# 4 CASUALTY RATES

## 4.1 The purpose of the assessment of the casualty rates in SAMSON

Although the description in this chapter is based on data available in 2004, the process has since been repeated every few years with recent data.
The casualty rates in SAMSON are used to assess the risk level based on the maritime traffic and a description of the environment in terms of traffic measure (like VSS and VTS), water depths, coastlines, platforms and other objects. SAMSON makes it possible to predict the casualty level in areas where not enough casualties have been occurred in the past to relate traffic with historical casualty data. SAMSON can also be used in complete new areas with potential new objects, like for example a wind farm, in order to predict the risk level.
The casualty rates used in SAMSON have to be related from time to time to actual casualty databases.

This Chapter describes the analysis of the worldwide casualty database from 1990-2002 in order to extract trends that can be used to keep the casualty rates in SAMSON up to date. The analysis was performed for the determination of the casualty rates for the database of 2000. After the implementation of the traffic database of 2004 the casualty rates were changed to the level of 2004.

## 4.2 Approach

### 4.2.1 Introduction

The assessment of the casualty rates will be performed in a number of steps. The Marin report OV073, 1995 (in Dutch) gives a detailed description of the accident analysis. The relation with weather conditions and the completeness of the databases was also analysed. In the present analysis the changes in the casualty rates through the years is analysed. This is possible by the large amount of casualty data that can be analysed. The trends found will be applied to the casualty rates of SAMSON.
The data sources used in 1995 and for the analysis of this report are mentioned in 4.2.2.
The approach is further described in 4.2.3.

### 4.2.2 Sources and databases

Currently the casualty rates in SAMSON are based on the 1995 study, in which different casualty databases were analysed, namely:

- The Lloyd's casualty database of 1978-1991 in MARSDEN-grid 216, meaning the area of the North Sea within 50º to 60º NB and 0º to 10º EL.;
- The DVK/AVV casualty database 1978-1991;
- The incident and action database of Directorate North Sea
- The incidents collected by the Coast Guard;

Within this analysis the same main sources will be used. However, the Lloyd's casualty database, as mentioned under the first bullet, is now achieved from Lloyd's Register-Fairplay Limited (LRF). The database, further called LRF-database, contains 17300 casualty records. Each record describes one ship involved in a casualty (in the terminology of LRF) somewhere in the world. Thus in case of **a collision, the LRF-database contains (at least) two records with the ships involved in the collision**. If only one ship exists, this means that the other ship was unknown or did not meet the requirements (for example too small) to be taken into the LRF-database.

The availability of the worldwide casualty database gives the opportunity to investigate some new phenomena and to assess relations with more accuracy. This will be done in chapter 4.3.

The data behind the other dots are collected by Rijkswaterstaat and put into the ONOVIS-database (ONgevallen en OVertredingen Informatie Systeem). This database contains only the casualties that occurred on the Dutch inland waterways and the Dutch part of the North Sea. By far the most casualties of this database concern the inland waterways, thus the part not covered by the SAMSON-model. Only the casualties that took place at sea are of interest for the SAMSON-model.

It is clear that the contribution of the ONOVIS-database for the casualties at sea that are relevant for SAMSON, is very limited. The ONOVIS-database cannot be used for the first analysis of the LRF-database in order to keep the LRF-database pure.

#### 4.2.3 Approach

The LRF-database has been delivered by LRF in February 2003 and contained all casualties that have been occurred since 1990. Some casualties from 2002 or some data fields are not filled in yet because sometimes this data arrives at LRF months after the casualty has been occurred. However, analysing 2002 and comparing numbers on a monthly base for 2002 and other years, it can be concluded that 2002 can be considered as being complete in the analysis.

The analysis is done in steps. The first step was to get an idea of the content of the database, thus what type of casualties have been occurred, in which years and where. In the next step the trends in the number of casualties through the years has been analysed. Finally the extracted trends are used to assess the present casualty rates in SAMSON.

A general remark is that nothing is known about the coverage of the LRF-database. LRF says that all casualties are included that have been published in the public domain. However, the public domain is not the same everywhere, which makes it difficult to declare trends found as general. A second problem is that the traffic volume and the traffic composition changes through the years, which have also their effect on the probability of different casualties.
The approach followed is, to extract the relations for the LRF-database and implement these relations where possible in SAMSON.

The database covers all world seas and the estuary and inland seas. The field MARSDEN grid contains the number of the 10 degrees square in which the first event of the casualty has been occurred. All casualties on the North Sea between 50º to 60º NB and 0º to 10º EL have a MARSDEN grid number 216, thus can be extracted from the complete database by this item. **In this report North Sea means the area of MARSDEN grid number 216.**
The worldwide results are compared with the North Sea results. Because the worldwide results are based on more casualties, the worldwide database is a better base for extracting relations. The results for the North Sea are used to see if the relation for the North Sea agrees with the derived relation based on the worldwide database.

## 4.3 Analysis of the worldwide casualties

The taxonomy of LRF has been used during the analysis of the casualties. In fact there is no choice. Annex A contains the names of all fields and a description of these fields that are present in the extract of the LRF-database.

### 4.3.1 Casualties divided over casualty types, years and severity

The LRF database contains all type of casualties worldwide divided over the years and casualty types and whether the casualty was a serious (S) or non-serious (N) one. The database of LRF is fed by what is found in the public domain and it is clear that ship owners, authorities or ports are not proud on some casualties that occur in their area and are not always willing to publish them. Especially the completeness of non-serious casualties is low.
The data generally show a decrease of the number of casualties through the years. However, the year 2002 shows on the North Sea but also worldwide a strong increase in the number of casualties and there is no clear explanation for this increase. Is the collecting of data strongly improved in 2002 or is it true that the casualty rate increases due to any reason? The number of casualties in the next years will give this answer.

The casualty types “War loss”, “Missing”, “Miscellaneous” and (blank) are not considered anymore, because their share can be neglected.

### 4.3.2 Casualties divided over casualty type and environmental location

The casualty records contain also an indication where they occurred, namely at (open) sea, in restricted water or in ports. This is coded in the LRF-database with the environmental location. The percentage at sea for each casualty except Fire/ Explosion is on the North Sea lower than the percentages summarised over all locations. This means that in the North Sea relatively more casualties happen than in the other areas (thus not at sea), which is also due to the relatively large number of ports.
There is a large difference in the severity of the casualties depending on where they occur. For example 25% of the collisions in a port are serious while this percentage is 43% for a collision at sea. The same differences can be found for Contacts and Hull/Machinery. This phenomenon was expected but this means that one has to be careful in drawing conclusions.

### 4.3.3 Casualties through the years

#### 4.3.3.1 Worldwide

The casualty rate varies with the ship type and the ship size. For this reason the SAMSON ship type has been determined and added to each record of the LRF database. The world-wide trends in the number of casualties are thus analysed for each type and size class of ships.

The cargo carrying ships have been summarised separately, because these ships can be considered as the most stable part of the LRF-database. The number and size of passenger ships increase strongly over the years, especially the use of fast ferries. This means that the casualty rate of 2002 cannot be compared with 1990 without considering the change in the ferry movements and the fleet. These movements are not available on a worldwide base. The remaining ship types miscellaneous, supply and fishing is also very area dependent, thus can disturb the general trends.

It appears that there is a decrease over the years. The decrease is very strong for the OBO, but also relatively strong for oil and chemical tankers, which can be considered as the result of international measures to improve the safety especially for this ship type.
The number of casualties with passenger ships increase, but it is difficult to conclude changes in casualty rates for this ship type, because then you need also the number of ferries worldwide, which probably grows very fast.

