessels certified for *coastal fishing* are less likely than other fishing vessels to be involved in groundings, but more likely to be involved in collisions. *Minor coastal* is most likely of certifications to be involved in allisions, whereas *coastal fishing* is most likely to be involved in fires. We also see that the *B/C/D certificates* are more likely to be involved in groundings and allisions than other accident types.

10.10 Multinomic analysis of operational state.

I performed a separate multinomic regression analysis on operational states. The reference category was set to *underway*. The model as a whole was statistically significant at the .000 level, with a Cox & Snell approximate explained variation of 34,7%. The results are given in table 10.9.1 below.

	Grounding				**Collision**				**Allision**			
	B	SE	p	OR	B	SE	p	OR	B	SE	p	OR
Intercept	2,528	0,07	0,00		0,934	0,08	0,00		-0,863	0,12	0,00	
Arriving Port	0,576	0,28	0,04	1,778	0,717	0,30	0,02	2,048	4,444	0,30	0,00	85,135
Along Quay	-4,760	0,25	0,00	0,009	-2,447	0,19	0,00	0,087	-0,817	0,23	0,00	0,442
Departing Port	-0,021	0,32	0,95	0,979	0,827	0,34	0,01	2,285	2,377	0,36	0,00	10,771
Fishing	-2,632	0,19	0,00	0,072	-1,137	0,19	0,00	0,321	-22,266	0,00	.	2,14E-10
Other Known	-2,387	0,21	0,00	0,092	-2,198	0,32	0,00	0,111	0,926	0,24	0,00	2,524
Unknown	-1,195	0,15	0,00	0,303	-1,135	0,19	0,00	0,321	0,326	0,23	0,15	1,385

Table 10.9.1: Multinomic regression of accidents on operational stage (N=5 858).

There was a statistical problem, presumably due to the low number of allisions during fishing, which results in no available significance for fishing in allisions. Although the validity of the model fit is uncertain, the model is still significant at the .000 level. I therefore proceed presenting the results.

The results show that there are significant differences among almost all the operational stages. **Arriving port** increases the odds of a grounding, a collision or an allision. In particular, port arrival is noteworthy, as the odds of an accident being an allision rather than a fire on arrival of port are 85 times higher. The vessel being **along quay** decreases the odds of groundings and collisions substantially. It also decreases the odds of allisions, but not quite as much. Put in another way, the most likely accident along quay is a fire/explosion, followed by an allision. **Departing port** increases the odds of a collision somewhat, but once again allisions have the highest increase in odds. Vessels that are busy **fishing** have highly decreased odds of groundings, and also substantial decrease in odds of collisions. I will not get into details on the **other known** stages, except to say that all other known operational stages are associated with decreased odds of groundings and collisions, but increased odds of allisions, compared to being underway.

In all, the model to a large degree serves to reinforce the previous findings from the integrated model featuring vessel, geographical and time qualities. In particular, the operational stage can be seen as a slightly different expression of the information in the "waters" category.

10.10.1 Predicted probabilities of operational states.

Predicted probabilities of operational states are given in table 10.10.1 below.

	Fire	Grd	Coll	All
Underway	6,1	76,0	15,4	2,6
Arriving Port	1,6	34,6	8,1	55,8
Along Quay	66,1	7,1	14,5	12,3
Departing Port	4,2	51,9	24,6	19,2

Table 10.10.1: Predicted probabilities of accidents by operational state (N=5 858).

We can note that probabilities vary quite a lot depending on operational stages. Take note that this analysis does not differentiate between vessel types, so this is an average effect across vessels. Most of these predictions make common sense. It is more likely that a grounding happens while the vessel is underway, and more likely that an allision happens in proximity of port. We can take note that allisions are much more likely on arrival of port than on departure, whereas the reverse is true for groundings. Fires are most likely to happen along quay. The findings mostly reinforce the findings on waters.

10.11 Logistic regression analysis of severity

I performed four individual logistic regressions on severity in fires/explosions, groundings, collisions and allisions. The results are given below in table 10.11.1.

	Fire (N=587)				Grounding (N=3380)				Collision (N=275)				Allision (N=449)			
	B	SE	p	OR	B	SE	p	OR	B	SE	p	OR	B	SE	p	OR
Vessel types																
Fishing <15m	-	-	-	-	**0,012**	0,31	0,97	1,012	**-2,576**	1,32	0,05	0,076	-3,872	1,81	0,03	0,021
Ferries	-	-	-	-	**-0,551**	0,23	0,02	0,576	**-0,140**	1,03	0,89	0,869	-1,754	0,72	0,02	0,173
Pass./cruise	-	-	-	-	**-0,392**	0,25	0,12	0,676	**-0,684**	0,86	0,43	0,505	-2,796	0,95	0,00	0,061
High Speed	-	-	-	-	**0,094**	0,33	0,77	1,098	**-19,959**	15826,28	1,00	0,000	-1,212	0,81	0,14	0,297
Other Pass.	-	-	-	-	**-0,103**	0,32	0,74	0,903	**-2,202**	1,56	0,16	0,111	-20,446	17873,65	1,00	0,000
Work/Service	-	-	-	-	**-0,546**	0,25	0,03	0,579	**-21,182**	12760,90	1,00	0,000	-3,359	1,74	0,05	0,035
Offshore Service	-	-	-	-	**-0,012**	0,39	0,98	0,988	**0,533**	1,44	0,71	1,704	-0,182	1,37	0,90	0,834
Well Boats	-	-	-	-	**-0,184**	0,30	0,54	0,832	**-0,938**	1,40	0,50	0,391	-20,608	23146,76	1,00	0,000
Tankers	-	-	-	-	**-0,065**	0,33	0,84	0,937	**-1,559**	1,54	0,31	0,210	-22,048	11478,99	1,00	0,000
Bulk	-	-	-	-	**-0,116**	0,25	0,64	0,890	**-0,994**	1,02	0,33	0,370	-1,624	1,32	0,22	0,197
Break Bulk	-	-	-	-	**-0,025**	0,16	0,87	0,975	**-2,286**	0,78	0,00	0,102	-1,437	0,82	0,08	0,238
Register																
NIS	-	-	-	-	**0,761**	0,19	0,00	2,141	-	-	-	-	-	-	-	-
Unknown	-	-	-	-	**0,437**	0,17	0,01	1,549	-	-	-	-	-	-	-	-
Foreign	-	-	-	-	**0,180**	0,71	0,80	1,198	-	-	-	-	-	-	-	-
Cargo																
Passengers	**-1,133**	0,39	0,00	0,322	**0,311**	0,21	0,14	1,364	**-1,105**	0,84	0,19	0,331	-	-	-	-
Fish	**0,088**	0,31	0,78	1,092	**0,239**	0,12	0,05	1,270	**-1,010**	0,48	0,04	0,364	-	-	-	-
Dry/Bulk/Cont.	**-0,578**	0,53	0,28	0,561	**0,409**	0,17	0,01	1,506	**0,449**	0,70	0,52	1,566	-	-	-	-
Bulk/Ore/Grain/Coal	**1,548**	0,71	0,03	4,701	**0,557**	0,19	0,00	1,746	**1,276**	0,89	0,15	3,583	-	-	-	-
Other Known	**0,239**	1,03	0,82	1,270	**0,195**	0,35	0,57	1,216	**3,173**	1,77	0,07	23,869	-	-	-	-
Oil/Chem/Gas	**-0,600**	1,20	0,62	0,549	**0,341**	0,39	0,39	1,406	**1,787**	1,64	0,28	5,971	-	-	-	-
Empty	**0,477**	0,31	0,12	1,611	**0,383**	0,19	0,04	1,467	**-0,508**	0,76	0,50	0,602	-	-	-	-
Unknown	**0,004**	0,27	0,99	1,004	**0,289**	0,15	0,06	1,335	**0,456**	0,57	0,43	1,578	-	-	-	-
Length																
<10.67 m	**1,620**	0,27	0,00	5,055	**1,151**	0,32	0,00	3,162	**3,061**	1,29	0,02	21,343	4,327	1,63	0,01	75,748
10.67-15 m	**71,261**	0,31	0,00	3,530	**0,715**	0,30	0,02	2,045	**2,654**	1,27	0,04	14,213	6,809	2,16	0,00	905,626
15-24 m	**0,515**	0,25	0,04	1,673	**0,445**	0,14	0,00	1,560	**0,733**	0,61	0,23	2,082	-0,689	0,85	0,42	0,502
Unknown	**-0,589**	1,15	0,61	0,555	**-1,287**	0,52	0,01	0,276	**-20,397**	14322,63	1,00	0,000	3,714	1,95	0,06	41,020
Vessel Age																
6-15	-	-	-	-	-	-	-	-	**1,187**	0,67	0,08	3,277	-	-	-	-
16-25	-	-	-	-	-	-	-	-	**0,680**	0,67	0,31	1,974	-	-	-	-
>25	-	-	-	-	-	-	-	-	**1,396**	0,66	0,03	4,037	-	-	-	-
Unknown	-	-	-	-	-	-	-	-	**0,524**	1,45	0,72	1,688	-	-	-	-
Region																
Swe.-Lind.	-	-	-	-	**0,192**	0,19	0,32	1,212	-	-	-	-	3,320	1,18	0,01	27,655
Lind.-Bergen	-	-	-	-	**0,252**	0,16	0,12	1,286	-	-	-	-	2,256	1,14	0,05	9,544
Bergen-Trond.	-	-	-	-	**0,291**	0,15	0,05	1,337	-	-	-	-	1,903	1,13	0,09	6,707
Trond-Tromsø	-	-	-	-	**0,402**	0,13	0,00	1,494	-	-	-	-	2,378	1,12	0,03	10,779
Svalb/JanM/Bj.	-	-	-	-	**-0,568**	0,48	0,24	0,566	-	-	-	-	3,865	2,24	0,08	47,714
Other/Unknown	-	-	-	-	**0,030**	0,57	0,96	1,031	-	-	-	-	-0,800	1,90	0,67	0,449
Waters																
Harbour	**-0,91**	0,317	0,004	0,402	**-0,595**	0,13	0,00	0,552	**-2,010**	0,54	0,00	0,134	2,171	1,55	0,16	8,765
Outer Coastal	**0,095**	0,298	0,751	1,099	**0,427**	0,10	0,00	1,532	**-0,129**	0,42	0,76	0,879	-0,769	0,39	0,05	0,463
Quay	**-0,702**	0,336	0,037	0,496	**-19,917**	9339,46	1,00	0,000	**-0,960**	1,22	0,43	0,383	-0,348	0,87	0,69	0,706
Oil Field	**21,132**	40192,97	1	1.504. 680.405	**-20,358**	40192,97	1,00	0,000	**-3,453**	2,16	0,11	0,032	-1,162	0,61	0,06	0,313
Other	**0,299**	0,739	0,686	1,349	**-0,468**	0,29	0,10	0,626	**-21,539**	16913,03	1,00	0,000	-1,814	1,55	0,24	0,163
Light																
Twilight	-	-	-	-	**0,024**	0,16	0,88	1,024	-	-	-	-	-	-	-	-
Dark	-	-	-	-	**0,333**	0,09	0,00	1,395	-	-	-	-	-	-	-	-
Unknown	-	-	-	-	**-0,013**	0,21	0,95	0,988	-	-	-	-	-	-	-	-
Sea State																
Moderate	-	-	-	-	**0,464**	0,11	0,00	1,590	-	-	-	-	-	-	-	-
High	-	-	-	-	**1,113**	0,22	0,00	3,044	-	-	-	-	-	-	-	-
Unknown	-	-	-	-	**-0,147**	0,11	0,18	0,863	-	-	-	-	-	-	-	-
Constant	**0,068**	**0,326**	**0,836**	**1,07**	**-1,708**	**0,18**	**0,00**	**0,181**	**-0,498**	**0,86**	**0,56**	**0,608**	**-1,909**	**1,19**	**0,11**	**0,148**

