The Development and Analysis of a Navigational Incident Database for Naval Vessels

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Operating a fleet of ships in all weathers and environments poses certain risks, and navigational incidents such as collisions, groundings and vessel strikings are bound to occur. The Royal Navy has always conducted extensive inquiries into the serious navigational incidents in order to establish the cause and so prevent reoccurrence. However, many less serious navigational incidents occur which, if collated and analysed on a database, could help better understanding of the nature of such incidents. This paper describes how a database that met these needs was designed and developed. Once completed, the database was analysed to compare trends between different vessel types and incident categories.

1. INTRODUCTION.

1.1. *The Problem*. On 4 June 1989 at 1540A HMS *Lindisfarne*, an offshore patrol vessel, was attempting to berth alongside HMS *Penelope* at Slip Jetty, Devonport Naval Base. During the manoeuvre, high winds caused *Lindisfarne*'s bow to collide with *Penelope*'s accommodation ladder, causing minor damage. On 4 May 1995 at 0834Z HMS *Illustrious*, an aircraft carrier, was approaching the entrance to Grand Harbour, Valletta, Malta. A tug employed to assist with the berthing approached too close and collided with her bow, partially overturning the tug and tipping two of the tug's crew members into the sea. No serious injuries resulted, but the tug was severely damaged.

What do these two apparently unrelated incidents have in common? One is a minor berthing incident in a naval base involving a small vessel, the other is a more serious collision incident overseas involving a large vessel. The answer is that both were navigational incidents involving naval vessels. However, the system employed in recording these, and the other 50 or so incidents that are reported annually, was unable to connect them. This was because no overall recording system existed. The reports signalled from ships involved in minor incidents were simply filed away, whilst the more serious incidents were investigated by a Board of Inquiry and their findings submitted to Higher Naval Authorities. There was no single point of reference for *all* navigational incidents and their outcome. It was clear that this deficiency could be rectified if all navigational incidents were recorded on a modern database. As soon as the incident was reported, it could be recorded, then further details could be added as the situation clarified. Once the incident had been resolved, the final outcome could be added and thus a comprehensive record of all incidents would be available. The power of a modern relational database also means that, if it could be populated with previous records, an analysis of all incidents over a period could be conducted.

https://doi.org/10.1017/S0373463399008401 Published online by Cambridge University Press

Hitherto unknown trends might be discovered that could lead to a better understanding of how and why incidents happen.

1.2 *The Aims*. The primary aim was to design and develop a database which would efficiently record all navigational incidents. This database would need to contain suitable fields to house the data and be pre-set with appropriate categories so that data retrieval would be a straightforward matter. Research into how other marine organisations handle their accident data would be a major factor to avoid unnecessary teething problems. The secondary aim was to populate the database with whatever historic data was available so that analyses of previous incidents can be conducted. It was considered that such analysis should be relevant to modern classes of vessels and so obtaining data from the mists of time would be unproductive; data from the last 10 years was therefore considered to be sufficient. Once the analyses of the historic incident data had been conducted and any trends established, it was hoped that positive recommendations to enhance navigational safety could be made.

2. NAVIGATIONAL INCIDENTS.

2.1. *What is an Incident*? Before exploring the techniques of using a database to record and evaluate navigational incidents, it was essential to define clearly what incidents should be considered. Compiling a list of all the unpleasant happenings that can befall naval vessels provided a starting point in eliminating the incidents that were not navigational in nature. The *primary* cause has been used in defining a particular incident, irrespective of any secondary or subsequent happening. For example, a collision with another vessel is clearly navigational in nature even if this results in a fire which could then become the major incident. However, a fire onboard would not normally constitute a navigational incident in itself. The following is a list of the primary causes that would constitute a navigational incident:

(a) Collision or unintentional contact with another vessel.
(b) Contact with a fixed structure or buoy.
(c) Incidents during berthing when either ship or jetty become damaged.
(d) Grounding.
(e) Damage caused to property by the excessive wash of a naval vessel.
(f) Heavy weather damage.

