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Maritime Accidents and Human Performance: the Statistical Trail

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Abstract

A multi-year project has been undertaken by the American Bureau of Shipping to identify publicly available databases of marine accidents, review the database structures, and analyze the contents. The main objective of the project is to better understand the role of the human in accident causation and consequence mitigation. This knowledge can be used to determine where the American Bureau of Shipping (ABS) and ship designers and operators might direct their efforts with regard to rulemaking, establishing design criteria and standards, planning operations, or directing future ship design or research and development efforts.

The technical task objectives of the project are to identify maritime accident and near miss databases and where possible: access the databases and assess the data content and organization; analyze the data for trends and causal 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 accident investigation methods that better recognize human error, produce a yearly report to update marine industry trends regarding incident causation.

Findings of this project noted that human error continues to be the dominant factor in maritime accidents and that among all human error types classified in numerous databases and libraries of accident reports, failures of situation awareness and situation assessment overwhelmingly predominate.

According to the data analysis, approximately 50% of maritime accidents are initiated by human error, while another 30% of maritime accidents occur due to failures of humans to avoid an accident. In other words, in 30% of maritime accidents, conditions that should have been adequately countered by humans were not.

It was also noted that there is a consistency of causal factor findings among the data and reports within the US, UK, Canada, and Australia.

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1.0 Introduction

This paper discusses the second year effort of a multi-year project that has been undertaken by the Safety Assessment and Human Factors Department of Corporate Technology 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 in accident causation and consequence mitigation. This knowledge can be used to determine where the American Bureau of Shipping (ABS) and ship designers and operators might direct their efforts with regard to rulemaking, establishing design criteria and standards, planning operations, or directing future research and development efforts. For vessel designers, builders, and operators, this effort will provide relevant information regarding the contribution of the human element in marine accidents and incidents. In the first year, the analysis of accidents included those associated with commercial passenger vessels, freighters, tankers, tugboats, and offshore supply vessels for accidents that occurred in US territorial waters, as investigated by the United States Coast Guard (USCG). Excluded from the analysis were incidents involving barges, recreational boats, ferries, fishing vessels, offshore installations, military vessels, and public, research and training vessels. In addition to the continued analysis of the US Marine Safety Management System (MSMS) data, accident data from the UK, Canada, and Australia were reviewed and analyzed. Also analyzed were automated means to examine the accident trends as contained in written reports that exist as electronic documents.

The overall objectives of the project are 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 causal patterns related to human performance, error, and accident causation.
- Identify research topics and projects based on accident data and stated or inferred causal factors.
- Produce a yearly report to update marine industry trends regarding incident causation, including human element contribution. The report is to be distributed within ABS and offered to the shipping industry.

1.1 Background

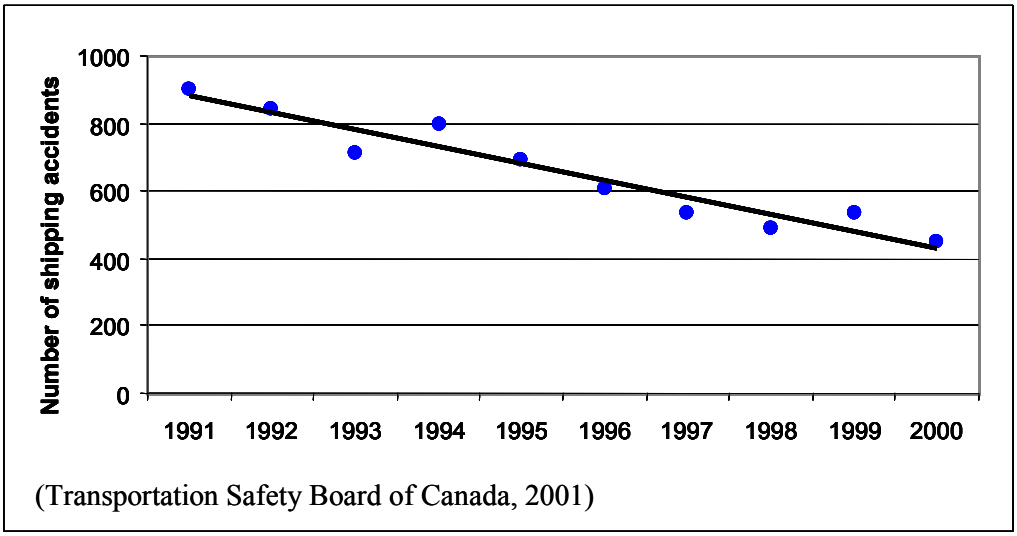
Considering the billions of tons of material shipped on the high seas every year, the millions of miles of wake left behind, and the seeming infrequency of major accidents, shipping might be said to be a rather safe industry. As shown in Figure 1, the trend over the past decade is one of steady decline in marine accidents leading to loss of property, life, and environmental damage (Transportation Safety Board of Canada, 2001). 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 (Iarossi, 2003). Considering the past several decades, accidents such as the Erica, Exxon Valdez, Prestige, Amoco Cadiz, Braer, and Sea Empress have repeatedly put shipping safety in the public and political eye and have sparked the writing of new laws or amendments to existing laws and international conventions.