Table 10.11.1: Logisitic regression of accident severity (individual models).

Severity in fires was significant at the .000 level, with a Cox & Snell of 18.8%. Severity in fires was significant at the .000 level, with a Cox & Snell approximate explained variation of 11.4%. Groundings were significant at the .000 level, with a Cox & Snell of 29%. Allisions were significant at the .000 level, with a Cox & Snell of 11.9%. We were able to explain relatively little of the variation in severity in most accidents, but a fair amount in groundings. Length and waters were the only variables that were significant across the individual models.

10.11.1 Results of analysis of severity

It is important to point out that the models of severity are separate and independent of each other, and are thus not directly comparable. For each type of accident, we compare severe versus non-severe damage to the vessel. That said, certain comparisons can still be made across models. Sections with no listed results were insignificant, and were thus taken out of the analysis. Results were listed in one table to facilitate comparisons.

Severity in fires is primarily associated with vessel *length*. The general pattern appears to be that the shorter the vessel, the higher the odds of an accident being severe. Additionally, *vessels carrying passengers* in groundings have lower odds of severity, and fires in *harbour areas* have lower odds of severity.

Severity in groundings has a higher number of significant items. Once again, *length* is associated with severity, with the same pattern as for fires: The shorter the vessel, the higher the odds of severity. Type of *cargo* is associated with severity in that vessels carrying ballast appear to have lower odds of severity in groundings. *Ferries and work/service vessels* have lower odds of severity, and traffic between *Bergen and Tromsø* is associated with higher severity than the northernmost region. Groundings in the *dark* tend to be somewhat more severe, and *higher seas* are associated with more severity.

Severity in collisions has somewhat fewer significant items. Once again, *length* is notable in that the shorter the vessel, the more severe the consequences, with odds ratios of 21 and 14. *Small fishing vessels*, however, have much lower odds of severity than larger ones. Also, *carrying fish* rather than ballast is associated with lower odds of severity. *Vessel age* is significant, and all older vessels have increased odds of severity. Collisions in *harbour areas* tend to be less severe.

Severity in allisions is significantly higher for *large fishing vessels* than for small ones, as well as for ferries and passenger/cruise ships. Vessel *length* has a radical effect on severity in allisions, with odds ratios of 75 for vessels below 10.67, and 905 for vessels 10.7-15 m. The odds are lower, however, for vessels 15-24 m. Allisions between *Sweden and Lindesnes* have much higher odds of severity, and all significant regions have higher odds than Tromsø-Russia of severity in allisions. It is noteworthy, though, that the only significant difference between *waters* is lower odds for outer coastal compared to narrow coastal.

10.11.2 Probabilities of severity

As noted, probabilities in logistic regression can be calculated by the formula P = $(1/1+e^{-L)}$. Selecting only significant items from the analysis of severity, and manipulating one parameter at the time yields the following results:

10.11.3 Severity in fires and explosions

Probabilities of severity in fires	
Large Fishing Vessel	51,7 %
Passenger Cargo	25,6 %
Bulk/Ore/Grain/Coal Cargo	83,4 %
Length <10.67 m	84,4 %
Length 10.67-15 m	100,0 %
Length 15-24 m	64,2 %
In the harbour area.	30,1 %
Along quay	34,7 %

Table 10.11.3.1: Probabilities of severity in fires.

There were no significant differences in severity among vessel types in fires, so with some caution we could argue that all vessel types have around 50% chance of severe damage in a fire. Vessels carrying passengers actually have the smallest probability of severe damage, whereas vessels carrying various bulk have a fairly high probability. The numbers for length have to be read with some caution. A vessel cannot logically be both longer than 15m, as the reference category is, and shorter than 15m at the same time. However, as there were no significant differences between vessel types, we could argue that length by itself changes the probability of severity in a fire. The reference length is actually over 24 m, so we could argue that all shorter vessels have higher probabilities of severity. Compared to the reference category of narrow coastal waters, harbour and quay areas are less likely to feature severe fires.

10.11.4 Severity in groundings

Probabilities of severity in groundings	
Large Fishing Vessel	15,3 %
Ferries	9,5 %
Work/Service Vessels	9,5 %
NIS vessels	27,9 %
Fish Cargo	18,7 %
Dry/Bulk/Cont. Cargo	21,4 %
Bulk/Ore/Grain/Coal Cargo	24,0 %
Empty Cargo	21,0 %
Length <10.67 m	36,4 %
Length 10.67-15 m	27,0 %
Length 15-24 m	22,0 %
Bergen-Trondheim.	19,5 %
Trondheim-Tromsø	21,3 %
Harbour Area	9,1 %
Outer Coastal Waters	21,7 %
Dark Conditions	20,2 %
Moderate Seas	22,4 %

Table 10.11.4.1: Probabilities of severity in fires.

There were a few significant differences in severity between vessel types in groundings. Large fishing vessels are slightly more likely to have severe damage than ferries and work/service vessels. NIS vessel have substantially higher probability of severe damage than NOR vessels in groundings, 27.9 against 15.3%. Length once again appears as a notable influence on severity, although the numbers have to be read with caution, as there is no such thing as a large fishing vessel under 15 m. For groundings, the numbers do though suggest that shorter vessels are more likely to incur severe damage. Finally, groundings in the harbour area tend to be less severe.

10.11.5 Severity in collisions

Probabilities of severity in collisions	
Large Fishing Vessel	37,8 %
Fishing Vessel <15m	4,4 %
Break Bulk Cargo	5,8 %
Fish Cargo	18,1 %
Length <10.67 m	92,8 %
Length 10.67-15 m	89,6 %
Vessel age >25y	71,1 %
Harbour Area	7,5 %

Table 10.11.5.1: Probabilities of severity in collisions.

In collisions, there were significant differences between large and small fishing vessels, as well as for length separately. The numbers have to be interpreted cautiously, but there appears to be grounds for further research into the effects of length on the type of damage a vessel incurs in all accidents.

10.11.6 Severity in allisions

Probabilities of severity in allisions	
Large Fishing	12,9 %
Fishing <15m	0,3 %
Ferries	2,5 %
Pass./cruise	0,9 %
Work/Service	0,5 %
<10.67 m	91,8 %
10.67-15 m	99,3 %
Swe.-Lind.	80,4 %
Lind.-Bergen	58,6 %
Trond-Tromsø	61,5 %
Outer Coastal	6,4 %

Table 10.11.6.1: Probabilities of severity in allisions.

Interestingly, as previous results have shown that passenger vessels are much more likely to encounter allisions, they tend to be less severe than for fishing vessels. Length once again appears to be a substantial influence on severity, this time with shorter lengths being associated with severity. Interestingly, allisions in the southern region tend to be more severe than elsewhere. Allisions in outer coastal waters seem somewhat unlikely accidents logically, but if they do appear, they can be expected to be less severe.

10.12 Logistic regression analysis of injuries

Individual logistic regression were performed on injuries. The reference category is a large fishing vessel, carrying ballast, with a GT of 500-3000, above 24 m length, in the Tromsø-Russia region, under good weather conditions and visibility. Models are listed below in table 10.12.1.