The changes through the years become more clear when the numbers are presented relative to the average value - see Figure 4-1. For tankers the factor 2.31 in 1990 was reduced to 0.42 in 2002, which means between 5 to 6 times lesser casualties, thus a large improvement in 12 years. However, the improvement cannot be assessed purely on the casualty database. For example if the number of tanker movements also should have been decreased with a factor 5 to 6, then the casualty sensitivity should have been unchanged. The analysis of the relation between the number of casualties and the number of movements cannot be done worldwide because the worldwide movements are not available. In this chapter the analysis is purely done based on the number of casualties. In the next chapter the relation casualty- movements is done for the North Sea based on the available information of the traffic on the North Sea.

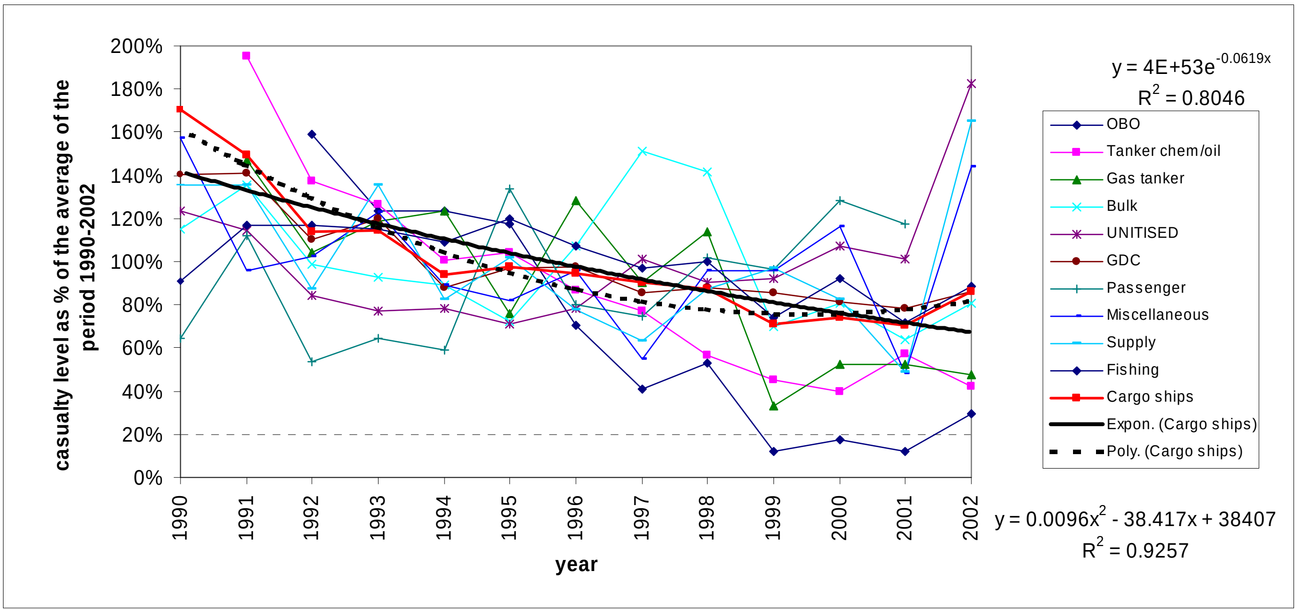


**Figure 4-1 Number of worldwide casualties at sea as % of the average value in the period 1990-2002**

Figure 4-1 presents the factors as percentages of the average over all years. The red line is the line representing the total of the cargo carrying ships. This line can be considered as the general trend. Two regression lines are determined from these general trend, one exponential and one quadratic polynomial.
The exponential equation is based on constant yearly change, which gives a good fit. The yearly change factor is exp(-0.069)= 0.933, thus each year 6.7% less casualties then the year before.
The fit of the quadratic polynomial is better. The number of casualties decreased steeper from 1990-1996, reached the lowest level in 2000 and is slightly increasing since 2000. The level in 2002 is nearly equal to that of 1996, but now the level is increasing which is less comfortable than a decreasing level in 1996. It is possible that the present ICT world has made the data of casualties better accessible, which means that the present increase of the number of casualties is due to a better coverage of what has been happened, and not due to a higher casualty sensitivity.
In any case one has to be eager to this phenomenon in the coming years. Based on Figure 4-1 (but not on Figure 4-2) the best approach seems to be to keep the casualty rates at a more constant level from 1996.

#### 4.3.3.2 North Sea

The same analysis as for the worldwide data is done for the North Sea data. Figure 4-2 presents the factors as percentages. The red line is the line representing the total of the cargo carrying ships. This line can be considered as the general trend. Two regression lines are determined from this line, one exponential and one quadratic polynomial.

The exponential equation is based on constant yearly change which is and the quadratic polynomial gives a very good fit. The yearly change factor is *exp*(-0.0585)=0.943 thus each year 5.7% less casualties then the year before. This factor is a little less than the factor worldwide. The quadratic polynomial runs nearly equal to the exponential line. In any case there is no indication here that the number of casualties is increasing since 2000. The polynomial gives even a stronger decrease in 2002 than the exponential one. This helps to conclude that the increase of the worldwide number of casualties is due to an improved data collection especially from areas further away from London and not due to a higher casualty sensitivity.

The $R^2$ value as indication for the goodness of the regression fit is much lower for the North Sea than in the worldwide analysis. The main reason is that the number of casualties becomes too small, which causes relatively large fluctuations.

It makes clear how fast the number of data comes below the level that is required to make firm conclusions.

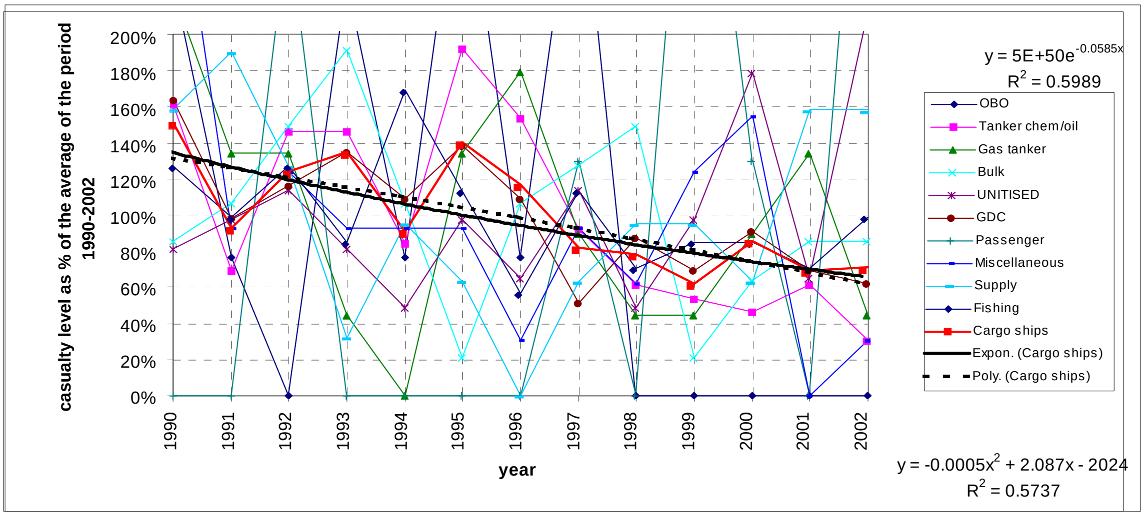


**Figure 4-2 Casualties at sea in the North Sea as % of the average value in the period 1990-2002**

### 4.3.4 General trend of the number of casualties at sea in the period 1990-2002

The previous analysis in 4.3.3 shows that there is a decreasing trend in the number of casualties per year at sea, worldwide and in the North Sea. In the North Sea the decreasing trend is also observable for the last years, while the trend worldwide shows a more or less constant level since 1997. It seems reasonable to assume that the decreasing trend is realistic and that the constant level worldwide is due to a continuously improvement of the coverage of the database in the areas further away from the collecting office in London.
The number of casualties in the coming years have to be followed in order to agree or disagree with this statement.