In general, accidents that involve property loss, death, injury, or environmental damage are subjected to investigation, often with the objective of identifying liability and culpability. There are, however, other uses for accident and incident data. One of these is to find, assess, and review existing maritime incident / accident databases to identify causal factors and trends associated with those maritime events. A major benefit of so doing is that it will allow analyses be conducted, and the results of such analyses can then be used to support the planning and guiding of rulemaking by classification societies, directing investment in safety activities, and directing safety research. In ABS, this responsibility comes under the Safety Assessment and Human Factors (SAHF) Group within Corporate Technology. Under an on-going research project, it has been developing 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.

FIGURE 1

Shipping Accidents from 1991 to 2000



(Transportation Safety Board of Canada, 2001)

The objective of the project is to better understand the role of the human element in accident causation and consequence mitigation. This knowledge can be used to:

- Determine where the shipping industry might direct efforts with regard to rulemaking and standardization, and directing future research and development efforts.
- Offer a report to vessel designers, builders, and vendors that provides relevant information regarding the contribution of the human element in marine accidents and incidents.

As in the first year, the analysis of accidents included those associated with commercial passenger vessels, freighters, tankers, tugboats, and offshore supply vessels for accidents that occurred in US territorial waters, as investigated by the United States Coast Guard (USCG). Excluded from the analysis were incidents involving barges, recreational boats, ferries, fishing vessels, offshore installations, military vessels, and public, research and training vessels. In addition to the continued analysis of the US Marine Safety Management System (MSMS) data, accident data from the UK, Canada, and Australia were reviewed and analyzed.

1.2 Scope

The scope of the project is 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 causal patterns related to human performance, error, and accident causation.
- Identify research topics and projects based on accident data and stated or inferred causal factors.
- Produce a yearly report to update marine industry trends regarding incident causation, including the human-element contribution. The report would be distributed within ABS and offered to the shipping industry.

2.0 Methodology

The project is being performed in three phases, each described below. This paper describes the interim product of Phase 3.

The objectives of Phase 1 were to survey accident and incident databases related to marine accidents and to assess the extent to which each contained accident causation information. The product of Phase 1was a report identifying a myriad of databases, assessments of each, and recommendations as to which databases should initially be accessed and the contents analyzed (Jones, 2002). That report is contained as an Appendix in the ABS Technical report: SAHF 2003-01 *Review and Analysis of Accident Databases: 1990 – 1999 Data*.

The objective of Phase 2 was to perform an analysis of the accident data in the Maritime Safety Management System of the United States Coast Guard (USCG).

The Phase 3 effort required acquiring updates of accessible databases, and to then repeat the analyses using procedures defined in Phase 2. This paper presents the results of reviews and analyses of Marine Investigation Module (MINMod) the MSMS database, MAIB accident reports, Canadian Transportation Safety Board (TSB Canada) accident reports, and Australian Transportation Safety Bureau (ATSB) accident reports.