	Fire (N=614)				**Grounding (N=3607)**			
	B	SE	p	OR	B	SE	p	OR
Reference	-3,012	0,46	0,00	0,049	-4,024	0,51	0,00	0,018
Vessel type								
Fishing <15m	-0,192	0,51	0,71	0,825	-1,224	0,71	0,08	0,294
Ferries	0,965	0,73	0,19	2,624	0,350	0,57	0,54	1,419
Pass./cruise	0,396	0,83	0,64	1,486	0,558	0,61	0,36	1,748
High Speed	-18,132	13393,87	1,00	0,000	1,746	0,68	0,01	5,734
Other Pass.	-18,148	8199,80	1,00	0,000	-0,027	0,82	0,97	0,973
Work/Service	-18,114	7880,25	1,00	0,000	0,235	0,68	0,73	1,265
Offshore Service	0,822	1,05	0,43	2,274	-16,869	5901,94	1,00	0,000
Well Boats	3,081	1,08	0,00	21,769	-0,290	1,06	0,78	0,749
Tankers	1,079	1,14	0,34	2,943	-16,347	3773,57	1,00	0,000
Bulk	2,246	0,80	0,01	9,449	-0,012	0,87	0,99	0,988
Break Bulk	-0,149	0,74	0,84	0,862	-0,843	0,65	0,20	0,431
Cargo								
Passengers	-	-	-	-	0,523	0,54	0,33	1,687
Fish	-	-	-	-	0,710	0,46	0,13	2,034
Dry/Bulk/Cont.	-	-	-	-	0,601	0,74	0,41	1,825
Bulk/Ore/Grain/Coal	-	-	-	-	-0,446	1,15	0,70	0,640
Other Known	-	-	-	-	0,393	1,12	0,73	1,481
Oil/Chem/Gas	-	-	-	-	-14,976	4485,78	1,00	0,000
Empty	-	-	-	-	1,284	0,50	0,01	3,611
Unknown	-	-	-	-	0,227	0,50	0,65	1,255
Gross Tonnage								
GT1_500	-	-	-	-	-1,018	0,38	0,01	0,361
GT_3000	-	-	-	-	-0,195	0,65	0,76	0,823
GT_unknown	-	-	-	-	-0,546	0,67	0,42	0,579
Length								
<10.67 m	-	-	-	-	1,737	0,75	0,02	5,678
10.67-15 m	-	-	-	-	1,943	0,63	0,00	6,979
15-24 m	-	-	-	-	0,483	0,45	0,28	1,620
Unknown	-	-	-	-	-16,471	5278,37	1,00	0,000
Sea State								
Moderate	0,259	0,60	0,67	1,296	-	-	-	-
High	4,416	1,19	0,00	82,784	-	-	-	-
Unknown	-0,136	0,42	0,75	0,873	-	-	-	-

	Collision (N=865)				**Allision (N=772)**			
	B	SE	p	OR	B	SE	p	OR
Constant	-3,644	0,51	0,00	0,026	-3,040	0,74	0,00	0,048
Region								
Swe.-Lind.	0,581	0,68	0,40	1,787	1,727	0,78	0,03	5,625
Lind.-Bergen	0,001	0,68	1,00	1,001	0,827	0,77	0,28	2,287
Bergen-Trond.	1,239	0,59	0,04	3,451	1,376	0,75	0,07	3,958
Trond-Tromsø	0,509	0,60	0,40	1,663	1,624	0,76	0,03	5,071
Svalb/JanM/Bj.	-17,559	20096,49	1,00	0,000	-17,305	27728,60	1,00	0,000
NCS/Arctic	-17,559	14210,36	1,00	0,000	-17,512	8350,23	1,00	0,000
Other/Unknown	-17,559	23205,42	1,00	0,000	1,115	1,28	0,38	3,049
Winds								
Moderate	-	-	-	-	-0,203	0,36	0,57	0,816
Strong	-	-	-	-	-1,699	0,55	0,00	0,183
Unknown	-	-	-	-	-0,346	0,27	0,21	0,708

Table 10.12.1: Logistic regression of accident injuries (individual models).

10.12.1 Results of analysis of injuries

Statistical tests show that all models were significant at the .000 level. Cox & Snell approximate explained variation was low for all models: 6.6% for fires, 1.6% for groundings, 0.1% for collisions and 4.1% for allisions.

As we can see from the models, factors associated with injuries vary across accident types. *Vessel types* are only significant for a few cases. In fires and explosions there are two:, the category of well boats, with an odds ratio of over 21, and bulk vessels, with an odds ratio of 10. In groundings, only high speed craft has a significant difference, with an increase in odds of injuries.

Cargo is only significant in groundings, and then only for empty vessels compared to vessels carrying ballast. Empty vessels have over three times higher odds of injuries.

Gross tonnage is only significant in groundings, where only the smallest group of vessels have decreased odds of injuries.

Length is also only significant in groundings, where the two shortest vessel groups have increased odds of injury.

Sea state is only significant for fires and explosions, where high seas has a substantial increase in odds of injury of over 82.

There were a few significant differences in odds of injuries among *regions* in collisions and allisions. Sweden-Lindesnes and Trondheim-Tromsø has higher odds of injuries in allisions, whereas Bergen-Trondheim has slightly increased odds of injuries in collisions.

Finally, *strong winds* actually decrease the odds of injuries in allisions, which based on previous findings suggests that passenger vessels decrease their activity level in strong winds, or else they take extra security precautions in strong winds, in particular when arriving or departing port.

10.12.2 Probabilities of injuries

Probabilities of injuries in fires

Fire	P
Reference	4,7 %
Well Boats	51,7 %
Bulk Vessel	31,7 %
High Seas	80,3 %

Table 10.12.2.1: Probabilities of injuries in fires.

The probability of an injury in a fire is quite low around 5% at the baseline. However, well boats and bulk vessels have much higher probabilities of injuries than other vessel types. Additionally, high seas increases the probability of injury in a fire to over 80%.

Probabilities of injuries in collisions

Collision	P
Reference	2,5 %
Bergen-Trond.	8,3 %

Table 10.12.2.2: Probabilities of injuries in collisions.

Probability of injury in a collision is also quite low at the baseline, and the only significant difference was that the Bergen-Trondheim region has around 5% higher probability of injuries.

Probabilities of injuries in groundings

Grounding	P
Reference	1,8 %
High Speed Craft	9,3 %
Cargo Empty	6,1 %
GT<500	0,6 %
<10.67 m	9,2 %
10.67-15 m	11,1 %

Table 10.12.2.3: Probabilities of injuries in groundings.

Probability of injuries in groundings is also quite low. High speed craft has around 7% higher probability of injury than other vessel types. Vessels registered with empty cargo also have slightly higher probabilities, and shorter vessels also have substantially higher probability of injuries in groundings.

Probabilities of injuries in allisions

Allision	P
Reference	4,6 %
Sweden-Lindesnes	21,2 %
Trondheim-Tromsø	19,5 %
Strong Winds	0,9 %

Table 10.12.2.4: Probabilities of injuries in allisions.

The baseline probability of an injury in an allision is quite low. However, vessels traveling in Sweden-Lindesnes and Trondheim-Tromsø have higher probabilities of injuries compared to Tromsø-Russia. Strong winds actually decrease the probability quite substantially of injuries in allisions.

10.13 Logistic regression analysis of fatalities.

I performed a series of individual logistic regressions on fatalities for different accidents. The final models were quite different, so they are listed one by one below.

10.13.1 Fatalities in fires and explosions

There were no significantly different qualities between fatalities and non-fatalities in fires and explosions. This could very likely be due to the statistically very small number of 6 fatalities in fires and explosions.

10.13.2 Fatalities in groundings

	B	SE	Sig.	OR
Nationality				
PMOU White List	2,178	0,84	0,01	8,830
PMOU Grey/Black/Oth.	-14,198	6071,10	1,00	0,000
Length				
<10.67 m	3,314	0,76	0,00	27,484
10-15 m	1,641	0,98	0,09	5,159
15-24 m	2,596	0,73	0,00	13,413
Unknown	-16,346	5138,83	1,00	0,000
Region				
Sweden-Lindesnes	-0,293	0,71	0,68	0,746
Lindesnes-Bergen	-0,401	0,66	0,54	0,670
Bergen-Trondheim	-0,657	0,65	0,31	0,518
Trondheim-Tromsø	-1,749	0,67	0,01	0,174
Svalbard/Jan M/Bj	-15,939	5643,11	1,00	0,000
Other/Unknown Regions	-17,149	6096,29	1,00	0,000
Seas				
Moderate	0,392	0,64	0,54	1,481
High	2,880	0,60	0,00	17,821
Unknown	0,762	0,54	0,16	2,143
Constant	-6,688	0,80	0,00	0,001

Table 10.13.2.1: Logistic regression of fatalities in groundings (N=3607).

The model was statistically significant at the .000 level, with a Cox & Snell approximate explained variation of 1.9%. We have thus been able to explain very little of the variation in fatalities in groundings.

There are a relatively large number of significant differences between fatalities and non-fatalities in groundings. First, nations on the *PMOU white list* have substantially higher odds of fatalities than Norwegian ships. Second, the *two shortest categories of ships* have even more substantially higher odds of being involved in fatalities than longer ships. Third, the *Trondheim-Tromsø* region has rather substantially lower odds of fatalities compared to Tromsø-Russia. Finally, *high seas* increase the odds of fatalities in groundings quite substantially.

Probabilities of fatalities in groundings

Groundings	**P**
Reference	0,1 %
White List	1,1 %
Length <10.67 m	3,3 %
Length 15-24	1,6 %
Trondheim-Tromsø	0,0 %
High Seas	2,2 %

Table 10.13.2.4: Probabilities of fatalities in groundings.

As we can see, the baseline probability of fatalities in groundings is fortunately very low. Statistically speaking, most of the effects are rather modest in absolute percentages, but we can note that white list vessels report ten times higher probability of fatalities than Norwegian vessels, that groundings in Middle Norway have a probability of zero of fatalities, and that high seas increases the probability twenty times of fatalities. The most extreme effect comes from groundings in short vessel, which increases probabilities by over 30 times. Still, none of these effects raise probabilities above around 3% in total.

10.13.3 Fatalities in collisions

Results from the regression analysis of fatalities in collisions are given below in table 10.13.4.1.

	B	SE	p	OR
Twilight	-0,194	0,791	0,806	0,823
Dark	-2,266	1,062	0,033	0,104
Light Unkn.	0,608	1,022	0,552	1,836
Moderate Vis.	1,831	0,648	0,005	6,240
Poor Visibility	1,599	0,828	0,053	4,950
No Visibility	0,69	0,805	0,391	1,995
Fog/Snow	-16,879	6294,308	0,998	0,000
Unknown Vis.	-0,078	1,032	0,940	0,925
Constant	-3,949	0,371	0	0,019

Table 10.13.4.1: Logistic regression of fatalities in collisions (N=865).

The model was statistically significant at the .000 level, with a Cox & Snell of 1.9%. We have thus been able to explain very little of the variation in fatalities in collisions.

Fatalities in collisions have two notable features. First, the odds of fatalities are substantially lower in *dark lighting conditions*. Second, *moderate visibility* is associated with increased odds of fatalities.