All casualties were used for the analysis in 4.3.3, but only the casualties at sea are representative for the SAMSON-model, because only what happens at sea is modelled in SAMSON. Therefore this group is analysed in more detail. Further the analysis is limited to the cargo carrying ships, because the collecting of the casualties of the other ships (passenger, miscellaneous, fishing, supply) is less accurate.

For each type of casualty the “yearly factor” during the period 1990-2002 has been determined based on regression with an exponential function, a linear function and a quadratic polynomial. The exponential function has been used to determine the constant yearly factor. The other regressions have been used as control mechanism to see if the factor found seems reasonable or not.
The exponential regression means that:

**the expected number of casualties in year i = a times (the yearly factor)$^{(i-1996)}$**

The value **a** and the **yearly factor** are calculated from the collected casualties. The value of **a** corresponds with the number of casualties in 1996.

As the quadratic regressions show a more constant casualty level since 1996, the exponential regression has also been performed for the period 1996-2002. This regression is only done for the total group and not for serious and non-serious separately, because the numbers become too low for this division. Table 4-8 contains the yearly factors.
Comparing the results of the period 1996-2002 with the total period 1990-2002, it can be concluded that the yearly factors of the two periods differ not too much. The quadratic curve with a more constant casualty level during the last years is more due to the type of regression analysis over a larger period than due to the behaviour in reality.

But there are some differences that has to be clarified:

- The yearly factor on the North Sea for collision CN is 1.019 for the whole period 1990-2002 and 1.054 for the period 1996-2002. But these factors are based on a small number of casualties in the period 1990-2002 and even less casualties in the period 1996- 2002. In fact these number of casualties are too few for the conclusion that the probability to be involved in a collision increases on the North Sea in the last period. The stochastic behaviour of the casualties can easily be the reason of the apparently increasing number of casualties.

  The worldwide trend (based on a relatively large number of collisions) gives a decreasing casualty rate for collision in both periods.
- The yearly factor for the Wrecked/Stranded casualty shows strange factors for the North Sea. The number of non-serious WS-casualties increases

considerably while the number of serious WS-casualties decreases considerably on the North Sea. The total number of WS-casualties decreases a little. The main reason is that the number of casualties on which the factors are based is very low.

**Table 4-8 Yearly factors for the number of casualties per year**

| Casualty | | Worldwide at sea | | | North Sea at sea | | |
|---|---|---|---|---|---|---|---|
| Casualty type | Severity Indicator (N=Non serious S=Serious) | Number of casualties 1990-2002 | Yearly factor 1990-2002 | Yearly factor 1996-2002 | Number of casualties 1990-2002 | Yearly factor 1990-2002 | Yearly factor 1996-2002 |
| CN | N | | 0.929 | | | 0.968 | |
| | S | | 0.991 | | | 1.084 | |
| CN Total | | | 0.956 | 0.934 | | 1.019 | 1.054 |
| CT | N | | | | | | |
| | S | | 0.858 | | | | |
| CT Total | | | 0.846 | 0.866 | | 0.832 | 0.801 |
| FD | N | | | | | | |
| | S | | 0.957 | | | 0.740 | |
| FD Total | | | 0.957 | 0.918 | | 0.740 | 0.925 |
| FX | N | | 0.942 | | | 0.896 | |
| | S | | 0.958 | | | 0.935 | |
| FX Total | | | 0.960 | 0.965 | | 0.952 | 0.929 |
| HM | N | | 0.803 | | | 0.840 | |
| | S | | 0.939 | | | 0.925 | |
| HM Total | | | 0.906 | 0.945 | | 0.913 | 0.862 |
| WS | N | | 0.964 | | | 1.208 | |
| | S | | 0.955 | | | 0.744 | |
| WS Total | | | 0.967 | 1.033 | | 0.995 | 1.126 |
| All | | | 0.883 | | | 0.930 | |
| | | | 0.951 | | | 0.939 | |
| All Total | | | 0.933 | 0.955 | | 0.943 | 0.940 |

The increase of the casualty types Collisions and Wrecked/Stranded on the North Sea are probably the result of the small number of casualties. A casualty can be considered as a realisation of a probabilistic value, which means that there are yearly deviations, even when the probability function does not change.

#### 4.3.5 Analysis of the Hull/Machinery casualty

The Hull/Machinery casualty type is more an incident than a casualty. However, the incident can lead to disastrous consequences. The Prestige is an example of such an incident. The Hull failure finally lead to the calamity of the Prestige. The effect of a Machinery failure is that the ship becomes disabled and starts drifting. In case the anchor cannot be presented, the ship drifts until the failure has been repaired, tug assistance has been arrived and the ship is under control, or the ship grounds. During the drifting phase the ship can strike a platform, offshore wind mill or other object. Thus drifting on its own is not a very serious incident, but it can lead to a real casualty.

Based on the description of the casualties a new subdivision is made. The subdivision of the Hull/Machinery casualty contains the following types:

- Anchor, a failure or loose of anchor;
- Hull, damage to hull often due to heavy weather conditions;
- Machinery, failure of main engine;
- 2Machinery, a failure in auxiliary machinery or electrical system (second order machinery failure);
- Navigation, failure of navigational instruments;
- Propeller, damaged or fouled propeller;
- Rudder, failure of rudder;
- Steering, failure of steering gear;
- X, other minor failures.

Figure 4-3 represents a survey of the different types of failures which have occurred worldwide through the years. Over the entire 1990-2002 period, worldwide, 19% of the HM failures deal with a Hull failure. Nearly 63% of all failures are a clear machinery failure. The other failures, especially 2Machinery, Propeller, Rudder and Steering (15% summarised) can be considered as a machinery failure.. All types show a decreasing number through the years. The figure contains the exponential trend lines for the two most frequent subdivisions “Hull” and “Machinery”. Based on the e-coefficient it can be concluded that both types of casualties decrease with nearly the same factor per year. This makes the casualty analysis easier because for most analyses the Hull/Machinery casualty can be considered as one group thus not subdivided.

