ACCIDENT DATABASE REVIEW OF HUMAN ELEMENT CONCERNS: WHAT DO THE RESULTS MEAN FOR CLASSIFICATION?

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SUMMARY

A project is underway to identify publicly available databases of marine accidents, review their structures, and analyze the contents. The objective of the project is to better understand the role of the human element in accident causation and consequence mitigation. With this knowledge, it is thought that classification societies and the maritime industry can better direct their efforts with regard to rulemaking, regulations, and establishing and applying design guidance. The analysis of accident data initially included those accidents associated with commercial vessels in US territorial waters, as investigated by the United States Coast Guard (USCG). Subsequently, accident data from Australia, Canada, Norway, and the UK have been reviewed and analyzed.

Based on three years of review, the following conclusions have been drawn:

- While the frequency of accidents is declining, human error continues to be a dominant factor in approximately 80 to 85% of maritime accidents.
- Failures of situation awareness and situation assessment overwhelmingly predominate, being a causal factor in the majority of those accidents attributed to human error.
- Human fatigue and task omission seem closely related to failures of situation awareness and the human errors and accidents that result.

This paper summarizes findings from the accident data reviewed and emphasizes findings related to human and organizational factors associated with accidents. The paper also outlines how the results of the data analyses are influencing the planned research and development activities at the American Bureau of Shipping (ABS) regarding the "human element."

1. INTRODUCTION

Considering the extensive presence of ships and humans at sea and the ostensible infrequency of major accidents, shipping might be said to be a rather safe industry. As shown by Figure 1, the trend over the past decade is one of steady decline in marine accidents leading to loss of property, life, and to environmental damage [1], however, the magnitude of damage inflicted by a major shipping accident increases the public attention paid to those accidents, and negatively influences the perceived safety of shipping [2].

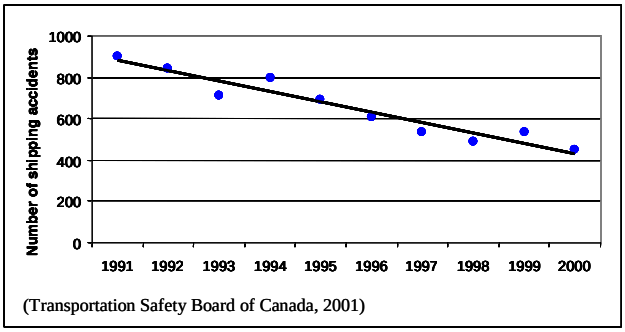

Figure 1: Shipping Accidents from 1991 to 2000

Nearly every accident that involves property loss, death or injury, or environmental damage is subjected to an accident investigation, if only to identify liability and culpability. There are, however, other uses for accident and incident data. One of these is to find, assess, and review these data to identify those factors associated with human error in maritime incidents / accidents. A major benefit to do so is to identify causal factors that in recent history are closely related to incidents and accidents. Findings that ensue from the analysis can then be used to: support the planning and guiding of rulemaking by classification societies; directing investment in safety activities, and; directing safety research. Another benefit can be the development of human factors / ergonomics methods to collect and analyze human-error-related root causes for near misses and marine accidents, and to formulate methods where these can be stored in databases to be used in the ongoing analysis of trends [3, 4, 5].

This paper presents the findings of a three-year project to identify publicly available databases of marine accidents, review the database structures, and analyze the contents.

The objective of the project is to better understand the role of the human element in accident causation and consequence mitigation.

2. OBJECTIVES AND SCOPE

The overall objectives of the project were to:

- Identify maritime accident and near-miss databases.
- Where possible, access the databases and assess the data content and organization.
- Analyze the data for trends and patterns related to human performance, error, and accident causation.
- Identify research topics and projects, based on accident data and stated or inferred causal factors.
- Support development of improved accident investigation tools and root cause taxonomies.
- Produce a yearly report to update marine industry trends regarding incident causation, including the human element contribution.

3. METHODOLOGY

The ongoing objectives were to continue to survey databases related to marine accidents and near misses, and to assess the extent to which each contained accident causation information suitable for analysis in terms of the general accessibility of the data (much of which is proprietary) and the structure of the data (constrained forms, free fill forms, or narrative descriptions).