Probabilities of fatalities in collisions

Collisions	P
Reference	1,9 %
Dark Conditions	0,2 %
Moderate Visibility	10,7 %

Table 10.13.2.4: Probabilities of fatalities in collisions.

Fatalities in allisions

No significant differences between fatalities and non-fatalities were found in allisions. This is not surprising, as there was only one reported case of fatalities in the selected sample.

11 Discussion.

I will now review the research questions listed in chapter 5.1:

1. *How do vessel qualities, geographical and weather data affect the relative risk of maritime accidents?*
2. *How does time, certification and operational state influence the relative risk of maritime accidents?*
3. *What factors contribute to severe damage, injuries and fatalities in maritime accidents?*

11.1 Vessels, geography, weather and maritime accidents.

11.1.1 Differences in accidents between vessel types and qualities.

The database originally separates vessels in three groups that were included in this analysis; fishing, passenger and cargo vessels. The simple example used in chapter 8.1 found significant differences between groundings for these groups. The NSRM research group proposed a subdivision of these groups into 12 vessel categories. In the integrated model (chapter 9.2.6), only a few of these vessel types remained significantly different from each other. Using large fishing vessels as the reference category, we only found significant differences for the following vessel types: ferries, passenger/cruise vessels, high speed craft, work & service vessels and break bulk vessels.

One point worth elaborating is why there not significant differences between more of the vessel types. I would like to offer three possibilities. First, there is the possibility that the results indicate that there are no major differences between vessel types beyond what the results show. This calls for a simplification of the vessel groupings in further analysis. Second, there is a possibility that the results are due to statistical shortcomings. In particular, some of the cargo vessel types are relatively small in terms of numbers, and the sample is not large enough to reveal significant differences. This interpretation also calls for a simpler categorization of vessel types. Third, there is the possibility that the current categorization does not properly capture underlying differences between vessel types. The result is still the same: The categorization of twelve vessel types only partially captures differences in accident risk. I propose that it might be feasible to use the general vessel groupings in further analysis, and focus more on vessel parameters such as gross tonnage and length to differentiate risk between vessels.

Relative probabilities between vessel types vary somewhat. For example, passenger/cruise vessels are around ten percent more likely to be involved in groundings than high speed vessels, whereas the situation is reversed for allisions. On the whole, though, there is relatively little variation across vessel types.

The influence of the added parameters varies. Foreign vessels appear more susceptible to groundings as opposed to other accidents. Higher tonnages are associated with somewhat decreased probabilities of groundings, and increased probability of allisions and fires. For passenger vessels and cargo, groundings are more likely to happen when the vessels are empty, whereas allisions are more likely when they carry passengers. Break bulk vessels are more likely to collide if they are shorter. Longer vessels are more likely in allisions and fires than shorter ones. The influence of regions is rather modest, and does not point in a very specific direction.

11.1.2 Geographical differences in accidents.

Some of the greatest variation comes from types of waters. Groundings are most likely in narrow coastal waters, collisions are most probable in outer coastal waters and allisions are most likely in port areas. Perhaps the most surprising result is that fires and explosions are much more probable along quay than in any other water.

11.1.3 Weather differences in accidents.

Weather has a limited effect on most of the relative probabilities of accidents. However, it is much less likely that a grounding with a passenger type vessel happens under no visibility than in good visibility. On the other hand, it is ten times more likely that a collision will happen to a passenger type vessel under no visibility, which is among the largest effects of the statistical analysis. Strong winds decrease the probabilities of collisions, and increase the probability of allisions.

11.1.4 The common traits scenario

The common traits scenario outlined in chapter 8 turns out be realistic. Taken together, the common traits in fires, collisions and allisions increase the relative probability of each accident by around three times.

11.2 Time, certification and operational state in maritime accidents.

The time variables yielded significant, but rather modest variation between the three year categories. The most notable result was that probabilities of accidents change quite substantially by night, where groundings become much more likely, and collisions become much less likely.

When it comes to certifications, the only consistently significant differences were between the various certifications for fishing vessels as well as the B/C/D certificates. Vessels certified for coastal fishing were less likely to be involved in groundings than other fishing vessels, and the B/C/D category were even less likely to be involved in groundings. These certificates were also a lot less likely to be involved in collisions, and a lot more likely to be involved in allisions than vessels certified for fishing. Vessels certified for coastal fishing had the highest probability of fires/explosions.

The analysis of operational states serve to reinforce the results on differences between waters. It is more likely that a grounding happens while the vessel is underway, and more likely that an allision happens in proximity of port. We can take note that allisions are much more likely on arrival of port than on departure, whereas the reverse is true for groundings. Fires are most likely to happen along quay.

11.3 Damage severity, injuries and fatalities

In terms of damage severity, the most consistent result was that it was associated with vessel length. The shorter the vessel, the higher the odds of an accident being severe, and this is particularly pronounced in allisions.

We were not able to explain a lot of variation in injuries. The most notable result was that high seas increases the risk of injuries in fires/explosions around 17 times from 4,7% to 80,3%. High speed craft have around five times higher probability of injuries than large fishing vessels. The most notable difference among regions was that vessels traveling in Sweden-Lindesnes and Trondheim-Tromsø have higher probabilities of injuries compared to Tromsø-Russia.

We could not explain a lot of the variation in fatalities. Most notably, groundings in short vessels increase probability of fatality by over 30 times compared to vessels longer than 24 m.

12 Conclusion: Risk influencing factors in maritime accidents.

In chapter 5, I defined a risk influencing factor as any factor that affects an undesired event. What factors affect the probabilities of accidents? We have found a number of factors that influence the relative probabilities of accidents. We cannot tell for certain whether these factors are true risk influencing factors, in that we do not know what the non-accidents look like. It could be that the differences in gross tonnages, for example, merely reflect differences in the total fleet. However, some differences between traits were not significant. Until the accident database has been compared to normal traffic, we can retain the hypothesis that the significant items represent risk influencing factors.

I will briefly summarize the potential risk influencing factors by type.

For the *vessel types*, there were significant differences between accidents, but only for some of the vessel types. The major difference between vessel types was that passenger vessels have much larger likelihoods of allisions.

For the *vessel qualities*, it is noteworthy that there is as much variation, or more, between gross tonnages and lengths of vessels as there is variation between vessel types. Put in other terms: The relative probabilities change more due to gross tonnage and length than due to vessel type.

For *geographical qualities*, there was much more variation between waters than between regions. Indeed, waters prove to be a highly influential risk influencing factor. Narrow coastal waters are a risk factor in groundings, whereas outer coastal are factors in collisions. Also, the risk of fires is considerable along quay.

For the *weather qualities*, visibility emerges as a notable factor in collisions. Apart from this, weather has a rather limited effect on accident risk.

An important takeaway from the regression analysis is that the common traits scenarios described in chapter 7 and 8 are indeed realistic scenarios. A typical fire scenario is thus a small fishing vessel in good weather travelling in outer coastal waters. A typical grounding scenario is a cargo or small fishing vessel travelling in narrow coastal waters in the dark. A typical collision scenario is a fishing or break bulk vessel travelling in good weather in outer coastal waters. A typical allision scenario is a passenger vessel travelling in good weather with somewhat stronger winds in narrow coastal waters.

To confirm these risk influencing factors, however, there is an urgent need to compare accident statistics against normal traffic data.

13 Literature

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14 Appendix: Descriptive statistics for regression analysis

The conditional probabilities in the regression analysis summate probabilities in rows. For reference, I have included descriptive statistics in this format here. Take note that this is a different format from the one used in the section on common traits, where traits are summated in columns.

14.1 Vessel qualities

Vessel Groups	Accident type					
	Fire/expl.	*Grounding*	*Collision*	*Allision*	*Total*	*N*
Fishing vessel	18,1%	61,7%	17,2%	3,0%	100,0%	2203
Cargo vessel	6,0%	70,2%	14,3%	9,5%	100,0%	2061
Passenger vessel	5,8%	50,3%	12,0%	31,9%	100,0%	1594
Total	**10,5%**	**61,6%**	**14,8%**	**13,2%**	**100,0%**	**5858**

Table 14.1.1: Distribution of accident types within vessel groups.

Vessel type	Accident type					
	Fire/expl.	*Grounding*	*Collision*	*Allision*	*Total*	*N*
Fishing <15m	23,2%	54,2%	20,5%	2,1%	100,0%	1054
Fishing >15m	13,3%	68,6%	14,2%	3,9%	100,0%	1149
Ferries	3,0%	46,3%	8,9%	41,8%	100,0%	902
Passenger/cruise	8,4%	56,0%	17,5%	18,1%	100,0%	382
High-speed	5,7%	47,5%	12,7%	34,2%	100,0%	158
Other passenger	15,8%	61,8%	16,4%	5,9%	100,0%	152
Work and service	10,3%	68,3%	11,9%	9,5%	100,0%	252
Offshore service	12,6%	45,3%	12,6%	29,5%	100,0%	95
Well boats	4,0%	84,2%	6,9%	5,0%	100,0%	101
Tanker	5,7%	68,1%	14,2%	12,1%	100,0%	141
Bulk	4,9%	68,4%	14,6%	12,1%	100,0%	206
Break bulk	5,1%	71,9%	15,4%	7,7%	100,0%	1266
Total	**10,5%**	**61,6%**	**14,8%**	**13,2%**	**100,0%**	**5858**

Table 14.1.2: Distribution of accident types within vessel types.

Nationalities by PMOU	Accident type					
	Fire/expl.	*Grounding*	*Collision*	*Allision*	*Total*	*N*
Norwegian ships	11,0%	61,2%	14,7%	13,1%	100,0%	5444
PMOU White List	4,2%	66,2%	15,8%	13,8%	100,0%	355
PMOU Grey, Black & Others	1,7%	64,4%	18,6%	15,3%	100,0%	59
Total	10,5%	61,6%	14,8%	13,2%	100,0%	5858

Table 14.1.3: Distribution of accident types within nationalities.

Individual nations belonging to each list are given below in alphabetical order.