2.2. *Present Reporting Regulations*. The requirements for naval vessels to report navigational incidents is found in the publication 'Queen's Regulations for the Royal Navy' (QRRN).[1] This publication covers collisions and other navigational incidents, and instructs the Commanding Officer of a ship to report any such incident in which damage is caused to HM Ships, other vessels, structure or property. The primary purpose of reporting navigational incidents is to ensure that the Higher Authority is immediately informed whenever a naval vessel is involved in such an incident so that appropriate action can be taken. If the vessel(s) is in need of assistance, and/or repairs, the information contained in the initial signal report allows the Higher Authority to initiate such action. Once initial action is complete, Higher Authority then decides if any further action, such as an investigation, is required. Usually, in cases where the incident is minor, no further action is taken, and the report is simply filed away. However, in cases where the staff of the Higher Authority consider that lessons may be learned from conducting an investigation, the details reported in the initial signal are used by the investigating team as a starting point for gathering evidence. It was clear, therefore, that the primary purpose of the signalled navigational incident report, (the QRRN 4503 report), is to inform Higher Authority without delay of an incident, and *not* to be a comprehensive report of an incident. This basic but crucial fact was to have an effect on the data put into the database, and led to a recommendation to alter the format of the signal report. Other sources of documentary evidence which would assist in populating a database included the Royal Navy Reference Book 'Reports of Collisions and Groundings'[2], in which a selection of the more serious incidents are described, together with Board of Inquiry (BOI) Reports and Archive Reports[3]. Sadly, signal reports were only available back to January 1988 but nevertheless became the primary source of data to populate the database, supplemented where possible by BOI and Archive Reports.

2.3. *Drawbacks of the Existing System.* The signal report was never intended to be a system of comprehensive incident reporting. In the past, there was never a need to audit all incidents and so only the serious ones were given close scrutiny. The naval command structure vests considerable autonomy and decision-making powers in its local commanders, which removes the requirement to forward every minor navigational report up the chain of command. Consequently, the Higher Authority will normally only view a brief signal report of all minor incidents, together with official reports of the serious ones. It is therefore important that the initial signal report contains sufficient information to populate accurately a database that can be used as a tool in quantifying and understanding navigational incidents, from the minor berthing incident through to the serious collision. As the database was being designed and refined, various ideas developed that could improve the signal reports, and these formed part of the final recommendations. The requirement to record accurately and analyse all incidents was given added impetus by recent developments concerning safety in the commercial maritime field, especially the offshore exploration and petrochemical industries. Many recent changes have been driven by legislation and litigation which has, in turn, driven the need for operators to produce auditable safety records that can be scrutinised and enable risk assessments to be conducted. Although MOD naval vessels have been exempt from this legislation, and there is an understandable belief that the Royal Navy's safety record is good, it would be of considerable value if this belief could be demonstrated using empirical data. An auditable database of navigational incidents would greatly contribute to this aim.

2.4. *Other Databases.* Before developing a database that could record and analyse navigational incidents for naval vessels, it was important to discover if any other maritime organisations had similar databases, and how these had been populated. Research was undertaken to establish if any lessons could be learned from other organisations' databases. During the course of this research, the following were studied: Lloyds Register,[4] DNV Technica's 'World Offshore Accident Databank',[5] The EURET Casualty Database,[6] The Marine Accident Investigation Branch (MAIB) Database and several other historical databases and publications concerning marine accidents. Large variations were found in the way other organisations collated their information, mainly due to the different purposes for which the databases had been developed. Despite this, there remained a common thread throughout on the grouping of incidents and accidents, both in their nature and severity. The MAIB database proved to be the most comprehensive, and a simplified version was initially used as a model for the naval database. However, once population began, it quickly became clear that major changes were necessary to accommodate the specific naval aspects of navigational incidents.