Accident and near miss data from the following have been reviewed and selected for analysis:

- The Marine Accident Investigation Board (MAIB, United Kingdom)
- Transportation Safety Board – Canada (TSB-Canada)
- Australian Transportation Safety Board (ATSB)
- The Nautical Institute's Marine Accident Reporting Scheme (MARS).
- The Det Norske Veritas Worldwide Offshore Accident Database (WOAD).

Most of the above sources present accident information in the form of narrative reports [6]. These were analyzed by reading each report, identifying the stated (or sometimes, inferred) accident root causes, and recoding them into a simple database according to accident causal factors. From there calculation of counts and frequencies within the data sets served as the analysis. For the cases of the USCG database and the WOAD database, accident data are coded within the context of a forced accident causation taxonomy. For these databases, accident root causes were analyzed by calculation of counts and frequencies within the data sets.

4. FINDINGS

4.1 USCG ACCIDENT DATABASE

Figure 1 presents the overall accident causation data for 71,470 records in the USCG database over the period 1991 to 2001, suggesting that human error was primarily responsible for approximately 46% of maritime accidents.

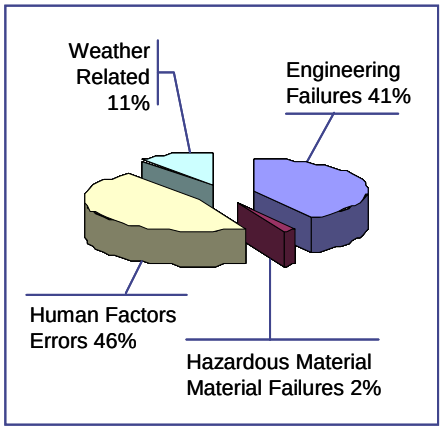

Figure 1. Top Level Failures (USCG Data)

Figure 2 presents accident data for the same period for those accidents and incidents cited as being primarily caused by human error. Shown in the figure is the top-level breakdown of near root causes for the human error category. Figure 2 clearly suggests failures of situation awareness and situation assessment being the primary human error, with about 70% of human errors falling into this category.

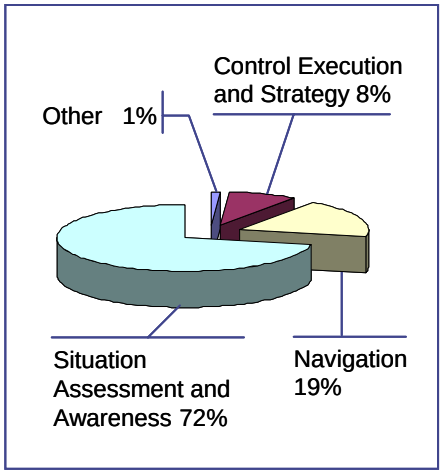

Figure 2. Human Errors – Tankers and Freighters (USCG Data)

There are no "cause – effect" relationships to be discerned from USCG data. The database contains quasi-statements such as:

- Control Execution - Navigation into Close Quarters - Improper.
- Situation Assessment - Other Vessel Intent – Misunderstood
- Situation Awareness - Radar Signals – Ignored.

The difficulty with statements such as these "root causes" is in devising means to obviate the conditions leading to an incident. In the above example, it is difficult to identify means to obviate the influences of "improper" or "ignored". Lacking *causes*, we have nothing to directly address. (How does one fully address a cause such as 'Radar Signals Ignored?').

Established causes need characterizing phrases such as: excess fatigue, awkward information design, inaccessible controls, high-acute workload. For example: "Radar Signals – Ignored – Due to High Workload." Workload is something that can be manipulated, on the other hand, "Ignored" cannot.

Inferences as to causes, however, may be had in the USCG data. For instance, situation-awareness failure appears to be a significant factor for human error in maritime accidents. According to the analyses presented here, significant factors associated with situation awareness failures include:

- Cognitive and decision errors, and Knowledge-Skill-Abilities errors
- Task omissions
- Risk taking.

The above are all commonly suspected to be artifacts of fatigue, influencing

- Likelihood of task omission to reduce required human effort, related to lack of situation assessment and awareness
- Decisions and perceptions of outcomes in relation to risk, related to situation assessment
- Risk tolerance and risk perception
- Stress, influencing decision making, particularly related to forced decision-making due to time constraints, or prematurely making decisions on partial or inaccurate data
- Workload, influencing likelihood of task omission to meet operational goals and objectives within schedules, related to risk-perception errors and risk taking, fatigue, and failures of situation awareness.