White List: Antigua and Barbuda, Bahamas, Barbados, Belgium, Bermuda, UK, Cayman Islands, UK, China, Croatia, Cyprus, Denmark, Estonia, Finland, France, Germany, Gibraltar, UK, Greece, Hong Kong, China, Iran, Islamic Republic of, Isle of Man, UK, Italy, Japan, Kazakhstan, Korea, Republic of, Latvia, Liberia, Malta, Marshall Islands, Netherlands, Panama, Russian Federation, Saudi Arabia, Singapore, Sweden, Turkey, United Kingdom, United States of America.

Grey List: Albania, Algeria, Belize, Bulgaria, Curacao, Egypt, Georgia, India, Lebanon, Libya, Malaysia, Morocco, Portugal, Saint Kitts and Nevis, Syrian Arab Republic, Tunisia, Tuvalu, Ukraine, Vanuatu.

Black List: Cambodia, Comoros, Cook Islands, Dominica, Honduras, Moldova, Republic of, Saint Vincent and the Grenadines, Sierra Leone, Tanzania, United Republic of, Togo.

Vessel Register	**Accident type**					
	Fire/expl.	*Grounding*	*Collision*	*Allision*	*Total*	*N*
NOR ships	10,5%	61,9%	14,0%	13,6%	100,0%	5113
NIS ships	3,3%	65,7%	16,9%	14,0%	100,0%	242
Foreign ships	20,8%	66,7%	0,0%	12,5%	100,0%	24
Unregistered & unknown	13,4%	55,9%	22,1%	8,6%	100,0%	479
	10,5%	61,6%	14,8%	13,2%	100,0%	5858

Table 14.1.4: Distribution of accident types within vessel registers.

Class	**Accident type**					
	Fire/expl.	*Grounding*	*Collision*	*Allision*	*Total*	*N*
Class DNV	6,5%	66,6%	13,2%	13,7%	100,0%	1537
Class ABS/BV/GL/LR	4,4%	70,8%	16,2%	8,5%	100,0%	517
Class other, unknown, unregistered	12,9%	58,3%	15,2%	13,6%	100,0%	3804
Total	10,5%	61,6%	14,8%	13,2%	100,0%	5858

Table 14.1.5: Distribution of accident types within classification societies.

Cargo	**Accident type**					
	Fire/expl.	*Grounding*	*Collision*	*Allision*	*Total*	*N*
Ballast	15,4%	64,6%	14,5%	5,5%	100,0%	1179
Passengers	4,7%	48,6%	12,7%	34,0%	100,0%	1141
Fish and fish produce	10,1%	71,7%	15,6%	2,7%	100,0%	995
Dry/Bulk/Container	3,7%	73,6%	15,2%	7,5%	100,0%	561
Bulk (Ore, coal, grains etc)	4,5%	78,0%	11,8%	5,8%	100,0%	313
Other known cargo	5,7%	70,1%	8,0%	16,1%	100,0%	87
Oil and oil produce	3,3%	68,3%	13,3%	15,0%	100,0%	60
Chemicals and gas	10,0%	80,0%	0,0%	10,0%	100,0%	20
Empty	23,1%	53,6%	13,5%	9,9%	100,0%	364
Not registered/unknown	13,3%	53,4%	18,3%	15,0%	100,0%	1138
Total	10,5%	61,6%	14,8%	13,2%	100,0%	5858

Table 14.1.6: Distribution of accident types within cargo types.

Gross Tonnage	Accident type					
	Fire/expl.	*Grounding*	*Collision*	*Allision*	*Total*	*N*
Below 500 GT	12,8%	63,8%	15,9%	7,6%	100,0%	3817
Above 3000 GT	8,3%	48,6%	14,0%	29,2%	100,0%	387
Between 500 and 3000 GT	4,6%	59,7%	10,9%	24,8%	100,0%	1471
Unknown GT	14,8%	57,9%	25,1%	2,2%	100,0%	183
Total	10,5%	61,6%	14,8%	13,2%	100,0%	5858

Table 14.1.7: Distribution of accident types within gross tonnages.

Length	Accident type					
	Fire/expl.	*Grounding*	*Collision*	*Allision*	*Total*	*N*
Below 10.67 m	25,1%	49,0%	23,9%	2,0%	100,0%	704
Between 10.67 and 15 m	18,4%	64,1%	15,4%	2,1%	100,0%	473
Between 15- and 24 m	16,6%	60,4%	18,1%	4,9%	100,0%	791
Above 24 m	5,6%	64,0%	12,1%	18,3%	100,0%	3795
Unknown	7,4%	53,7%	24,2%	14,7%	100,0%	95
Total	10,5%	61,6%	14,8%	13,2%	100,0%	5858

Table 14.1.8: Distribution of accident types within vessel lengths.

Ship Age: Continuous

I include this histogram to detail the distribution of vessel age.

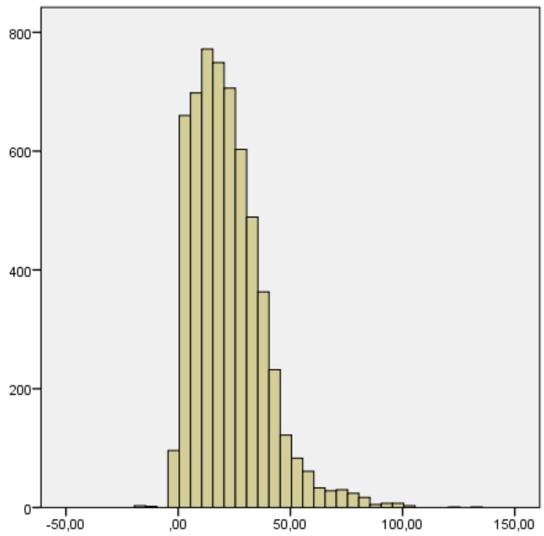


Figure 7.1.1: Vessel age in years.

Ship Age: In categories

Ship Age	Accident type					
	Fire/expl.	*Grounding*	*Collision*	*Allision*	*Total*	*N*
Ship Age 0-5	10,1%	58,7%	12,8%	18,4%	100,0%	744
Ship Age 6-15	10,0%	60,9%	16,2%	13,0%	100,0%	1436
Ship Age 16-25	9,0%	61,8%	16,8%	12,4%	100,0%	1419
Ship Age 25+	12,3%	63,4%	13,0%	11,3%	100,0%	2057
Ship Age Unknown	7,9%	56,4%	15,8%	19,8%	100,0%	202
Total	10,5%	61,6%	14,8%	13,2%	100,0%	5858

Table 14.1.9: Distribution of accident types within vessel age.

14.2 Geographical qualities

Regions	Accident type					
	Fire/expl.	*Grounding*	*Collision*	*Allision*	*Total*	*N*
Swedish border - Lindesnes	9,0%	54,6%	21,4%	15,1%	100,0%	524
Lindesnes - Bergen	8,7%	54,2%	17,5%	19,6%	100,0%	1120
Bergen - Trondheim	6,6%	65,6%	11,4%	16,4%	100,0%	1274
Trondheim - Tromsø	9,8%	68,9%	12,6%	8,6%	100,0%	1902
Tromsø - Russian border	20,8%	54,5%	17,5%	7,2%	100,0%	899
Svalbard/Jan Mayen/Bjørnøya	0,0%	87,8%	8,2%	4,1%	100,0%	49
Norwegian Continental Shelf/Arctics	6,3%	0,0%	25,0%	68,8%	100,0%	32
Other/Unknown regions	17,2%	58,6%	5,2%	19,0%	100,0%	58
Total	10,5%	61,6%	14,8%	13,2%	100,0%	5858

Table 14.2.1: Distribution of accident types within accident regions.

Waters	Accident type					
	Fire/expl.	*Grounding*	*Collision*	*Allision*	*Total*	*N*
Narrow coastal waters	4,0%	82,0%	9,6%	4,3%	100,0%	2568
In the harbour area	10,2%	39,5%	16,4%	33,8%	100,0%	1460
Outer coastal waters	16,0%	58,0%	23,7%	2,3%	100,0%	1357
Along the quay	48,6%	7,4%	9,7%	34,2%	100,0%	257
Oil field	3,3%	3,3%	23,3%	70,0%	100,0%	30
Separation area	0,0%	0,0%	100,0%	0,0%	100,0%	5
Other/unknown	9,9%	64,1%	11,0%	14,9%	100,0%	181
Total	10,5%	61,6%	14,8%	13,2%	100,0%	5858

Table 14.2.2: Distribution of accident types within accident waters.

14.3 Weather qualities.

Lighting conditions	Accident type					
	Fire/expl.	*Grounding*	*Collision*	*Allision*	*Total*	*N*
Light	11,9%	51,7%	19,8%	16,6%	100,0%	2479
Twilight	10,2%	59,5%	16,8%	13,4%	100,0%	440
Dark	6,7%	74,6%	10,4%	8,3%	100,0%	2344
Unreg./unknown	19,5%	52,9%	9,4%	18,2%	100,0%	595
	10,5%	61,6%	14,8%	13,2%	100,0%	5858

Table 14.3.1: Distribution of accident types within lighting conditions.

Sea State	Accident type					
	Fire/expl.	*Grounding*	*Collision*	*Allision*	*Total*	*N*
Calm	8,3%	62,4%	16,7%	12,5%	100,0%	3236
Slight/moderate	9,4%	70,7%	14,4%	5,6%	100,0%	737
High	3,8%	77,9%	9,2%	9,2%	100,0%	131
Unknown	15,5%	55,0%	11,7%	17,8%	100,0%	1754
Total	10,5%	61,6%	14,8%	13,2%	100,0%	5858

Table 14.3.2: Distribution of accident types within sea states.