3. THE DATABASE STRUCTURE.

3.1. *The Choice of Fields.* It was clear from the outset that, in choosing the fields, there would need to be a compromise between ensuring that all the available and relevant data concerning a navigational incident could be recorded, whilst not making the fields too large or so complicated that any database query would not produce a meaningful answer. The same was true of the choice of categories available within each field. It was also clear that some of the fields would need to be input from a range of specified choices (in order to be able to group incidents together for statistical purposes), whilst others would simply allow free text to be added (an example would be a field to describe how the incident had occurred). In choosing how many different categories to offer in each field, there was also a concern about the risk of data paucity if too many categories were available. It was known that about 50 navigational incidents were being reported each year and that reliable data could be gathered for the previous nine years. Therefore the total entries in the database would initially be only about 450. If excessive choices were available in each field, some fields would have only a handful of data in certain categories. This could result in statistically insignificant results during analysis. The following fields were initially selected:

1. Date
2. Time
3. Ship's Name
4. Ship's Type (e.g. frigate, carrier, etc.)
5. Type of Incident (grounding, collision, etc.)
6. Geographic Location
7. Incident Description
8. Incident Severity

There was a need to add extra fields in which to put supplementary information (if available) that could help complete the picture about the incident. These supplemental fields could also allow post-incident information to be added, such as whether a Board of Inquiry was conducted and a brief summary of its findings. The following extra fields were chosen:

9. Incident Outcome
10. Comments by HQ Authority
11. Damage Repair Costs
12. Environmental location (in harbour, pilotage, coastal waters or open sea)
13. Weather and Environmental Information
14. Tug Involvement

The final four from the list above were not originally included, but were added as part of an iterative process as the database was being populated and shortcomings in data recording were identified. In a similar fashion, several of the other fields were modified (either by increasing the field size or extending the choice of categories) as the database developed.

3.2. *The Incident Category.* After studying the incident & accident categories used in other databases and reports, it made sound sense to attempt to retain similar definitions in order to maintain a degree of uniformity. However, whilst there is a general agreement on the definition of grounding (vessel's hull making unintentional contact with the seabed), there was considerable diversity of opinion on the definitions of striking, collisions, impacts and other incidents where a vessel makes

https://doi.org/10.1017/S0373463399008401 Published online by Cambridge University Press

unintentional contact with another vessel, object, structure, jetty or buoy. In addition to the terms already used, there is another that is routinely used in the Naval Service to describe an incident in which accidental damage is caused during the action of coming alongside a berth or jetty, usually caused by a misjudged approach. This is termed a 'berthing incident' and may be peculiar to naval operations as warships often berth without using tugs, or by using tugs to assist, rather that conduct, the manoeuvre. Furthermore, warships are thin-skinned, fragile vessels and are easily dented during heavy contact alongside. It was noted that the majority of signal reports involved berthing incidents and were of a minor nature, and so this type of incident required its own category. After several iterations to establish the various categories for 'naval vessels bumping into something', the following list of definitions was found to cover adequately all the reported incidents that were to be entered in the database:

1. STRIKING – When a naval vessel makes contact with another vessel where one of the vessels is alongside, at anchor or secured.
2. COLLISION – When a naval vessel makes unintentional contact with an underway vessel, a buoy or a structure.
3. GROUNDING – When a naval vessel makes unintentional contact with the seabed, or an object on the seabed.
4. COLD MOVE – When damage is caused to a naval vessel being moved not under its own power.
5. BERTHING – When damage is caused to a naval vessel berthing or unberthing as part of a planned manoeuvre to or from that berth.
6. MISC. – Any miscellaneous incident not covered by one of the above categories, and including wash damage, heavy weather damage and damage caused when ships are secured alongside each other.

The following notes and comments are offered to expand on the definitions:

(a) *Collisions*. If a tug collides with the side of a vessel whilst passing a hawser or assisting with berthing, this would be a berthing incident as both vessels are involved in the specific manoeuvre of berthing. If, however, a tug collides with a naval vessel whilst transiting a harbour, this would be a collision as neither vessel was involved in an actual berthing manoeuvre and the International Regulations for the Prevention of Collisions at Sea should have prevailed.