4.2 MAIB - TSB CANADA - ATSB REPORT REVIEWS

ABS acquired 150 accident reports from the web site of the Australian Transportation Safety Bureau, 100 accident reports from the Web site of the Canadian Transportation Safety Board (TSB Canada), and 100 accident reports from the United Kingdom Marine Accident Investigation Board. ABS read these 350 reports and summaries and attempted to codify the causal factors of each accident [10, 11, 12, 13]. According to MAIB data, 82% are associated with the occurrence of human error, compared to 85% as represented by the ATSB data, and 84% according to the TSB Canada data.

By way of example, Table 1 identifies the causal factors of ATSB accident reports, as assessed by the author.

Causal Factor	Count
Task omission	16
Situation assessment and awareness	15
Knowledge, skills, and abilities	13
Mechanical / material failure	6
Risk tolerance	5
Bridge resource management	5
Procedures	5
Watch handoff	5
Lookout failures	5
Unknown cause	5
Communications	4
Weather	4
Navigation vigilance	3
Complacency	3
Fatigue	3
Maintenance related human error	3
Business management	3
Commission	2
Manning	2
Uncharted hazard to navigation	1
Substance abuse	1
Total	109

Table 1 Causal Factors of Shipping Accidents (ATSB Data)

In Table 2, the above causal factors were qualitatively grouped according to the judgment of the author. While the groupings were based on expert opinion, they are considered to be reasonable for the purposes of the present analysis. It is readily acknowledged that the causal factors of Table 2 can be otherwise grouped according to differing opinion, assumptions, or interpretations. For example, whether "Task Omissions" belong to the risk or some other group is left to the reviewer. In this analysis "Task omissions" are placed under risk since the reading of the reports suggest these omissions are due to complacency or risk taking, rather than other reasons such as forgetting. The reader is advised to consider and interpret any implications of Table 3 accordingly.

There was a high degree of consistency among these three sources as to how root causes clustered. Figure 3 presents a sample of root cause groups based on the MAIB reports.

Situation Awareness Group	Situation assessment and awareness	15
	Knowledge, skills, and abilities	13
	Commission	2
	Total	**30**
Management Group	Fatigue	3
	Communications	4
	Bridge resource management	5
	Procedures	5
	Manning	2
	Business management	3
	Watch handoff	5
	Total	**27**
Risk Group	Risk tolerance	5
	Navigation vigilance	3
	Complacency	3
	Substance abuse	1
	Task omission	16
	Lookout failures	5
	Total	**33**
Maintenance Human Errors	Maintenance human error	3
	Total	**3**
Non Human Error Group	Uncharted hazard to navigation	1
	Material failure	6
	Weather	4
	Unknown cause	5
	Total	**16**

Table 2. Accident Causation by Qualitative Groupings (ATSB Data)

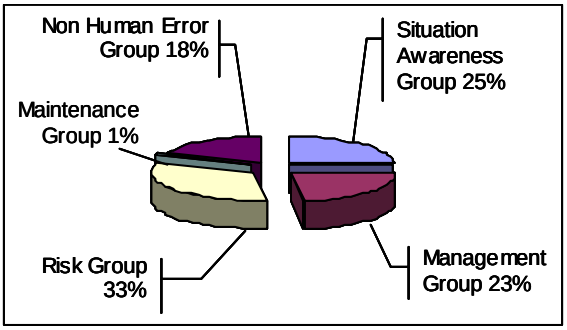

Figure 3. Accident Causation by Qualitative Groupings of Root Causes (MAIB)

Other observations from the review of the MAIB, ATSB, and TSB Canada reports include:

- Insufficient knowledge, skills, and abilities noted were typically due to assignment of duties to new and inexperienced mates. There were few cases where Masters possessed insufficient KSAs.
- Bridge Resource Management failures tended to be due to communications or failure to generate passage plans, and where plans were generated, the plans only addressed entrance buoy-to-entrance buoy (as opposed to dock-to-dock).
- Situation assessment and awareness continues to be the dominant factor in failures of human performance, consistent with the findings of the USCG data, and the situation awareness failures were typically due to task omission.
- There were many task omissions related to position fixing in restricted waters, with pilots, masters and mates relying on a single means to fix a position (ARPA or RADAR or GPS). This may suggest high workload and fatigue on the part of those personnel