Visibility	Accident type					
	Fire/expl.	*Grounding*	*Collision*	*Allision*	*Total*	*N*
Good (>5 nm)	9,5%	60,0%	16,0%	14,5%	100,0%	3419
Moderate (2.1.-5 nm)	6,1%	69,2%	12,2%	12,5%	100,0%	607
Poor (0.5-2 nm)	3,6%	80,5%	9,9%	6,0%	100,0%	333
None (>0.25 nm)	,4%	68,2%	26,7%	4,7%	100,0%	258
Tight fog, snowfall (<0.5 nm)	2,7%	76,4%	16,9%	4,0%	100,0%	225
Unknown	23,0%	51,1%	10,1%	15,7%	100,0%	1016
Total	10,5%	61,6%	14,8%	13,2%	100,0%	5858

Table 14.3.3: Distribution of accident types within visibility.

Wind force	Accident type					
	Fire/expl.	*Grounding*	*Collision*	*Allision*	*Total*	*N*
Weak	8,0%	61,1%	18,8%	12,1%	100,0%	1849
Moderate	8,8%	66,6%	15,4%	9,2%	100,0%	1203
Strong	3,7%	73,3%	6,7%	16,2%	100,0%	889
Unknown	17,1%	53,5%	14,2%	15,3%	100,0%	1917
Total	10,5%	61,6%	14,8%	13,2%	100,0%	5858

Table 14.3.4: Distribution of accident types within wind forces.

14.4 Time qualities

Year	Accident type					
	Fire/expl.	*Grounding*	*Collision*	*Allision*	*Total*	*N*
1981-1991	13,6%	61,4%	17,8%	7,3%	100,0%	2298
1992-2002	7,2%	65,2%	16,7%	10,8%	100,0%	1809
2003-2014	9,8%	58,1%	8,8%	23,4%	100,0%	1751
Total	10,5%	61,6%	14,8%	13,2%	100,0%	5858

Table 14.4.1: Distribution of accident types within years.

Seasons	Accident type					
	Fire/expl.	*Grounding*	*Collision*	*Allision*	*Total*	*N*
Jan-Mar	10,3%	63,2%	13,3%	13,2%	100,0%	1604
Apr-Jun	11,6%	56,1%	18,5%	13,8%	100,0%	1237
Jul-Sep	11,3%	58,7%	16,6%	13,4%	100,0%	1362
Oct-Dec	9,1%	66,5%	11,8%	12,6%	100,0%	1655
Total	10,5%	61,6%	14,8%	13,2%	100,0%	5858

Table 14.4.2: Distribution of accident types within seasons.

Time data:

Data for time have been approximated to the nearest hour, and then split into five categories. A large number of accidents in the database were timed to midnight. There is good reason to believe that this is due to the exact accident time being unknown. A histogram shows this very clearly graphically. I have therefore timed all accidents reported as happening at midnight as “unknown”.

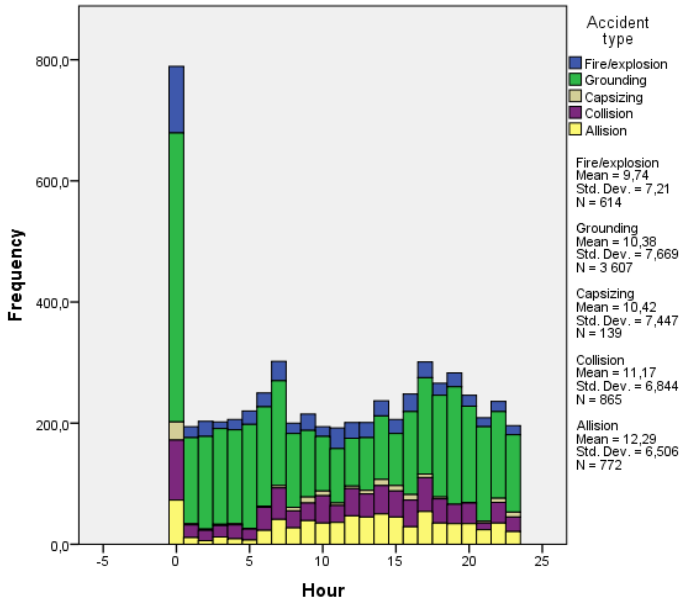


Figure 7.4.1: Original distribution of hours within accident types

Hours	**Accident type**					
	Fire/expl.	*Grounding*	*Collision*	*Allision*	*Total*	*N*
Time 01-06	9,2%	74,7%	10,8%	5,4%	100,0%	1264
TIme 07-12	12,0%	52,4%	17,9%	17,7%	100,0%	1268
Time 13-18	10,5%	52,4%	18,9%	18,2%	100,0%	1416
Time 19-23	7,6%	67,8%	11,7%	12,9%	100,0%	1151
Time Unknown	14,5%	62,8%	13,0%	9,6%	100,0%	759
Total	10,5%	61,6%	14,8%	13,2%	100,0%	5858

Table 14.4.3: Distribution of accident types within hours.

14.5 Other notable qualities

Certification	**Accident type**					
	Fire/expl.	*Grounding*	*Collision*	*Allision*		*N*
Enclosed waters	5,2%	52,0%	22,5%	20,2%	100,0%	173
Protected waters	3,6%	43,7%	8,3%	44,4%	100,0%	529
Inshore <5 n.m.	6,7%	59,5%	12,5%	21,3%	100,0%	343
Inshore <25 n.m.	10,2%	63,1%	13,1%	13,5%	100,0%	274
Minor coastal traffic	5,6%	73,0%	12,0%	9,4%	100,0%	551
Major coastal traffic	4,8%	73,1%	19,3%	2,8%	100,0%	145
Northern & Eastern Sea	4,5%	77,3%	13,5%	4,8%	100,0%	400
European traffic	4,8%	74,0%	8,7%	12,6%	100,0%	231
International & Overseas	14,0%	41,9%	27,9%	16,3%	100,0%	43
Unlimited traffic	6,9%	64,5%	14,3%	14,3%	100,0%	217
Fjord fishing	12,5%	53,1%	34,4%	0,0%	100,0%	32
Coastal fishing	20,1%	58,0%	19,3%	2,6%	100,0%	388
Bank fishing	13,8%	70,8%	12,0%	3,5%	100,0%	400
Sea fishing	9,3%	74,7%	12,7%	3,2%	100,0%	557
Others/unknown	17,1%	53,1%	19,6%	10,2%	100,0%	1452
Certificate B/C/D	8,1%	41,5%	1,6%	48,8%	100,0%	123
Total	10,5%	61,6%	14,8%	13,2%	100,0%	5858

Table 14.5.1: Distribution of accident types within certifications.

Operational stage	**Accident type**					
	Fire/expl.	*Grounding*	*Collision*	*Allision*	*Total*	*N*
Underway	6,1%	76,0%	15,4%	2,6%	100,0%	3597
On arrival port	1,6%	34,6%	8,1%	55,8%	100,0%	902
Along quay	66,0%	7,1%	14,6%	12,3%	100,0%	268
On departure port	4,2%	51,9%	24,6%	19,2%	100,0%	260
Fishing	36,8%	33,2%	30,1%	0,0%	100,0%	193
Other known	28,6%	32,9%	8,1%	30,4%	100,0%	161
Unknown/others	16,1%	61,2%	13,2%	9,4%	100,0%	477
Total	10,5%	61,6%	14,8%	13,2%	100,0%	5858

Table 14.5.2: Distribution of accident types within operational stages.

Damage severity	Accident type					
	Fire/expl.	*Grounding*	*Collision*	*Allision*	*Total*	*N*
No damage	4,4%	51,8%	11,4%	32,5%	100,0%	114
Less damage	7,6%	74,7%	5,7%	11,9%	100,0%	2963
Severe damage	13,0%	78,2%	4,0%	4,8%	100,0%	1108
Shipwreck, no sinking	55,8%	40,3%	3,9%	0,0%	100,0%	77
Total shipwreck	39,4%	48,7%	10,5%	1,4%	100,0%	429
Total	12,5%	72,1%	5,9%	9,6%	100,0%	4691

Table 14.5.3: Distribution of accident types within damage severity.

Injuries	Accident type					
	Fire/expl.	*Grounding*	*Collision*	*Allision*	*Total*	*N*
No	10,3%	62,8%	14,7%	12,3%	100,0%	5639
Yes	16,0%	31,1%	16,4%	36,5%	100,0%	219
Total	10,5%	61,6%	14,8%	13,2%	100,0%	5858

Table 14.5.4: Distribution of accident types within injuries.

Fatalities	Accident type					
	Fire/expl.	*Grounding*	*Collision*	*Allision*	*Total*	*N*
No	10,5%	61,7%	14,6%	13,3%	100,0%	5808
Yes	12,0%	50,0%	36,0%	2,0%	100,0%	50
Total	10,5%	61,6%	14,8%	13,2%	100,0%	5858

Table 14.5.5: Distribution of accident types within fatalities.

14.6 Appendix: Correspondence analysis of accidents and vessels.

Correspondence analysis is a descriptive/exploratory technique designed to analyse simple two-way and multi-way tables containing some measure of correspondence between the rows and columns. Rather than delve into the statistical theory behind this technique, I will illustrate it with a simple imaginary example, before applying it on the present data. The analysis is applied using the guidelines given by Fox (2014)

Imagine a situation where fires and explosion almost always happened on fishing vessels, gorundings almost always happened on passenger vessels, collisions only happened on cargo vessels, and allisions was rather evenly distributed among vessels. This could result in the constructed data given in the table below:

VESSEL	**ACCIDENT**				
	Fire	*Grounding*	*Collision*	*Allision*	*Total*
Fish	8	1	1	4	14
Passenger	1	8	1	3	13
Cargo	1	1	8	3	13
Total	10	10	10	10	40

Table 13.1.1: Constructed example crosstab for correspondence analysis.

This particular example would explain 74% of the variation in accidents due to the variation in vessel types. If allisions had been more closely associated with one vessel type, we would have been able to explain almost all the variation.

Now, I skip all the technical explanation, and present what is called a symmetrical normalization graph of the correspondence analysis. The result is given below. In figure 13.1.1.