(b) *Striking*. This definition covers the situation of a naval vessel, secured alongside or at anchor, which is hit by a passing craft. It also covers the naval vessel underway which hits a secured vessel, e.g. when approaching a berth, being set off-course and running into a vessel secured at an adjacent berth.

(c) *Grounding*. Only applies to vessels that unintentionally make contact with the seabed, and does not include the intentional grounding of landing ships or planned bottoming of submarines.

(d) *Cold Move*. This category is exclusively for vessels being moved by tugs, with the ship's own propulsion system playing no part. In naval ports the Admiralty Pilot, and not the ship's Commanding Officer, will usually be responsible for the move.

(e) *Berthing*. As described above, the tug which dents the warship whilst pushing it onto a berth results in a berthing incident. If a naval vessel makes a serious error of navigation whilst attempting a berthing manoeuvre, misses the planned berth and collides with some other structure or vessel underway, it counts as a collision, or, if it collides with a secured vessel, then it counts as a striking.

3.3. *The Incident Severity*. The MAIB Database uses nine separate seriousness categories, and subdivides them, inter alia, into accidents to persons and accidents to ships. These seriousness categories do not therefore increase in ascending severity, but rather sub-classify the accident type. Owing to the relatively small initial population in the naval database, it was considered better to use severity categories that operated on a sliding scale. Four levels of severity were chosen, starting with *Minor* and increasing progressively to *Serious*, then *Severe* and lastly *Loss* (of ship or life). The categories would be based not only on the level of damage or injuries caused, but also on the effect of the incident on the ship's operational programme. The rationale for this was that several incidents had been observed where only minor damage had been sustained, but there had been serious detriment to the operational life of the ship. A good example was a towed-array frigate about to depart on an important deployment that placed her stern too close to a jetty whilst unberthing and slightly bent all the blades on one propeller. The bent blades would have produced too much cavitation noise for the frigate to have been successful on patrol and so the programme was changed and another frigate was required to stand-in whilst the damaged frigate underwent an emergency docking to change the propeller. This incident was clearly *Severe* even though the damage was relatively minor. The initial aim was to establish this progressive scale on a logarithmic basis, such that the numbers of incidents in a lower category were an order of magnitude greater that the numbers in the next category; for example, the perfect database would contain incidents in the following ratio: 1 *Loss*:10 *Serious*:100 *Severe*:1000 *Minor*. All incidents were assessed against the definition for each category (described below), and the ratios emerged as follows: 4 *Loss*: 11 *Serious*: 45 *Severe*: 500 *Minor*. Despite the fact that the ratios did not conform to the perfect model it was decided to retain the category definitions as they did group the incidents logically. Additionally, the *Loss* category includes a small speedboat that was swamped by a warship's wash and does not therefore have the same gravitas as others of the same category, such as the tragic incident where a submarine pulled a fishing boat underwater after snagging its nets, resulting in the loss of all the fishing vessel's crew. This example clearly demonstrates that, even when a robust definition is devised in order to classify incidents by severity, a skewing of the figures may still occur. The definitions for the four categories of severity are summarised as:

(a) *Minor*. Superficial damage caused, no injuries to personnel, no detriment to the operational programme, or damage can be repaired locally.
(b) *Serious*. Involves damage that requires specialist dockyard repairs and/or the ship's operational programme is affected. Any injuries associated with the incident would be slight.
(c) *Severe*. Considerable damage caused that requires the ship to proceed for immediate repairs. Any injuries associated could be serious.
(d) *Loss*. An incident in which *any* vessel involved in the incident sinks, or life is lost.