4.3 POLLUTION INCIDENTS IN THE STATE OF CALIFORNIA

A pollution analysis was performed for the State of California based on USCG Accident Database from 1991 to 2001, as reported within the USCG Marine Safety Management System database. There were approximately ten thousand records involving the state of California. The analysis excluded many types of vessels (recreational, school, public, recovery, research, and unspecified vessel types), leaving about 3.5 thousand State of California records of interest. Figure 4 presents primary causes of California pollution as revealed in the USCG database. Figure 5 presents primary human error causes for California pollution events.

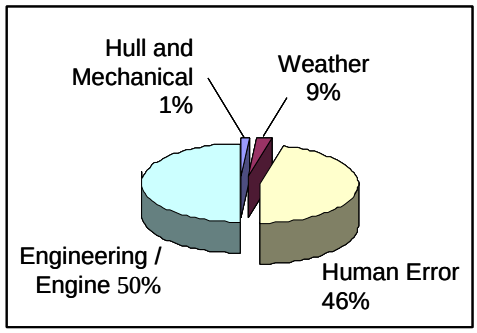

Figure 4 Primary Causes – California Pollution (USCG data)

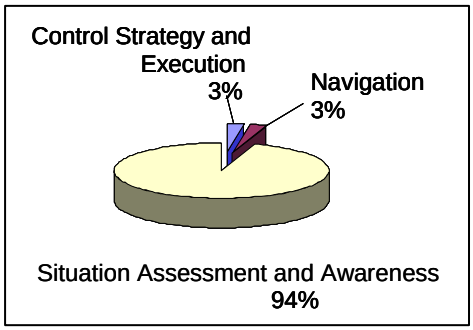

Figure 5. Human Errors – California Pollution (USCG data)

4.4 MARINE ACCIDENT REPORTING SCHEME

Quoting from the Nautical Institute's web site:

> The Marine Accident Reporting Scheme is a confidential reporting system run by The Nautical Institute. The aim of the scheme is to allow full reporting of Accidents (and Near Misses) without fear of litigation. It is hoped that with this free information exchange valuable lessons may be learnt by others and future similar accidents avoided. [7]

As MARS reports are anecdotal, reports generally cannot be used to analyze and identify specific root causes of the events reported, since:

- The mariners involved in accidents and near misses are generally the reporters, and likely are not expert in accident investigation and in the identification of root causes.
- Reports are generally written by those mariners directly involved in near misses and accidents, and may therefore involve bias.
- Little or no root cause analysis is reported.
- Reports are frequently unstructured, and ad hoc. Mariners using MARS are free to report whatever they wish. In some cases very well conceived summaries of an event sequence are provided where true root causes can be inferred. In other cases, what is provided are unsubstantiated and sometimes emotionally charged opinion.

About a third of the approximately 650 MARS reports were read and reviewed. The chief observation is that people related issues predominate as suggested causes, overwhelming equipment failures and conditions of weather and sea. Common themes that emerged upon review of the MARS reports tended to be as follows:

Failure to follow the Rules-of-the Road. Many near misses are reported when the keep way vessel is reported as being forced to take action at the last moment. In reading those reports, two prevailing mariners thoughts regarding causes emerge. First is risk taking and risk tolerance, where those reporting suggest that the other ships officers "know better" and opine that for reasons of expediency or complacency they ignore the rules. Second is lack of knowledge or experience, wherein the rules are not followed because they are not well understood by the other ship's mariners. Whether the reporting mariners correctly assessed the conditions on the other bridge(s) is tenuous, however, the finding to be had is that there is a definite trend in reporting by these mariners that the "rules-of-the-road" are frequently ignored or abused. As one mariner put it: "It is sadly obvious that half the world's shipping is wandering around expecting the other half to keep out of their way."

Bridge Resource Management (BRM). Communications and Master – Pilot relations are noted in MARS reports. Communications failures reported typically involve the failure to communicate and language difficulty. Another common BRM issue involves the relationship between the Master and Pilot, where reports of misunderstood or uncertain command, professional discord and disagreement, and meager communications are noted.