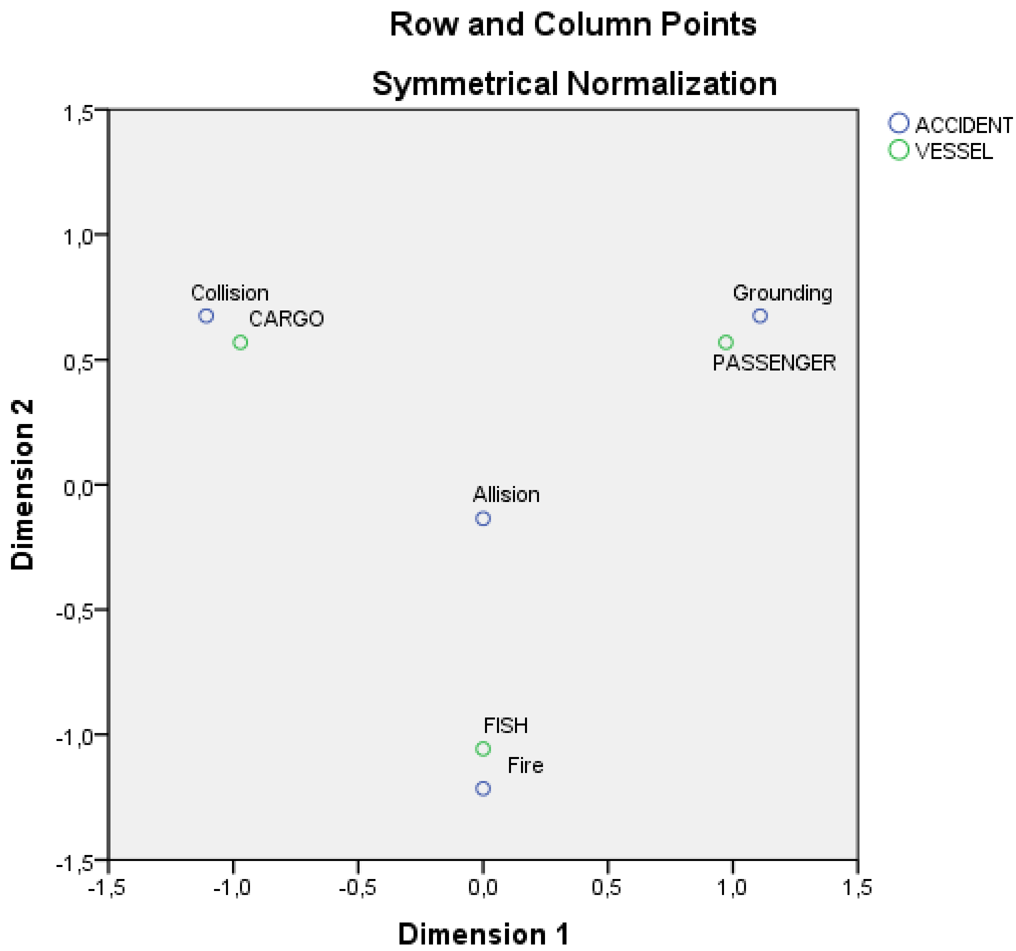


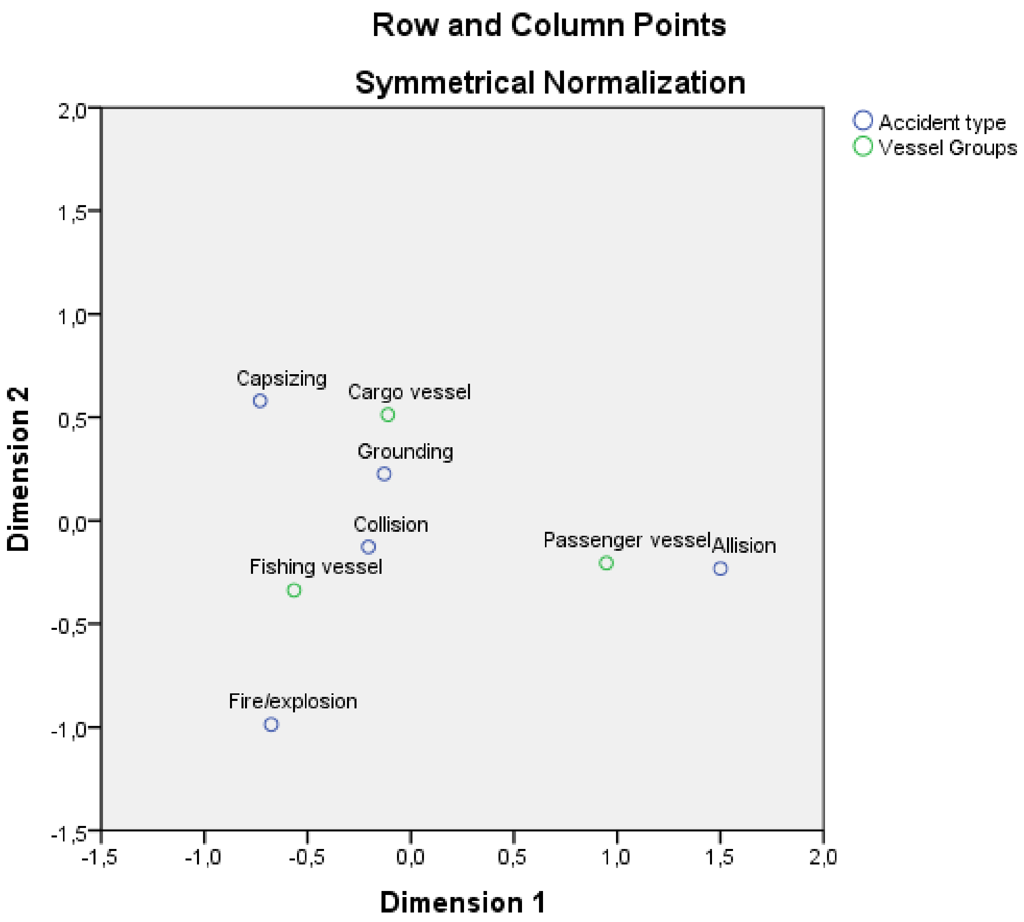
Figure 13.1.1: Symmetrical normalization of constructed accidents and vessel groups.

The graph shows quite clearly what we already knew: collisions correspond with cargo vessels, groundings with passenger vessels, and fires with fishing vessels. Allisions do not correspond with any vessel group, although the distance between allisions and fishing vessels is slightly shorter than to the other two vessel types, as there is one more case of allisions in fishing vessels. There is also very little correspondence between accident types, which suggests that they are qualitatively very different. Fox (2014) points out that care must be taken when interpreting the plot, as distances between columns and rows are not defined.

I will now apply symmetrical normalization to the real accident data. Crosstabulations are available in the descriptive data section.

Symmetrical normalization of accidents and vessel types.

First, here is a plot for accidents and the general vessel groups:



The correspondence analysis shows that the variation in vessel groups explains 15.5% of the variation in accidents. We can graphically see clearly that allisions correspond with passenger vessels. However, the other correspondences are not quite as clear. Fishing vessels appear to correspond both to fires/explosions and collisions, whereas cargo vessels appear to correspond to capsizings, groundings and to a lesser degree collisions.

Further tests of symmetrical normalization did not reveal any distinct patterns that were considered useful in the further analysis. It was decided that correspondence analysis would not be able to capture the complexity of the analysis, and it was subsequently dropped from further use. The research group decided that the logistic and multinomic techniques were more suitable for the task.

14.7 Appendix: NMA vessel codes.

Sjøfartsdirektoratet
Norwegian Maritime Authority

Fartøytypekoder

00 Ukjent

0 Tankskip
0A Tankskip: Septik
0B Tankskip: Animalsk/ Vegetabilsk olje
0C Tankskip: LNG
0D Tankskip: Ammoniak
0E Tankskip: Klor
0F Tankskip: Tanklekter
0G Tankskip: Flytende kjemisk/gass
0H Tankskip: - ubestemt
0I Tankskip: - ubestemt
0K Tankskip: - ubestemt

1 Tankskip
1A Tankskip: Septik
1B Tankskip: Olje
1C Tankskip: LPG
1D Tankskip: Kjemikalier
1E Tankskip: Asfalt
1F Tankskip: Vin/ Vann/Konsentrater
1F1 Tankskip for vin
1F2 Tankskip for vann
1G Tankskip: Fosfor
1H Tankskip: Svovel
1I Tankskip: - ubestemt
1K Tankskip: - ubestemt

2 Kombinertskip
2A Kombinertskip: Stykkgods/Bulk/ Container
2B Kombinertskip: Tank/Malm (O/O)
2C Kombinertskip: Tank/Bulk (O/B)
2D Kombinertskip: Tank/Bulk/Malm (OBO)
2E Kombinertskip: Tank/Stykkgods
2F Kombinertskip: Kjemikalie/Bulk
2G Kombinertskip: Tank/Malm/Slurry
2H Kombinertskip: Kjemikalie/Olje
2I Kombinertskip: Tank/Bulk/ Tunglast (Flo-Flo)
2K Kombinertskip: Kjemikalie/Asfalt

3 Bulkskip
3A Bulkskip: - ubestemt
3B Bulkskip: Vanlig bulk
3C Bulkskip: Trefordelings-produkter
3D Bulkskip: Bil
3E Bulkskip: Malm
3F Bulkskip: Sement
3G Bulkskip: Sand
3H Brønnfartøy
3I Bulkskip: - ubestemt
3K Bulkskip: - ubestemt

4 Stykkgodsskip
4A Stykkgodsskip:- ubestemt
4B Stykkgodsskip: Vanlig stykkgods
4C Stykkgodsskip: Fryse- og kjøle
4D Stykkgodsskip: Palle
4E Stykkgodsskip: Roll-on/Roll-off
4F Stykkgodsskip: Container
4F1 Containerskip
4F2 Semicontainerskip
4G Stykkgodsskip: Lekterskip (LASH)
4H Stykkgodsskip: - ubestemt
4I Stykkgodsskip: Spesialbygd bilskip
4K Stykkgodsskip: - ubestemt