3.4. *Using the Database*. The database was designed to run on a standard office PC and reside in a Pentium computer with a 25 Mb RAM, situated at Fleet

Headquarters. The software used is the Microsoft Access© Database Management System. During the research phase, it was discovered that one of the lessons learned from the MAIB accident database, as expressed by the staff who use it, is the labourious method of data entry. In the light of this, and other similar advice, it was considered important to ensure this aspect was properly addressed. It was felt that, if the database was cumbersome to use, it would detract from its value and be a disincentive to any operator exploring its full potential. Therefore, one of the key aims in designing this database was to facilitate easy, user-friendly entry of the data. The choice of Microsoft Access© as the database management system meant that the Windows operating environment could be employed to the full. In particular, the use of pull-down menus to offer a limited choice of options for specific fields would simplify the data entry process. Therefore, in fields where a specific entry is required, a pull-down menu has been offered. Examples of these types of fields are the 'Vessel Type' field (where a specific class of vessel is chosen from the definitive list) and the 'Tug Involved' field that offers a simple Y or N choice. In fields that require free-text data entry, no such option is given; but the amount of data that can be recorded is governed by each field length. The layout of the database therefore allows new incidents to be quickly and accurately recorded, existing entries to be modified and, using the Access search facility, allows data searches to be conducted given selected parameters. The database has also been designed so that future expansion is possible, either by adding categories available in various fields (e.g. new ships arriving in the Fleet) or by adding complete new fields should the need arise.

4. DATABASE ANALYSIS.

4.1. *Plotting the Data.* Once the database had been populated with the historical records, the search facility was used to make various comparative analyses and the results tabulated and graphically plotted. Data has been compared using vessel type, incident category, incident severity, geographic locality and tug involvement. Where possible, comparisons were made year-on-year to determine trends. The scarcity of data in many fields necessitated the grouping together of categories in order to obtain statistically meaningful numbers. Vessel types were grouped together into Minor War Vessels (MWV), Frigates and Destroyers (FF/DD), Aircraft Carriers and Assault Ships (CVS/LPD), all classes of Submarines (SUBS) and Naval Auxilliary Vessels (RFA). The small number of hulls in some vessel groups caused distortion of the results where a statistically small sample would have a disproportionate effect. This was particularly noticeable in the CVS/LPD group, where great caution was required when interpreting the results of analysis. Additionally, in order to obtain a feel for the vulnerability of different vessel classes when entering different ports, data from other sources was used in conjunction with incident data from the database to produce a series of port entry/departure incident graphs.

4.2. *The Incident Rates.*

4.2.1. Berthing incidents are the most numerous and account for 42% of all reports, yet 95% of them are classed as *Minor*. Berthing incident rates have shown a steady decline since 1989 but began to rise sharply in 1996. MWVs have the highest berthing incident rates, but are only slightly ahead of FF/DDs and RFAs, whilst Submarines have the lowest rate. These rates are as expected; MWVs often visit small harbours with difficult entries, frequently without tug support. The likelihood of a minor bump when berthing is high. By contrast, Submarines will always employ tugs to berth as, by their nature, these vessels cannot afford any berthing damage. Berthing

https://doi.org/10.1017/S0373463399008401 Published online by Cambridge University Press

incidents where tugs were involved averaged 10% of all berthing incidents, but no trends could be observed within this figure.

4.2.2. Striking incident rates are less than a half of the berthing incident rates, but vessel vulnerability is broadly similar. RFAs suffer the highest rate, possibly due to their time spent at exposed berths, as they regularly visit foreign ports where barges, lighters and tugs may not be well handled. This view is supported by the fact that 67% of all RFA strikings were caused in foreign ports. MWVs and FF/DDs have an average striking incident figure whilst Submarines have a zero rate, which is explained by their method of always manoeuvring with tugs and being given protected alongside berths that require all other vessels to pass by a wide margin.