3.0 Findings

3.1 Review of ATSB Accident Reports

ABS acquired 150 accident reports from the web site of the Australian Transportation Safety Bureau (ATSB). SAHF read 100 reports and summaries and attempted to codify the causal factors of each accident. Based on that review, the Data in Table I were identified as primary root causes.

3.2 Review of TSB Canada Reports

ABS acquired approximately 100 accident reports from the web site of the Canadian Transportation Safety Board (TSB Canada). SAHF read these reports and summaries and codified the causal factors of each accident in the same manner as the ATSB reports. Based on that review, the data in Table III were identified as primary or contributing root causes. Note that these are also consistent with the findings of the analysis of the MINMod data within the USCG Marine Safety Management System and the ATSB data.

In Table IV, below, the above causal factors are qualitatively grouped in the same manner as the ATSB findings.

According to TSB Canada data, 84% are directly *associated* with the occurrence of human error, compared to 85% as represented by the ATSB data.

3.3 Review of United Kingdom Marine Accident Investigation Board (MAIB) Reports

ABS acquired 100 accident reports via e-mail from the United Kingdom Marine Accident Investigation Board (MAIB). SAHF read these reports and summaries and codified the causal factors of each accident in the same manner as the ATSB and TSB Canada reports. Based on that review, the data in Table V were identified as primary or contributing root causes.

Note that these are also consistent with the findings of the analysis of MINMod data, the ATSB data, and the TSB Canada data.

In Table VI, below, the above causal factors are qualitatively grouped in the same manner as the ATSB and TSB Canada findings.

According to MAIB data, 82% are directly *associated* with the occurrence of human error compared to 85% as represented by the ATSB data and 84% according to the TSB Canada data.

Figure 2 summarizes and compares the accident data for MAIB, TSB-Canada, and the ATSB.

TABLE I

Causal Factors of Shipping Accidents per Review of ATSB Accident Reports

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

In Table II, the above causal factors were qualitatively grouped according to the judgment of ABS staff.

TABLE II

Accident Causation by Qualitative Groupings for ATSB Data

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**

Total causes identified:	109
Mechanical failures, etc:	16
Percent Human Error related:	85%

TABLE III

Causal Factors of Shipping Accidents per Review of TSB Canada Accident Reports

Causal Factor	Count
Situation assessment and awareness	29
Bridge management / communications	18
Weather	15
Complacency	14
Business management	14
Task omission	13
Knowledge, skills, and abilities	13
Maintenance related human error	12
Mechanical / material failure	10
Risk tolerance	10
Navigation vigilance	10
Fatigue	7
Design flaw	6
Procedures	5
Lookout failures	5
Inspection error	5
Uncharted hazard to navigation	4
Unknown cause	3
Substance abuse	2
Commission	1
Man-machine interface	1
Manning	1
Watch handoff	0
Total	198

TABLE IV

Accident Causation by Qualitative Groupings for TSB Canada Data

Situation Awareness Group	Situation assessment and awareness	29
	Knowledge, skills, and abilities	13
	Commission	1
	Total	**43**
Management Group	Fatigue	7
	Bridge management / communications	18
	Procedures	5
	Manning	1
	Business management	14
	Watch handoff	0
	Fatigue	7
	Total	**52**
Risk Group	Risk tolerance	10
	Navigation vigilance	10
	Complacency	14
	Substance abuse	2
	Task omission	13
	Lookout failures	5
	Total	**54**
Maintenance Human Errors	Maintenance human error	12
	Design flaw	6
	Inspection error	5
	Total	**23**
Non Human Error Group	Uncharted hazard to navigation	4
	Mechanical / material failure	10
	Weather	15
	Unknown cause	3
	Total	**32**

Total causes identified:	204
Mechanical failures, etc:	32
Percent Human Error related:	84%