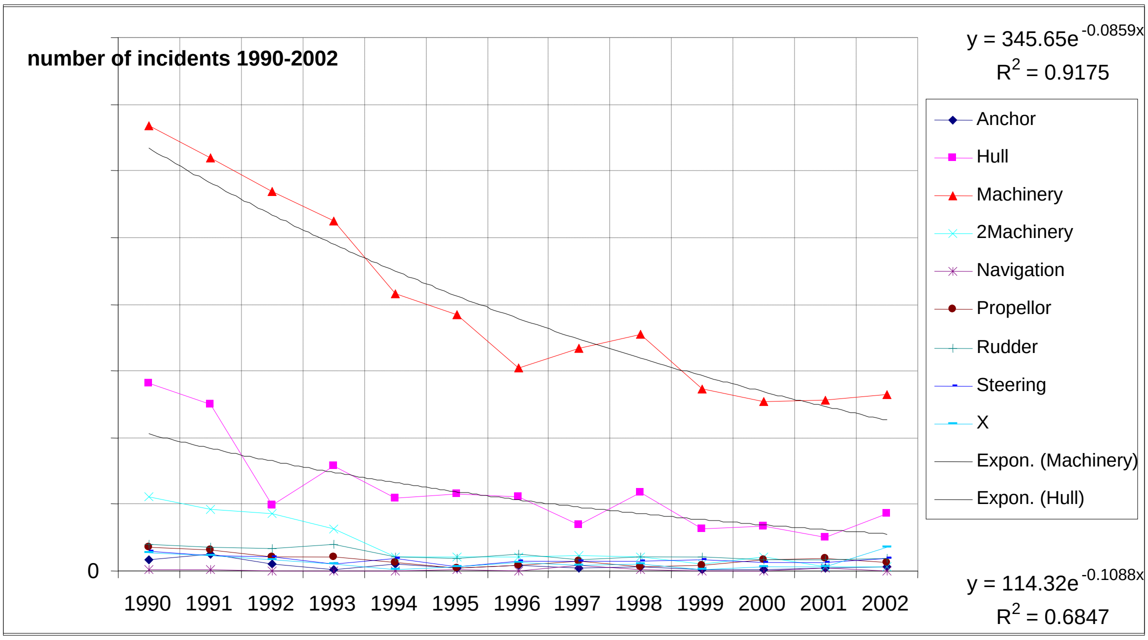


**Figure 4-3 Different type of Hull/Machinery failures through the years**

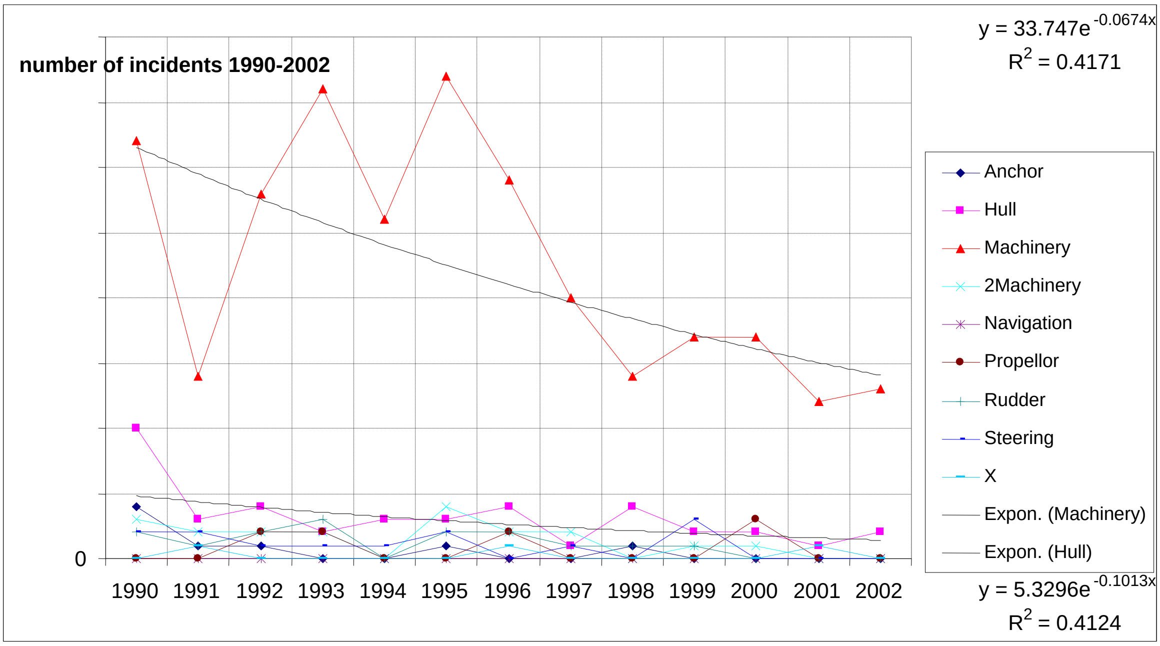


**Figure 4-4 Different type of Hull/Machinery failures on the North Sea through the years**

The same analysis is done for the Hull/Machinery casualties on the North Sea, as shown in Figure 4-4. The numbers of different types of incidents already become very low, resulting in relatively large variations around the average value and bad fits for the regressions. Most important is to see that the share of the Hull failure is only 10.2% of the total, while this share was 19% for the worldwide data. The reason for this lower share is the relatively calm sea state in the North Sea. The share of the Machinery failure on the North Sea is larger but this is mainly due to the smaller share of the hull failure.

**Conclusions of the Hull/Machinery analysis**

The conclusions of the Hull/Machinery casualty analysis are:

- The share worldwide of the Hull failure amounts 19% of the HM casualties
- The probability of a Hull failure on the North Sea is 50% of the average worldwide probability due to the relatively calm sea.
- The share of the Machinery failure is 78% of the HM failures, of which 63% deal directly with the machinery and 15% with systems that are essential for good ship operations.

## 4.4 Update of SAMSON casualty rates

### 4.4.1 Introduction

With SAMSON the number of exposures (casualty sensitive situations) for each type of casualty is determined based on an extensive description of the traffic and the environment. An exposure is a dangerous situation that can result in a casualty when something happens, e.g. an engine failure, or when an avoidance manoeuvre does not happen. Only one out of many exposures will end in a real casualty. The relationship between the number of exposures and the number of casualties cannot be derived on a worldwide base, because in that case the maritime traffic and environmental conditions should have to be modelled for the whole world.

The relation between **the number of exposures and the number of casualties** can and is derived for the North Sea in [1].

**Base for the assessment of the casualty rates in SAMSON**

The general approach for the examination of the casualty rate per ship type and size class is that:

- The type and size dependency (factors) are determined from the casualties observed in the worldwide casualty database
- The average casualty rate is determined from the exposures calculated for the North Sea area (50°-60° N and 0°-10°E) with SAMSON and the number of casualties observed in this area.

In [1] a detailed analysis was described in which the Lloyds database was compared with local databases. That part of the work is not repeated. It is assumed that the coverage of the Lloyds casualty data is unchanged, which means that the same incompleteness factor is used as in [1].
The worldwide casualty database from 1990-2002 has been used for analysing trends that can be applied to the casualty rates. The most significant result is the effect of the **yearly factor** that can be applied to the probability that an exposure leads to a casualty. Table 4-8 contains this yearly factor.

The update of the casualty rate, described in this Chapter has been performed in 2003 and 2004. The casualty rates are determined for the level of 2000, because at that time the last traffic database was based on the ship voyages of 2000 from LMIU.

Later un update was made for the traffic database of 2004. It is recommended to update the casualty rates in line with the traffic database.

When required in projects, it is possible to use the casualty rates for more recent years or even future years. In such a cases the yearly changes can be implemented by defining measures in SAMSON that increase or decrease the casualty rate matrices with a certain factor. The yearly trend are derived in this chapter.

**It is recommended to apply the yearly change of the casualty rates and to use the casualty rates that correspond with the year of the traffic scenario.**

The general changes in the number of casualties cannot be applied directly to the casualty rates, because the average worldwide casualty rate can increase by:

- The increasing size of the ships worldwide

- The composition of the world fleet in ship types. For example, container ships can be more casualty sensitive than other ship types.

Further the worldwide totals could not be related to exposures, because the worldwide traffic flows are not known.

In the following sections it is explained how the worldwide casualty data is used to update the casualty rates in SAMSON.

#### 4.4.2 Change of the composition of the world fleet

The sources available are:

a) Ship description file of all ships with at least one voyage in 1995, crossing the North Sea, Baltic Sea or Atlantic approach of NW Europe;
b) Ship description file of all ships with at least one voyage in 2000, crossing the North Sea in 2000, Baltic Sea, Atlantic Approach of NW European ports or the Mediterranean;
c) Ship description of all ships in 2000;
d) World fleet characteristics for 1995 and 2001 (books of LMIS).