4.2.3. Collision incident rates are very similar across the vessel types and no one group is considered more at risk than the others. It appears that aircraft carriers are just as likely to suffer a collision as small patrol craft. It should be remembered that not all collisions are vessel-to-vessel, and that many involve collisions with fixed structures and buoys so ship-handling ability as well as 'Rule of the Road' application is involved. Furthermore, only 78% of these incidents were considered minor. Three percent (or three incidents) resulted in the loss of a vessel and, in one case, the loss of four lives. Collision incident rates have steadily climbed during the observed period by 250%. Regrettably, there is nothing in the database that gives a clue as to the reason for this year-by-year increase. It could be speculated that human error is to blame, resulting from increasing pressures on the bridge team, coupled with ever-increasingly congested waterways. 22% of collision incidents are classified as *Serious* or above and account for all the *Loss* incidents reported in the database.

4.2.4. Grounding incident rates are considerably lower than the rates for most other incidents and have remained steady over the years with no one-vessel group being more at risk. Grounding incidents generally resulted in *Serious* or greater damage, and 50% of the reported incidents occurred in pilotage waters. The fact that most groundings occur in pilotage waters is not surprising, as these are hazardous to navigate (see Table 1). However, the fact that fewer incidents happen in harbour than in coastal waters is interesting. It is considered that the higher degree of diligence required when manoeuvring in harbour makes the bridge team more alert than in coastal waters when the less experienced members may be holding the watch. It is interesting to note that all grounding incidents that occurred in open sea involved submarines hitting the seabed whilst dived. It is also noteworthy that 65%–70% of all groundings occurred in UK territorial waters.

Table 1. Location of reported groundings.

Locality	Percentage occurrence	Proportion that occurred in UK waters (%)
Pilotage Waters	50	65
Coastal Waters	32	70
Harbours	12	67
Open Sea	6	67

4.2.5. A comparison of port entry/departure rates between naval bases, UK commercial ports and foreign ports was conducted and expressed as incidents per 100

https://doi.org/10.1017/S0373463399008401 Published online by Cambridge University Press

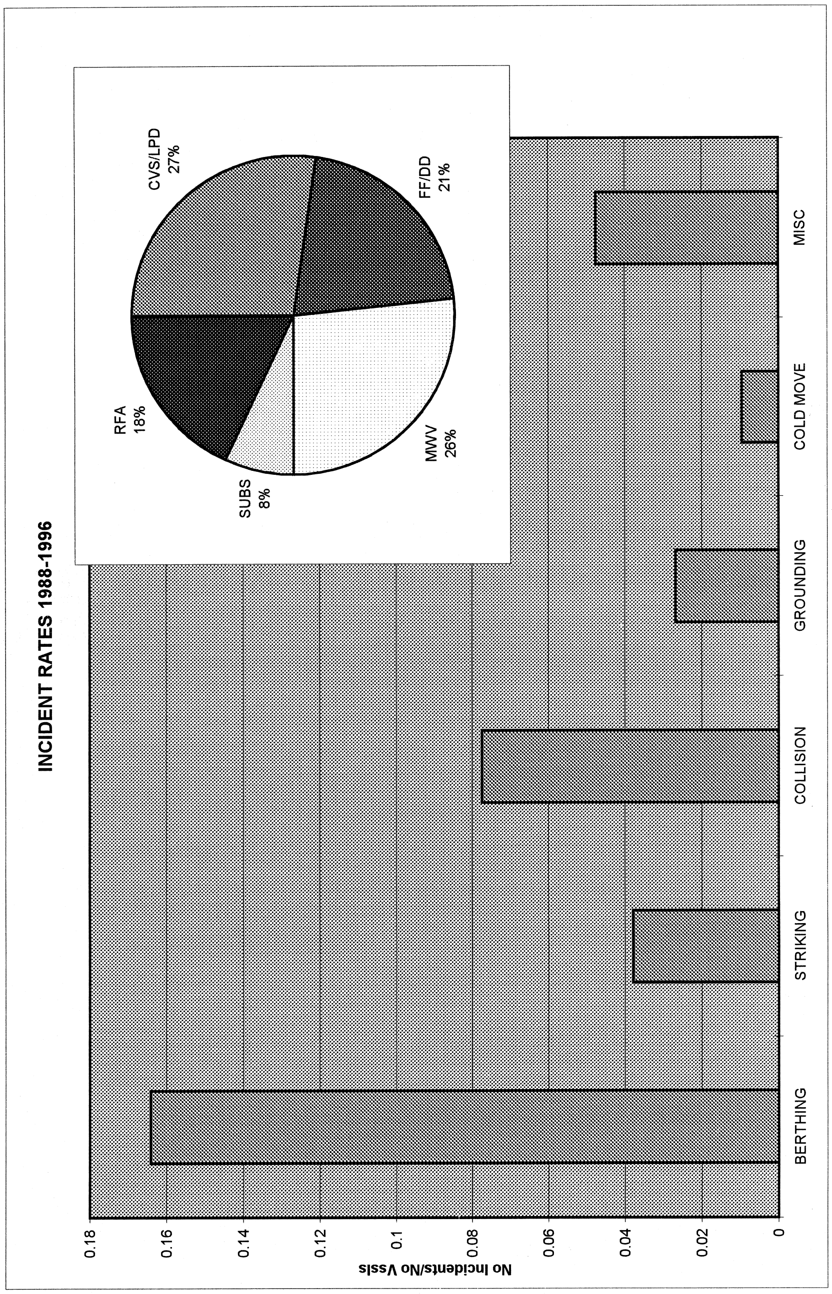
INCIDENT RATES 1988-1996
No Incidents/No Vssls
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
BERTHING
STRIKING
COLLISION
GROUNDING
COLD MOVE
MISC
CVS/LPD
27%
FF/DD
21%
MWV
26%
SUBS
8%
RFA
18%