Bridge Automation. There is some concern expressed about Bridge automation and complacency, with undo reliance on global positioning systems, electronic charting systems, and collision avoidance systems leading to the exclusion of using other means to fix a position. One area of concern regards Global Marine Distress Signaling System, with the number of false alarms running at a reported 97%, many mariners would seem to prefer the return of a radio operator. There are reports of automation resulting in reduced manning, attend that with the notion that automation often *increases* workload for cases where automation augments, rather than replaces, older technology. Automation, manning, and workload all impinge heavily on the next theme, lookouts.

Lookouts. A number of reports discuss the inadequacy of lookouts. It seems, from several of the MARS reports that lack of a proper lookout is common. About 5% of the MARS entries mentioned the lack of a proper lookout, including no apparent lookout at all. Clearly, as mariners are fond to say, "the chart is not the sea," and neither is a Global Positions System, Electronic Charting System, radar, or Electronic Chart Display Information System. In terms of human learning and motivation, looking out the bridge windows is much like a task of opportunity, being performed as time and energy permits. In terms of classic human learning, looking out is not particularly rewarding – so much time looking out, so little to see (in an operational sense). It is easy to perceive how that task can be shunned to perform some seeming more demanding (and usually auditable) task. Quoting from a MARS report, "The tanker ploughed on and appeared to be deserted, with no one on deck and, as far as could be seen no one on the bridge . . . The tanker passed 2 cables on our port quarter and steamed straight down our wake." Reports from other sources also note a frequent lack of a proper lookout. Quoting from MAIB, "The initiating cause of the collision was . . . [Vessel A] chief officer was unaware of the approach of his ship to [vessel B], and [vessel B] bridge team was unaware of the approach of [vessel A]." In other words, the collision was a surprise on *both* bridges.

4.5 WORLD WIDE OFFSHORE ACCIDENT DATABASE

Det Norske Veritas (DNV) started in 1970 to systematically collect offshore accident information from

all parts of the world. The data in WOAD have been publicly available since 1983. According to DNV:

> Safety of offshore units involved in exploration, development and production is of considerable concern to employees, companies and authorities. Risk and reliability analyses are applied extensively as a means of providing a basis for decisions in the offshore business. Hence, studies of past accidents and application of accident statistics are important in the work for improving safety. Knowledge of how and why accidents happened and how they were - or could have been mastered - is vital in planning how to avoid them in the future. [8]

Also according to DNV, "WOAD is presently the largest [offshore accident database] of its kind in the world. The information stored is important as basis for risk assessment and safety planning offshore."

ABS examined the WOAD data from January 1970 to April 2003. In all, 4,660 accident records exist in WOAD. At the highest level, WOAD tracks accident causes according to the following constrained list:

- Engineering cause,
- Human cause,
- Human and engineering cause,
- Cause not specified.

Table 3 shows the breakdown of these accidents by root cause as recorded in the database.

Engineering Cause	2841
Human Cause	872
Human and Engineering Cause	378
Not Specified	1352

Table 3. Causes of Offshore Accidents - WOAD

Consistent with the R&HF 2002 and 2003 reports on accident causation, approximately twice as many accidents are directly caused by human error compared to accidents that indirectly involve human error. Not consistent with the earlier reports is the figure for overall contribution of human errors to accidents. Earlier reports concerning shipping suggested that about 85% of accidents involve human error. According to the WOAD data, that figure is about 23%. Differing risks (offshore vs. shipping), functions, manning, operations and the like may explain this. In addition, differences in the means of accident investigation and reporting likely influenced this finding. The USCG is highly rigorous in the means and activities in accident analysis and reporting, and the root cause taxonomy of the USCG database is more granular than is WOAD's. Either of these may explain the difference in apparent accident rate due to human error.