The databases a and b have been used to develop the traffic database of respectively 1995 and 2000. By comparing the databases of 1995 and 2000, it could be extracted that the number of route bound ships in the Dutch part of the North Sea was nearly the same while the average size (GT) of the ships was increased with about 20%.
Such an increase can have an impact on the number of casualties, because the casualty rate depends on the size of the ship. The databases of a) and b) are used to determine if the increase of the 20% on the Dutch North Sea is due to local circumstances or is representative for the worldwide shipping. The databases a) and b) have different number of records because a) does not include the Mediterranean, thus has much less ships. For this reason the numbers have to be compared relatively. A first comparison is given in Figure 4-5 in which the size of the ships is presented cumulatively.
The two curves fall nearly together. Differences are difficult to recognise in this presentation. Therefore a second comparison is given by dividing the ships of the 1995 database over 20 GT classes. The limits of these 20 GT classes are derived from the 1995-database, such that the share of ships in each class is 0.05, which means 5% of the total number of ships. Next the share of the ships of the 2000-database in each class is determined. The result is given in Table 4-11. This table gives more information than the figure. The changes are negligible in the lowest GT classes. In the classes from 2000-4000 GT the increase is more than 10%. From 8000 to 20000 GT the numbers seem to decrease. In the larger size classes there is an increase in some classes, while the number in the largest size class decreases a little.
No structural differences can be extracted from the table. The differences can be the result of the difference of the Mediterranean traffic with the other traffic.

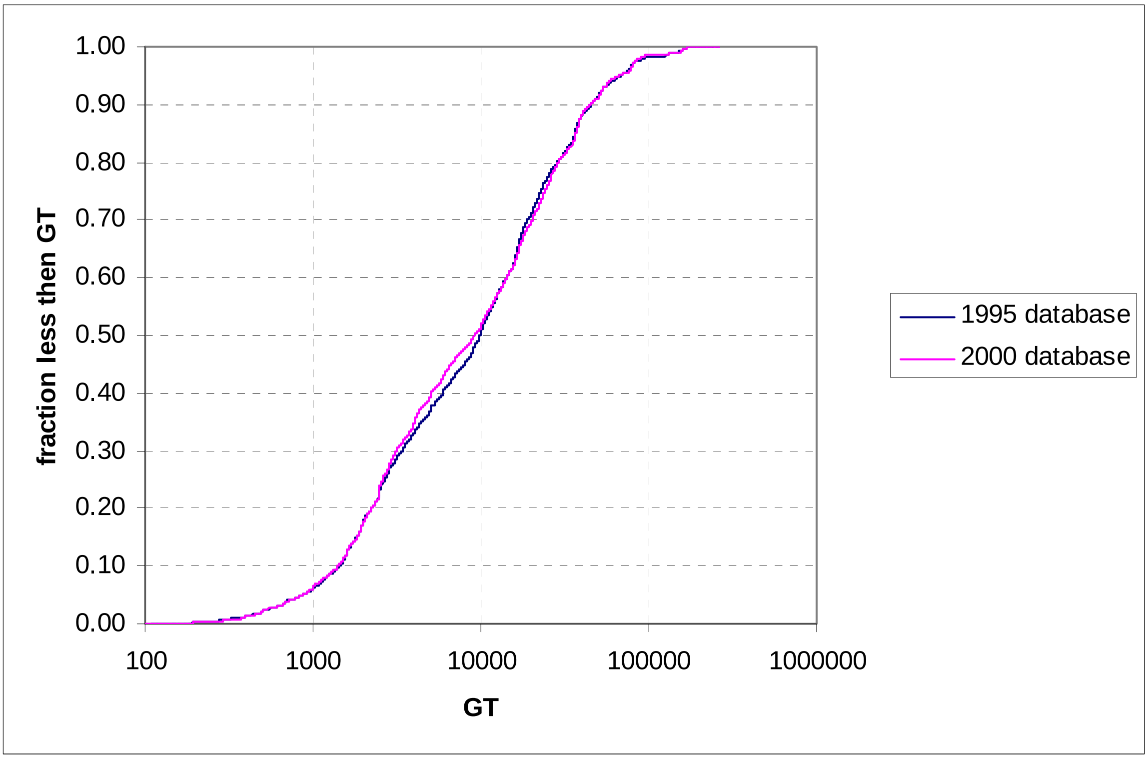


**Figure 4-5 Cumulative distribution of size**

**Table 4-11 Number of ships from the 1995- and 2000- databases divided over 20 GT-classes**

| Class | GT class limits | | Share in 1995 | Share in 2000 | Share in 2000/ Share in 1995 |
|---|---|---|---|---|---|
| | Lower | upper | | | |
| 1 | 100 | 866 | 0.05 | 0.0503 | 100.7% |
| 2 | 866 | 1432 | 0.05 | 0.0514 | 102.9% |
| 3 | 1432 | 1828 | 0.05 | 0.0469 | 93.9% |
| 4 | 1828 | 2230 | 0.05 | 0.0496 | 99.2% |
| 5 | 2230 | 2688 | 0.05 | 0.0593 | 118.7% |
| 6 | 2688 | 3430 | 0.05 | 0.0569 | 113.9% |
| 7 | 3430 | 4417 | 0.05 | 0.0587 | 117.5% |
| 8 | 4417 | 5967 | 0.05 | 0.0525 | 105.0% |
| 9 | 5967 | 7950 | 0.05 | 0.0509 | 101.8% |
| 10 | 7950 | 9888 | 0.05 | 0.0358 | 71.7% |
| 11 | 9888 | 11742 | 0.05 | 0.0426 | 85.3% |
| 12 | 11742 | 14153 | 0.05 | 0.0445 | 89.0% |
| 13 | 14153 | 16490 | 0.05 | 0.0400 | 79.9% |
| 14 | 16490 | 18943 | 0.05 | 0.0476 | 95.1% |
| 15 | 18943 | 22608 | 0.05 | 0.0448 | 89.7% |
| 16 | 22608 | 28306 | 0.05 | 0.0644 | 128.8% |
| 17 | 28306 | 36250 | 0.05 | 0.0466 | 93.3% |
| 18 | 36250 | 45423 | 0.05 | 0.0576 | 115.1% |
| 19 | 45423 | 67727 | 0.05 | 0.0504 | 100.8% |
| 20 | 67727 | 260851 | 0.05 | 0.0489 | 97.8% |

A last comparison of the number of ships through the years could be extracted from the World Fleet Statistics published by of LRF with total shipping fleet statistics of five years. The publication of 2001 does not contain the same tables as in the 1995 publication. This is the reason why Table 4-12, with the comparison of the number of ships in the period 1990-2001, contains different ship types. The changes through the years illustrated in Table 4-12 are also small.

**Table 4-12 Comparison of shipping totals from 1990-2001**

| Year | Total GT | ships | Average GT | increase from previous year | Ships selected | Source |
|---|---|---|---|---|---|---|
| 1990 | 659265171 | 41038 | 16065 | | Cargo carrying | Word fleet statistics 1995 |
| 1991 | 672897203 | 41356 | 16271 | 1.28% | Cargo carrying | Word fleet statistics 1995 |
| 1992 | 680281391 | 41303 | 16471 | 1.23% | Cargo carrying | Word fleet statistics 1995 |
| 1993 | 695877428 | 42152 | 16509 | 0.23% | Cargo carrying | Word fleet statistics 1995 |
| 1994 | 704011114 | 42689 | 16492 | -0.10% | Cargo carrying | Word fleet statistics 1995 |
| 1995 | 717514440 | 43802 | 16381 | -0.67% | Cargo carrying | Word fleet statistics 1995 |
| 1996 | 490915495 | 33351 | 14720 | | Merchant > 1000GT | Word fleet statistics 2001 |
| 1997 | 505037697 | 33924 | 14887 | 1.14% | Merchant > 1000GT | Word fleet statistics 2001 |
| 1998 | 514813608 | 34324 | 14999 | 0.75% | Merchant > 1000GT | Word fleet statistics 2001 |
| 1999 | 526335299 | 34822 | 15115 | 0.78% | Merchant > 1000GT | Word fleet statistics 2001 |
| 2000 | 540675039 | 35157 | 15379 | 1.75% | Merchant > 1000GT | Word fleet statistics 2001 |
| 2001 | 557130893 | 35471 | 15707 | 2.13% | Merchant > 1000GT | Word fleet statistics 2001 |
| 2002 | | | | | | No data available |

The composition of the worldwide fleet changes very slowly through the years which is also caused due to the average age of 17 years for the worldwide fleet meaning a 6% replacement of ships per year. This means, for example, that the use of larger ships on some trades mean that the old ships will sail on other trades.