Figure 1.

ship entries/departures. Predictably, the lowest incident rates were experienced in naval bases where port familiarity was important. Incident rates in UK commercial ports came out highest, and this is explained by the large number of minor bumps in small harbours (most notably from the MWV group visiting small fishing ports). No overall significant trends resulted from these figures, and the small sample size resulted in year-by-year distortions.

4.2.6. In general, small hull numbers distorted incident rates, but the CVS/LPD group came out as the vessels most at risk from a navigational incident. MWVs came second highest whilst FF/DDs and RFAs displayed an average risk. Submarines displayed the lowest risk. In simple terms, any given vessel had the following chance of suffering a navigational incident during any year:

CVS/LPD	56%
MWV	47%
FF/DD	37%
RFA	32%
Submarines	13%
Overall average	37%

CVS/LPDs had a higher incident rate involving the *Serious* (and worse) incidents whilst RFAs had the lowest rate. MWVs had the highest rate for *Minor* incidents. The reasons for these trends are not obvious. Modern warships are more expensive and complex than their predecessors and so a light knock nowadays may result in more extensive damage than has hitherto been the case. An example would be the vulnerability of the bow dome fitted to modern frigates that makes berthing alongside, however gentle, a risky business. Thus a relatively insignificant incident ten years ago, not even warranting a report, could cause extensive damage to a warship nowadays. To illustrate the analysis undertaken, two graphs are reproduced as Figs 1 and 2.

5. CONCLUSIONS. The provision of a user-friendly, navigational incident database for naval vessels has been a positive step forward in the recording and analysis of incidents. Following the signalled report from a ship, the data can be readily entered and further amplifying information may be added later as and when it becomes available. The primary aim of the database is to provide a modern data storage and retrieval system to record naval navigational incidents. The database can be accessed to conduct searches or observe trends and is a useful tool in monitoring navigation safety across the Fleet. At present, the database population is sparse for certain categories of vessels; therefore, any comparative analysis must be viewed with caution. It has been observed that incident trends, when plotted graphically, can show wild variations over time, and it is assessed that this is due to small statistical samples having a disproportionate effect. As time passes, and the data population grows, this effect is likely to ameliorate and more credence may be place on observed trends. To date, analysis has shown that certain categories of vessels are at higher risk of suffering an incident than others. Most notably the MWV and CVS/LPD groups are in this higher risk category, whilst submarines enjoy lower incident rates. Additionally, different vessel groups have different susceptability to grounding, berthing, striking incidents and collisions. However, the difference in incident rates between vessel groups is not significantly large when observed over the seven-year time span presently recorded in the database. Although collision rates show a distinct