TABLE V

Causal Factors of Shipping Accidents per Review of MAIB Accident Reports

Causal Factor	Count
Situation assessment and awareness	16
Bridge management / communications	7
Weather	7
Complacency	5
Business management	2
Task omission	7
Knowledge, skills, and abilities	3
Maintenance related human error	1
Mechanical / material failure	4
Risk tolerance	4
Navigation vigilance	5
Fatigue	4
Design flaw	0
Procedures	1
Lookout failures	7
Inspection error	0
Uncharted hazard to navigation	0
Unknown cause	5
Substance abuse	1
Commission	3
Man-machine interface	1
Manning	4
Watch handoff	1

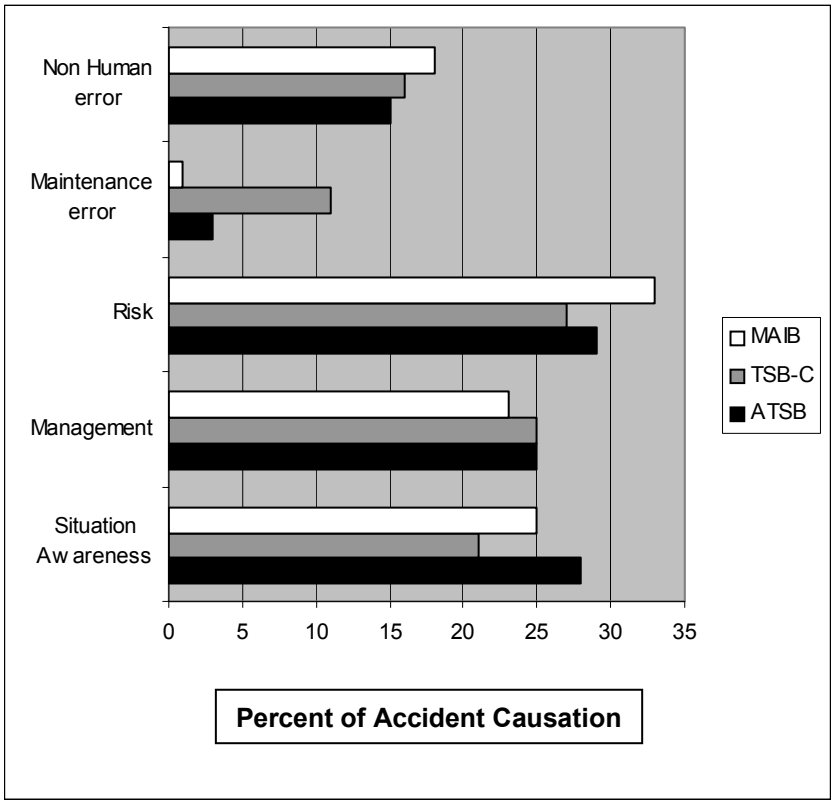
TABLE VI
Accident Causation by Qualitative Groupings for MAIB

Situation Awareness Group	Situation assessment and awareness	16
	Knowledge, skills, and abilities	3
	Commission	3
	Total	**22**
Management Group	Fatigue	4
	Bridge management / communications	7
	Procedures	1
	Manning	4
	Business management	2
	Watch handoff	1
	Man-machine interface	1
	Total	**20**
Risk Group	Risk tolerance	4
	Navigation vigilance	5
	Complacency	5
	Substance abuse	1
	Task omission	7
	Lookout failures	7
	Total	**29**
Maintenance Related Human Errors	Maintenance human error	1
	Design flaw	0
	Inspection error	0
	Total	**1**
Non Human Error Group	Uncharted hazard to navigation	0
	Material failure	4
	Weather	7
	Unknown cause	5
	Total	**16**

Total causes identified:	88
Mechanical failures, etc:	16
Percent Human Error related:	82%

FIGURE 2

Percentage of Accident Causation by Qualitative Groupings for MAIB, TSB-Canada, and ATSB Data



3.4 Additional MSMS / MINMod Data Analysis

Descriptions of USCG MSMS Database and MINMod Data Organization are presented in the Phase 2 report (ABS, 2003). This report expands on the Phase 2 report by updating the 1991 to 1999 data to include accident data for the years 2000 and 2001. In addition, ten-year trend data are presented.