**Conclusion**

The worldwide shipping database c) of 2000 can be used as a basis for comparing the number of casualties divided over the size classes. With respect to the division over the ship type classes one has to be more careful because the growth in some ship type classes is considerably ( f.e. container ship).

### 4.4.3 Correction of gross tonnage value in the casualty database

Nowadays, the Gross Tonnage (GT) is measured according to the International Convention on Tonnage Measurement of Ships in 1969, which came into force in 1982. This gross tonnage is broadly, the capacity in cubic feet of the spaces within the hull, and the enclosed spaces above the deck available for cargo, stores, fuel, passengers and crew, with certain exceptions, divided by 100. Thus 100 cubic feet of capacity is equivalent to 1 gross ton.

Previous to this convention the gross (register) tonnage (GRT) was measured in a different way. When the new measurement of the gross tonnage came into force, It was not obliged to measure anew an existing ship. In many databases, under which the casualty database of LRF, the same field “Gross Tonnage” is used for the old GRT and new GT-value that was in use at the moment of the casualty. Some ships were found

with two different gross tonnage values in the casualty database. The first occurrence with a GRT-value and the second occurrence with a GT-value (after a new measurement).
Because the SAMSON size classes are based on the gross tonnage this phenomenon was very difficult to deal with. Especially for a smaller ship the GT-value can be much higher, often more than 2 times as high, than the old GRT-value. The factor for large ships lies around 1.0. The effect is that the numbers of casualties in the smaller size classes are not accurate.

This problem has been tackled on the following manner. For each year before 2000 the average factor GT/GRT ((Gross tonnage of shipping database of 2000) / (Gross tonnage of the casualty database)) is determined for each type and size combination for the ships that exist in the casualty database and in the Lloyds shipping file of 2000. This calculated factor(year, type, size) has been used for updating the gross tonnage value of a ship in the casualty database that was involved in a casualty before 2000 and does not exist anymore in the Lloyds shipping file of 2000. The gross tonnage of a ship of the casualty database of 2000 or later is not updated, because this gross tonnage value will already be a GT-value in most cases. The effect of this improvement was that some of the casualties were moved to a larger size class. Further this enlargement was important to get a more realistic comparison between the casualty probability and the size as dealt with in 4.4.4.

### 4.4.4 Size sensitivity

The sensitivity of different casualties to the size of the ship is analysed for the worldwide database, after the update of the gross tonnage value in the casualty database according the process described in 4.4.3. Further, it is assumed that the Lloyds shipping file of 2000 is representative for the whole period. For the large size classes this will be not true, because in 2000 larger ships were sailing than in 1990.

Because a casualty at sea can only occur when the ship is at sea, the sea time is estimated for each ship in the shipping file of 2000. The time at sea increases from 50% for ships below 500 GT until 90% for ships above 30000 GT. For each ship in the shipping database of 2000, the time at sea is determined based on the GT-value. In the analysis the number of casualties can be related to the **ships at sea**.

The 8 SAMSON size classes are not very suitable for this analysis because the number of ships varies considerably over the size classes. Therefore 20 new size classes were determined in such a way that each size class contains roughly the same number of ships (thus 5% of the world fleet at sea). The borders of each size class are determined by sorting all ships of the Lloyds shipping file of 2000 on the GT-value, and set a border after each 5% of the ships at sea field. This approach results in strange borders but the distribution is uniformly distributed over the size classes. Next the number of casualties in each size class are counted based of the “corrected” gross tonnage value (see 5.3). In case the casualty sensitivity depends not on the GT the casualties should be uniformly spread over the size classes with roughly 5% of a certain casualty in each size class.

To show the casualty rate sensitivity with the GT, the % of the casualties of a certain type is divided by the % of the ships at sea. The result for each size class is given in Figure 4-6 This figure shows the normalised casualty rate over the GT range. The GT is presented on a logarithmic scale, because otherwise the points nearly overlap each other for small GT-values. Because the length is related with $GT^{1/3}$ the figure gives the casualty sensitivity with the length of the ship.

Each dot represents 5% of the ships at sea. Because point 16 lies on 20,000 GT this means that 22.5% of the ships has a GT of 20,000 or higher.
The figure makes clear that all casualties start with a value less than 1 in the smallest GT classes. Thereafter, for increasing GT the value is varying around a value just above 1.0 and in the largest GT classes some values raise to extreme values.

The very low value of (% casualties)/(% ships at sea) for the smaller GT classes is not considered as realistic but is due to a number of reasons, namely:

- The damage costs will be relative low;
- No threat of a large oil or chemical spill
- Thus limited attention of the media for the casualty, thus a smaller probability that the casualty will be published in the public domain and entered in the casualty database.

The same figure is now given cumulatively. The lower limit of the 6$^{th}$ size classes is 1322 GT. This means that 6 x 5%=30% of all ships at sea have a GT smaller than 1322 GT. For FD the cumulative value in Figure 4-7 is 1.5. This means that 1.5 x 30% = 45% of all foundered ships had a GT-value less than 1322 GT. Of course the curve of each casualty type runs to the value 1 for the largest GT-value. If the curve starts from values above 1.0 it means that the casualty rate is less for larger ships (see FD = foundering) If the curve raises from values less than 1.0 then the casualty rate is relatively high for larger ships (see H = Hull damage).
A figure as Figure 4-7 does not give the right relationship when the above statements for the relative small casualties for small ships are right. When the first five classes are left out from the analysis the cumulative Figure 4-7 changes into Figure 4-8. In this new figure the casualty rate for foundering runs more likely with what was expected and is not disturbed due to missed casualties in the smallest size classes.
For this reason the 5 smallest GT classes are not considered anymore in the further analysis. It is assumed that the relation for these size classes is similar to that of the classes just above this range.