INCIDENT SEVERITY COMPARISON BY YEAR

All Incidents

SEVERITY/YEAR	1988	1989	1990	1991	1992	1993	1994	1995	1996	TOTAL
MINOR	30	59	61	46	39	31	25	26	50	367
SERIOUS	1	1	3	1	2	6	5	7	7	33
SEVERE	2	0	0	0	0	1	2	1	2	8
LOSS	1	0	1	0	0	0	0	1	0	3
TOTAL	34	60	65	47	41	38	32	35	59	**411**
No of Vessels	184	187	180	167	147	137	134	122	121	
Incident Rate	**0.18**	**0.32**	**0.36**	**0.28**	**0.28**	**0.28**	**0.24**	**0.29**	**0.49**	

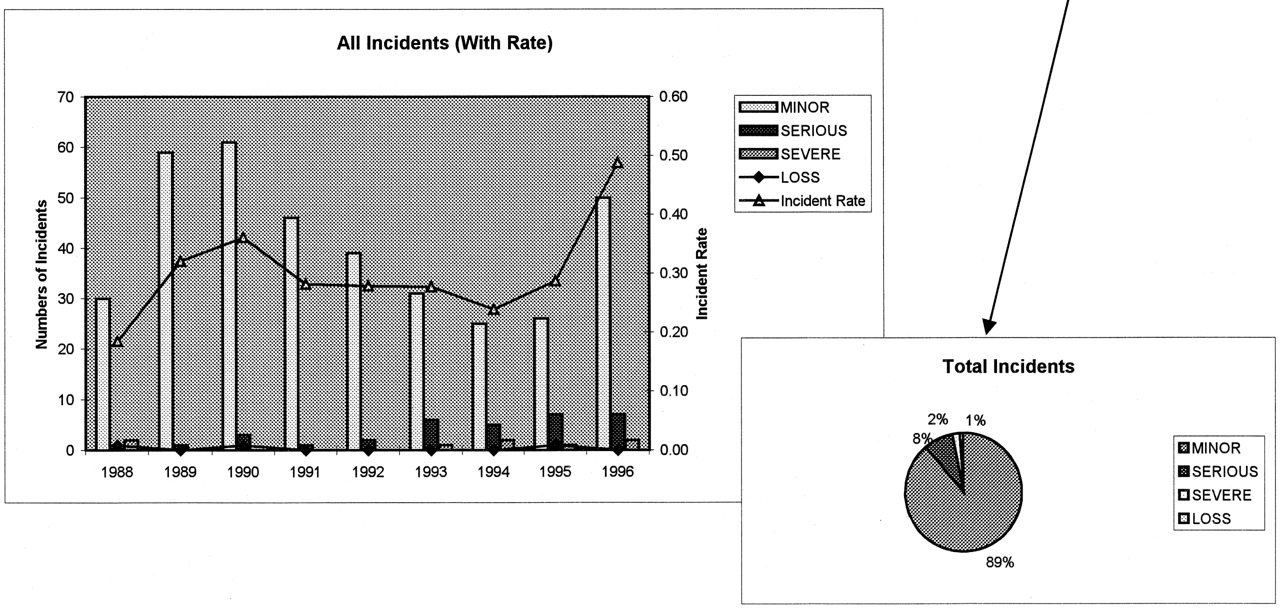

Figure 2.

increase over time, this trend could quite easily be reversed in future. Clearly more work is required in assessing whether the presently-observed trends continue, and this would best be undertaken when ten years of data has been accrued. In the meantime, the data is being used, with caution, to educate future commanding officers and bridge teams about the navigational risks inherent in specific circumstances they might face in future. Although it may not yet be a precise science, it is a step in the direction of safer ship operations and is based on empirical data.

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KEY WORDS

1. Military. 2. Safety. 3. Accidents. 4. Data.