Figure 3, below, updates the overall accident causation data for 71,470 accidents in the database over the period 1991 to 2001. The data are consistent with those found in the Phase 1 and 2 reports, which suggested that human error was *primarily* responsible for approximately 46% of maritime accidents.

Figure 4 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. These data are consistent with the findings of the Phase 2 report. Review of Figure 2 shows a consistent pattern in regard to failures of situation awareness and situation assessment as being the *primary* area of human error, with nearly 50% of human errors falling into these categories, which is consistent with the findings of the Phase 2 report.

FIGURE 3
Top-Level Accident Cited Causation for USCG MSMS Database

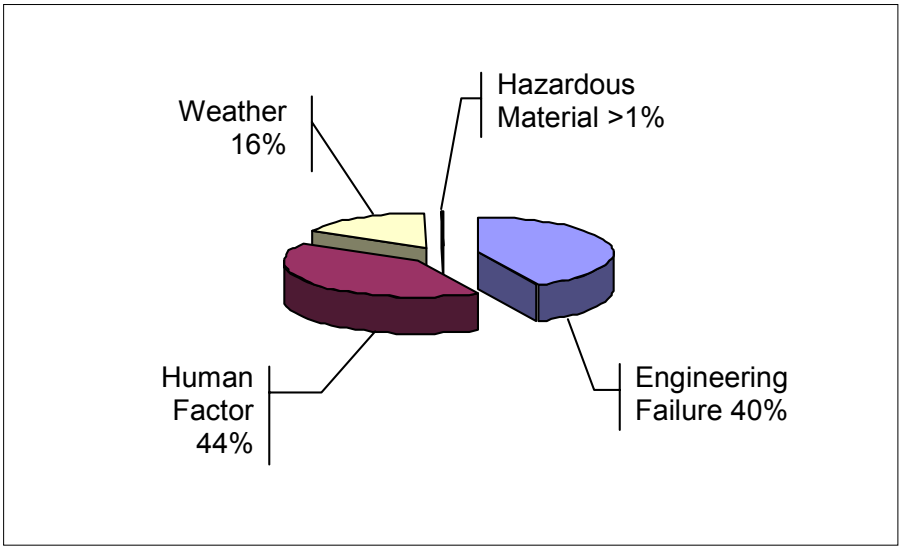


FIGURE 4
Top-Level Breakdown of Near Root Causes for Human Error Induced Accidents

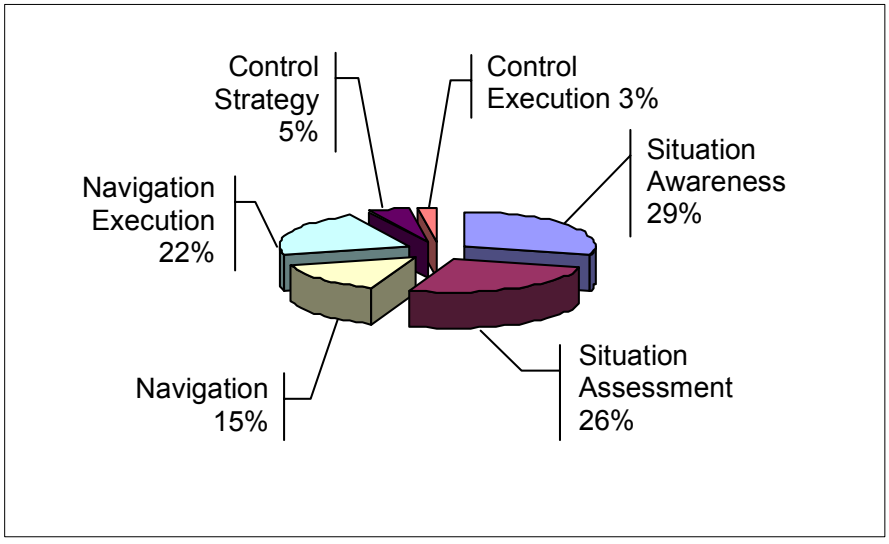
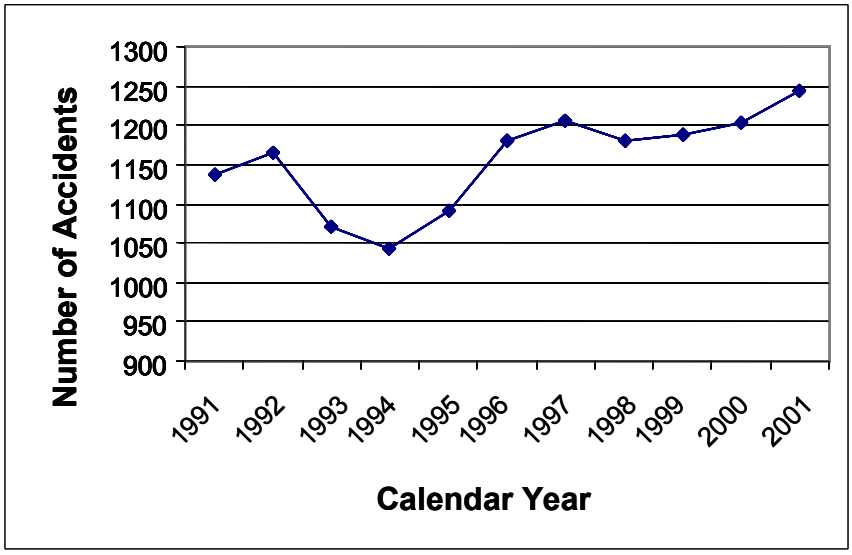