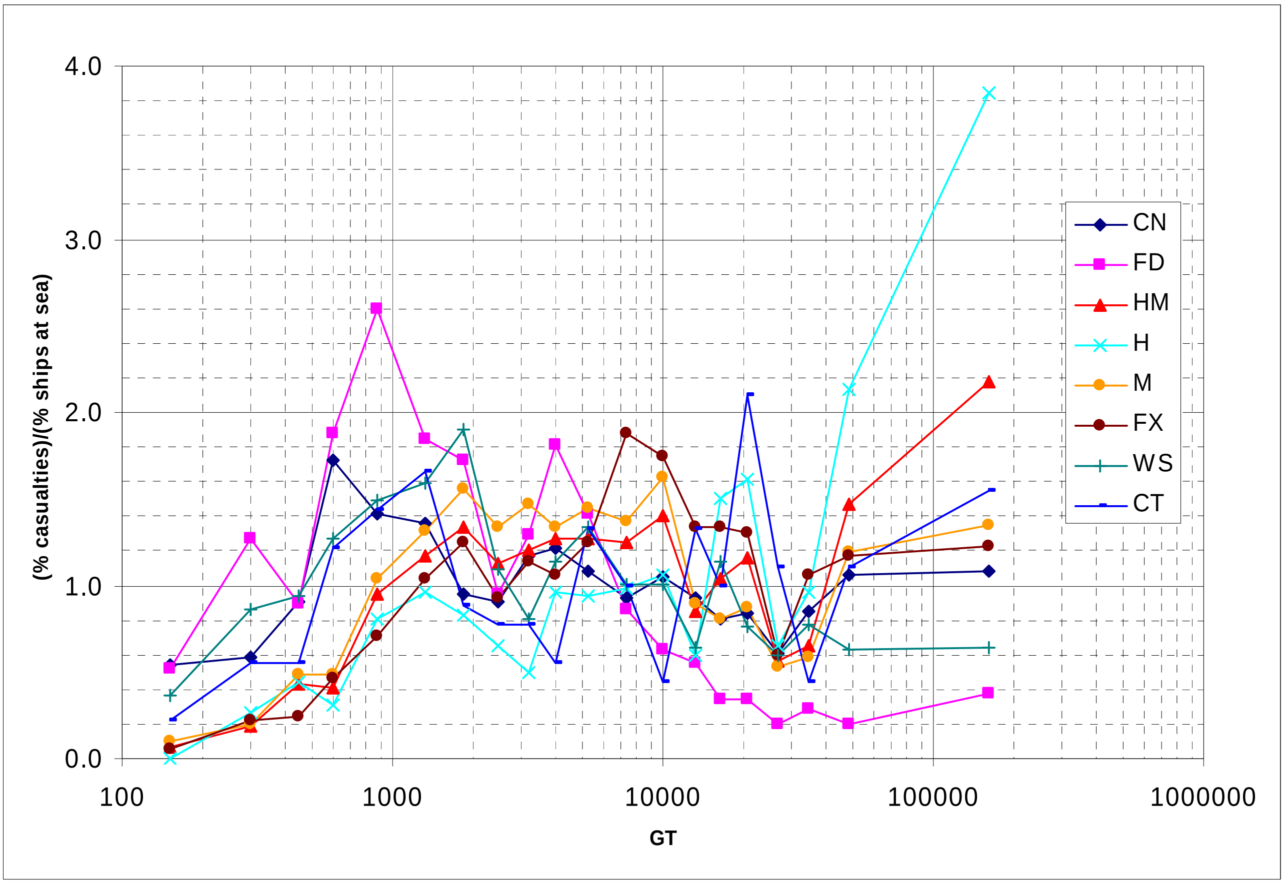


**Figure 4-6 (share casualties)/(share ships at sea) per size class for casualties at sea worldwide**

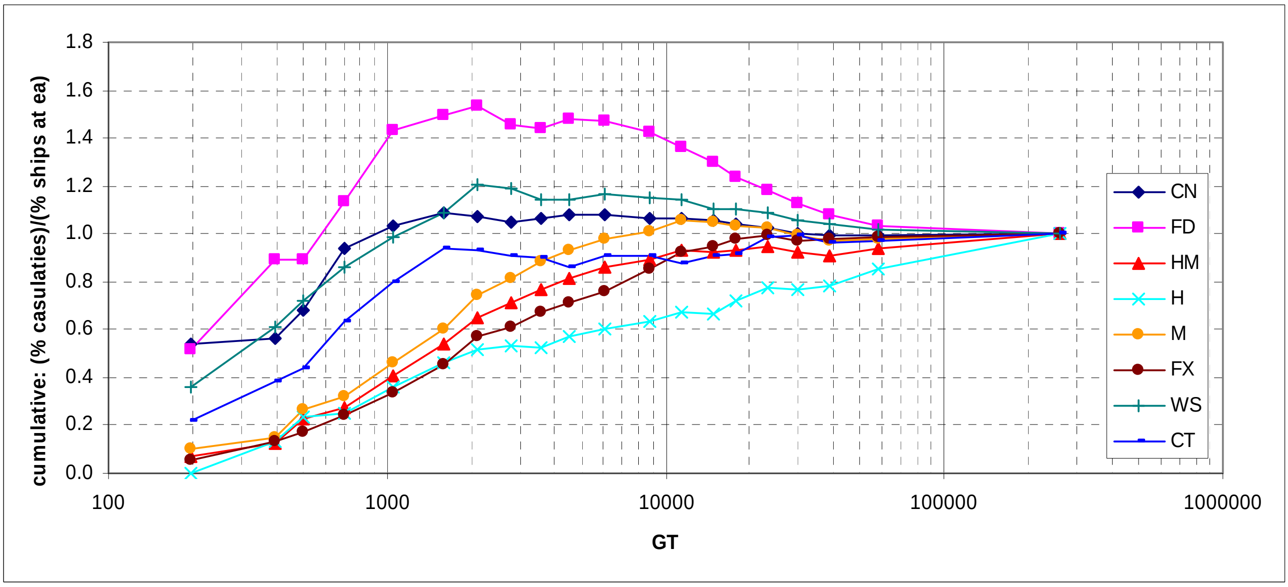


**Figure 4-7 Cumulative: (share casualties)/(share ships at sea) per size class for casualties at sea worldwide**

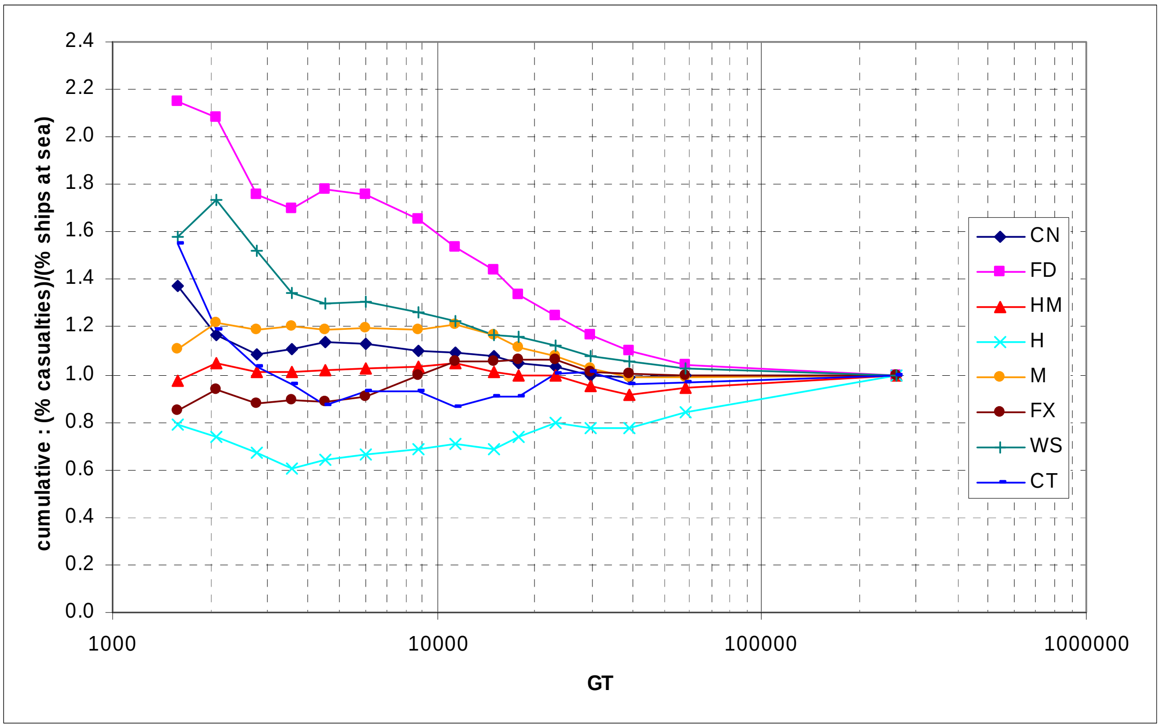


**Figure 4-8 Cumulative: (share casualties)/(share ships at sea) for the upper 15 size classes for casualties at sea worldwide**

One more data handling process has been performed before the analysis, namely smoothing of the variations. Therefore the number of casualties in each size class are averaged over three size classes. The result is presented in Figure 4-9. Not every casualty type can be related straight proportionally with the number of ships. For example a collision is related with the number of encounters and a contact and a wrecked/stranded is related with the contact respectively stranding opportunity. The Hull/Machinery casualty cannot be related directly with the number of ships, because the dependency for hull failure increases strongly with the GT while the machinery failure does not change much with increasing GT.