5. DISCUSSION AND CONCLUSIONS

Comparing the findings of the reviews of MAIB, ATSB, and TSB Canada reveals some interesting consistencies. First is that management practices, failures of situation awareness, and risk taking/risk tolerance each represent about 25% of accident causation for their respective source (MAIB, ATSB, and TSB Canada). Second is that for each of these sources, fully and consistently 80 to 85% of all accidents are either directly initiated by human error or are associated with human error by means of inappropriate human responding to threat situations. Of these, about 50% of maritime accidents were *initiated* by human error, and another 30% of were *associated* with human error. This means that in each case some event other that human error initiated an accident sequence, and that failures of human performance led to the failure to avoid an accident, or to mitigate its consequences. In other words, conditions that should have been countered by humans were not adequately addressed.

Comparing the data from these sources to the ongoing findings of the USCG accident database, failures of situation awareness are credited with more than 60% of all accident causes. For MAIB, ATSB, and TSB Canada, on the other hand, this figure is about 25%. Note however, that for these sources of accident data, management failures are identified as a causal factor in approximately 25% of accidents. Within the USCG database, there is no coded category for management induced error. It may be that accident investigators populating the USCG data base, lacking a management causal category, instead use situation assessment or awareness to codify those management causes. There really is no cleaner alternative within the USCG database. If this is the case (tenuous though it may be, and it is freely admitted that this assumption is conjectural and arguable), then if management causes and situation awareness causes are collapsed, all four databases would be remarkably consistent. The MAIB, et. al. accident data sources do, however, point to a need to address management practices and policies as an accident cause in accident investigation and subsequent archiving of findings.

While there was general consistency of the findings of data sources (MAIB, TSB-Canada, ATSB, and USCG) for previous years, WOAD presents different findings. Offshore data from WOAD suggest that human error is associated with 23% of accidents and near misses, significantly less than the levels suggested by USCG, MAIB, and the TSB's. Considering the offshore data from WOAD, for accidents involving human error, about twice as many accidents are primarily caused by human error as opposed to being associated with human error. Further, USCG data on offshore pollution events in California suggests that 46% are caused or associated

with human error. The difference in findings between the USCG and WOAD data may lie in the dissimilar reporting schemes used, the USCG hierarchy of accident causation being much more sophisticated in specifying diverse human related accident causes.

MARS contains much interesting information, but seems too unstructured and undisciplined to be of value in reliably identifying root causes of a nature sufficient to guide ABS and R&HF in rule making or in identifying research themes and requirements. MARS has great value in providing a *sense* of what are the present concerns of mariners, and MARS is laudable for providing a forum to report near misses as well as accidents and casualties. In the MARS databank: lack of competence, knowledge and ability; fatigue, workload, and manning, complacency, and; risk tolerance seem to be indicted by mariners as the main culprits in accidents and near misses.

These analyses have lead to a variety of ABS activity over the course of this project. Two of the more significant activities are discussed below.

Root Cause Analysis Methods and Tools. The analysis of marine incidents suggests that about 80% of incidents are related to human error, yet many ship owners and operators do not have a standardized method for identifying root causes such as human error. It is felt that ABS and its clients having at hand a standard method for conducting incident investigations that will uncover root causes related to incidents will have significant long range benefits to safety. The uncovering of root causes related to incidents may also have long-range benefits to ABS Rules and the rule development process. Such data could then be used by ABS to modify rules, better understand the effectiveness of ABS Rules on safety, and develop new tools and techniques to address industry issues. The Marine Root Cause Analysis Technique (MarCAT) and associated software tool will allow ABS and ABS Clients to analyze incidents, monitor trends (with industry participation) and take preventative and corrective actions to decrease future losses and improve safety, reliability, and efficiency. These tools will specifically acknowledge human error causes along those addressed in the body of this report (e.g., failures of situation awareness, communications, KSAs, and so forth).

On a final note, MarCAT requirements and design acknowledge the accident investigation and reporting goals of the International Maritime Organization's *International Safety Management System Code*, and the *International Ship and Port Facility Security Code.*

Provision of BRM guidance. A need was recognized to provide widely available guidance for the shiping industry addressing bridge resource management, mariner fatigue, communications, and situation awareness. This was initiated via a series of literature reviews on these topics. The reviews in turn lead to the development of ABS guidance addressing bridge resource management, situation awareness, and fatigue countermeasures. That guidance is currently in draft form. As an adjunct to the guidance on BRM, ABS is pursuing two additional needs:

- Research and development of a tool to predict mariner fatigue over the course of a voyage plan
- Identification and validation of mariner fitness-for-duty test tools (to test for fatigue).

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