5 Passasjerskip/ferger
5A Passasjerskip/ferger: Statseide passasjer- /patrulje
5B Passasjerskip/ferger: Passasjer/Cruise
5B1 Passasjerskip
5B2 Cruiseskip
5C Passasjerskip/ferger: Bil
5C1 Bilferge
5C2 Ro/Ro-passasjerferge
5D Passasjerskip/ferger: Jernbane
5E Passasjerskip/ferger: Hotell/Losji/Hospital/ Misjon/Utstilling
5E1 Hotell-/Losji- /Restaurantskip
5E2 Misjonsskip
5E3 Utstillings- /Demonstrasjonsskip
5E4 Hospitalskip
5F Passasjerskip/ferger: Komb. passasjer/stykkgods
5G Passasjerskip/ferger: - ubestemt
5H Passasjerskip/ferger: Luftpute
5I Passasjerskip/ferger: Katamaran/Trimaran/ Hydrofoil
5I1 Katamaran
5I2 Hydrofoil
5I3 Trimaran
5I4 Katamaran: Passasjer
5I5 Katamaran: Komb. passasjer/stykkgods
5I6 Katamran: Last
5K Passasjerskip/ferger: Andre små passasjer/ ferge/lege/skyss
5K1 Fartøy med begrenset pasasjerbefordring
5K2 Lege-/Skyssfartøy

6 Fisk/fangstfartøy
6A Fiske/fangstfartøy: - ubestemt
6B Fiske/fangstfartøy: Fabrikk/Hvalkokeri
6B1 Fabrikkskip
6B2 Hvalkokeri
6C Fiske/fangstfartøy: Selfanger/Hvalfanger
6C1 Selfanger
6C2 Hvalfanger
6D Fiske/fangstfartøy: Fiske
6E Fiske/fangstfartøy: Tråler
6F Fiske/fangstfartøy: Hekk-/Fabrikktråler
6G Fiske/fangstfartøy: Skjelltråler
6H Fiske/fangstfartøy: Taretråler
6I Fiske/fangstfartøy: - ubestemt
6K Fiske/fangst: fartøy - ubestemt

7 Spesialskip
7A Spesialskip: Slepe/Berging
7A1 Slepebåt
7A2 Bergingsfartøy
7B Spesialskip: Isbryter
7C Spesialskip: Forskning/Værvarsling/ Oppsyn/Seismisk
7C1 Seismisk
7C2 Oppsynsskip
7C3 Forskningsfartøy
7C4 Patruljefartøy
7C5 Hjelpeskip for seismisk fartøy
7D Spesialskip: Forsynings-/Hjelpeskip for plattformer
7D1 Forsyningsskip for plattformer
7D2 Hjelpeskip/ Beredskapsfartøy for plattformer
7E Spesialskip: Fyr og forsyning
7E1 Fyrskip
7E2 Forsyningsskip for Fyrvesenet
7E3 Arbeidsbåt for Fyrvesenet
7E4 Inspeksjonsfartøy
7F Spesialskip: Los/ Redning/ Sjøbrannsprøyte
7F1 Los
7F2 Redningsfartøy
7F3 Sjøbrannsprøyte
7G Spesialskip: Mudder-apparat /Sandpumpe
7G1 Mudderapparat
7G2 Sandpumpe
7H Spesialskip: Kranfartøy/Flytekran
7H1 Kranfartøy
7H2 Flytekran
7I Spesialskip: Verksted
7K Spesialskip: Andre spesial/Sandblåser/ Dykker
7K1 Dykkerfartøy
7K2 Sandblåser
7K3 Sand-/steindumper

8 Spesialskip
8A Spesialskip: Ekspedisjonsfartøy
8B Spesialskip: Kabel
8C Spesialskip: Tankrengjøring
8D Spesialskip: Lager
8E Ikke benyttet
8F Spesialskip: Opplæring
8F1 Skoleskip
8F2 Opplæringsfartøy
8G Spesialskip: Bore
8H Ikke benyttet
8I Spesialskip: Oljevern
8K Spesialskip: Mindre arbeidsbåt
8K1 Foringsbåt

9 Diverse
9A Diverse: - ubestemt
9B Diverse: Undervannsfartøy
9C Diverse: Fritidsfartøy
9C1 Husbåt/-lekter
9D Diverse: Livbåt
9E Diverse: Lekter/Pølsetanker
9E1 Lekter
9E2 Pølsetanker
9F Diverse: Flytedokk
9G Diverse: Flyttbare innretninger
9G1 Boreinnretning inkl. boreskip
9G2 Boliginnretning
9G3 Konstruksjons- og serviceinnretning
9G4 Flytende Produksjonsinnretning
9G5 Rørleggingsfartøy
9G6 Del til fast produksjonsinnretning
9H Diverse: Flytebro/Flytebrygge/ Pontong/Foringslekter
9H1 Flytebro
9H2 Flytebrygge
9H3 Pontong
9H4 Foringslekter
9H5 Oppdrettsanlegg
9I Diverse: - ubestemt
9K Diverse: Andre flytende konstruksjoner

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Figure 13.2.1: NMA vessel codes (NMA 2002)

14.8 Appendix: Cargo vessel types with translations.

14.8.1 Work and service vessels

Norwegian	English
7A: Slepe/Berging	Tugboat/Salvage vessel
7A1: Slepebåt	Tugboat
7B: Isbryter	Icebreaker
7C: Forskning/Værvarsling/Oppsyn/Seismisk	Research/meteorological/supervision/seismic
7C1: Seismisk	Seismic
7C2: Oppsynsskip	Supervision vessel
7C3: Forskningsfartøy	Research vessel
7C4: Patruljefartøy	Patrol vessel
7C5: Hjelpeskip for seismisk fartøy	Assistance vessel for seismic vessel.
7E: Fyr og forsyning	Lighthouse/supply
7E3: Arbeidsbåt for Fyrvesenet	Work vessel for Lighthouse Authority
7E4: Inspeksjonsfartøy	Inspection vessel
7F: Los/Redning/Sjøbrannsprøyte	Pilot/Salvage/Fire enginge
7F1: Los	Pilot vessel
7F2: Redningsfartøy	Salvage vessel
7F3: Sjøbrannsprøyte	Fire engine
7G: Mudderapparat/Sandpumpe	Dredger/Sand pump
7H: Kranfartøy/Flytekran	Crane vessel/Floating crane
7H1: Kranfartøy	Crane vessel
7H2: Flytekran	Floating crane
7K: Andre spesial/Sandblåser/Dykker	Other special/sandblaster/diving vessel
7K3: Sand-/steindumper	Sand/rock dumper
8A: Ekspedisjonsfartøy	Expedition vessel
8B: Kabel	Cable vessel
8F: Opplæring	Training vessel
8F2: Opplæringsfartøy	Training vessel
8G: Bore	Drilling vessel
8I: Oljevern	Petroleum security
8K: Mindre arbeidsbåt	Small work vessel
8K1: Foringsbåt	-
9A: Fartøy som fører 12 eller færre passasjerer	Vessel carrying 12 or fewer passengers
9B: Undervannsfartøy	Under water vessel
9E: Lekter/Pølsetanker	Barge/?
9E1: Lekter	Barge
9F: Flytedokk	Floating dock
9I: Diverse --> ubestemt	Various – indeterminate
9K: Andre flytende konstruksjoner	Other floating constructions

14.8.2 Offshore service vessels

Norwegian	English
7D: Forsynings/hjelpeskip for plattformer	Offshore supply vessel
7D1: Forsyningsskip for plattformer	Supply vessels
7D2: Hjelpeskip/Beredskapsfartøy for plattformer	Platform assistance/readiness

14.8.3 Wellboats

Norwegian	English
3H: Brønnfartøy	Well boats

14.8.4 Cargo: tank vessels

Norwegian	English
0A: ---> ubestemt	Indeterminate tank vessel
0B: Animalsk/vegetabilsk olje	Animal/vegetable oil
0C: LNG	LNG
0E: Klor	Chlorine
0F: Tanklekter	Tank barge
0G: Flytende kjemisk/gass	Liquid chemical gas
0H: Tankskip --> ubestemt	Indeterminate tanker
1B: Olje	Oil tanker
1C: LPG	LPG
1D: Kjemikalier	Chemicals
1E: Asfalt	Asphalt
1F: Vin/Vann/Konsentrater	Wine/water/concentrates
1F2: Tankskip for vann	Water tanker
1I: Tankskip --> ubestemt	Indeterminate tanker
1K: Tankskip --> ubestemt	Indeterminate tanker

14.8.5 Cargo: Bulk vessels

Norwegian	English
2A: Stykkgods/Bulk/Container	Break bulk/bulk/container
2B: Tank/Malm (O/O)	Tank/Ore
2C: Tank/Bulk (O/B)	Tank/Bulk
2D: Tank/Bulk/Malm (OBO)	Tank/Bulk/Ore
2F: Kjemikalie/Bulk	Chemicals/Bulk
2H: Kjemikalie/Olje	Chemicals/Oil
2K: Kjemikalie/Asfalt	Chemicals/Asphalt
3A: Bulkskip --> ubestemt	Indeterminate bulk
3B: Vanlig bulk	Regular bulk
3C: Treforedlingsprodukter	Woodwork vessel
3D: Bil	Car
3E: Malm	Ore
3F: Sement	Cement
3G: Sand	Sand
3I: Bulkskip --> ubestemt	Indeterminate bulk
3K: Bulkskip --> ubestemt	Indeterminate bulk

14.8.6 Cargo: Goods vessels (godsbåter)

Norwegian	English
4: Stykkgodsskip	Break bulk
4A: Stykkgodsskip --> ubestemt	Indeterminate break bulk
4B. Vanlig stykkgods	Regular break bulk
4C: Fryse- og kjøle	Freezing/cooling
4D: Palle	Pall
4E: Roll-on/Roll-off	Roll-on/Roll-off
4F: Container	Container
4F1: Containerskip	Container vessel
4F2: Semicontainerskip	Semi container vessel
4H: Stykkgodsskip --> ubestemt	Indeterminate break bulk
4I: Spesialbygd bilskip	Special car transport vessel
4K: Stykkgodsskip --> ubestemt	Indeterminate break bulk

14.9 Appendix: Map of Norwegian waters

Figure 13.4.1: Map of Norwegian territorial waters (Kartverket 2014).

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