Figure 4-9 contains the averaged casualty sensitivity for the upper 15 size classes with the best fitted regression lines for the casualties hull, machinery, foundering and fire/explosion that are proportionally related with the time at sea. During bad weather conditions the probability of a foundering increases extremely, but for the size sensitivity it can be assumed that the weather sensitivity (as factor) is the same for each size class.

The found regression lines are not very satisfying. For the casualty FD no reasonable regression line of any shape could be found. The difference in the foundering rate between small and large ships is too large.

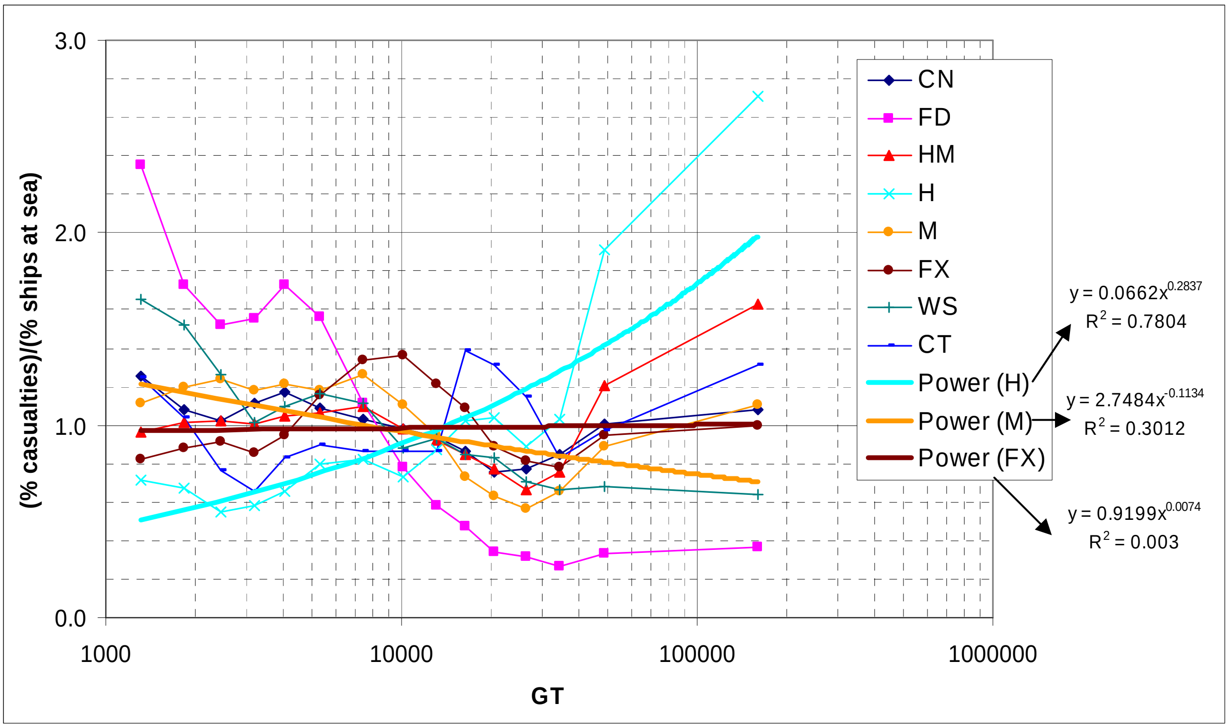


**Figure 4-9 (share casualties)/(share ships at sea) for the upper 15 size classes for casualties at sea worldwide with regression lines**

The formulae of the regression lines for H, M and FX are presented. As can be seen on the figure the differences between the regression line and the observations are relatively large, making these lines not very reliable. Therefore, the figures are also given as a function of the size class Figure 4-10. For this new, linear instead of logarithmic, presentation form, it was possible to define other types of regression lines. However, this also did not result into better regression lines.

The casualties CN, CT and WS seem not to fluctuate too much around the average value 1.0 and are assumed not to be sensitive on the size of the ship. Moreover, these casualty types are related with other exposures that cannot be determined on a worldwide scale.

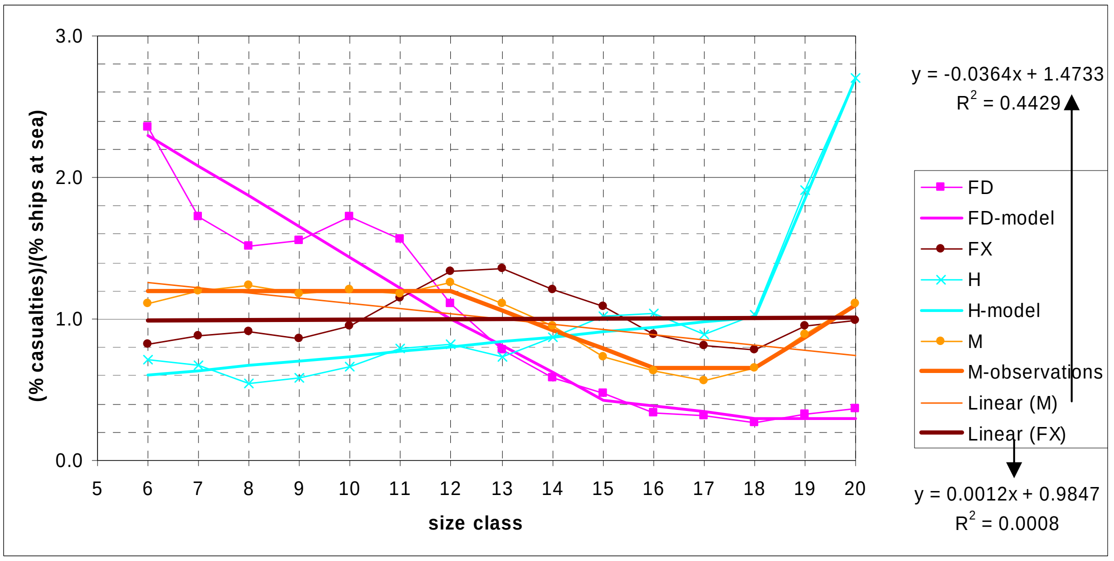


**Figure 4-10 (share casualties)/(share ships at sea) for the upper 15 size classes for casualties at sea worldwide with regression lines**

Finally, it was decided not to use regression lines over the full size range, but to work with own models for the different casualty types for modelling the size dependency. The models used for the four considered casualties are presented in Figure 4-10 and are composed of a number of linear lines. These models follow the observed number of casualties and can be considered as “best estimate models”

The hull and machinery and fired/explosion model are very simple with a slope for small GT-values and a constant level for the larger values. The hull casualty is increasing with the size class with an increasing slope. The foundering probability is continuously decreasing with the size, and ending on a level of 0.3. This means that the likelihood of a ship, of size class 6 foundering is 2.4/0.3= 8 times higher than that for a ship of size class 20. The main reason why larger a ship founders with lower frequencies is that the ship has different compartments. If only one compartment is leaking and being filled with water, the other compartments have enough floating power to save the ship.

The relations found here are used during the assessment of the new casualty rates for SAMSON.

## 4.5 Spread of casualties over ship type and size classes per casualty type

The relation between casualty rate and size of the ship depends on the casualty type (see 4.4.4). For example, the foundering decreases strongly with the ship size and the hull failure probability increases with the ship size. The different behaviour of each casualty type requires a separate model for each casualty type. Each casualty type is analysed by the determination of a number of tables, that lead to the model used. In Annex A the detailed tables are given for the casualty type Machinery, the casualty, or better incident, that occurs most frequently.