Figure 5 shows a ten-year trend in accidents categorized in MSMS as being attributable to human errors. Since the total number of accidents attributable to all causes varied each year, the data in Figure 5 have been normalized and reflect "expected values" for accident rates due to human performance failures as a function of exposure (in this case, normalized to a mean-expected-yearly value for accidents of all causal categories). As is evident from the figure, the indicated trend is unstable but suggests a slight increase in the number of accidents associated with human error. Over the past decade, the human element has received much scrutiny by the maritime industry, and whether the suggested trend is real or an artifact of increased sensitivity to human error on the part of accident investigators cannot be determined.

FIGURE 5

Ten-Year Trend in Accidents Categorized as Attributable to Human Error



4.0 Discussion

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 / 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 response to threat situations.

Comparing the data from these sources to the ongoing findings of the USCG MSMS, failures of situation awareness (29%) and assessment (26%) are credited with about 55% of all human errors. 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 MSMS, there is no coded category for management-induced error. It may be that accident investigators populating the MINMod data base, lacking a management causal category, instead use situation assessment or awareness to codify those management causes. There really is no alternative. If this is the case (tenuous though it may be), and management causes and situation awareness causes are collapsed together, then all four databases would be consistent. The MAIB, et. al. accident data sources do, however, point to a need to address management practices and policies as a specific accident causal entity.

Based on observations involving review of the MSMS, root cause analysis tools should be structured to accommodate multiple root and near root causes of accidents, consistent with the manner in which accidents typically occur. These tools should specifically acknowledge human error causes along with those addressed in the body of this report (e.g., failures of situation awareness, communications, KSAs, and so forth). Root cause analysis tools might be provided with a specific data field or checklist that specifically documents the adequacy of human performance related to an accident. A checklist might contain items such as:

- Was human error the initiating event leading to the accident?
- Did human error contribute to the accident, either by failure to avoid the accident or to increase its severity?

- Were human responses to conditions appropriate to avoid the accident or to reduce the severity of the accident?
- Did human error occur that influenced mitigation of the consequences of the accident?

ABS is currently involved in the development of an accident investigation tool that extensively incorporates human performance concerns in accident causation. The ABS Incident Investigation / Root Cause Analysis (II/RCA) tool provides a standardized methodology for investigating incidents and identifying root causes of all types. II/RCA will be supported by a software tool. The purpose of automating the methodology is to provide ABS clients a tool to produce consistent and standardized incident analysis findings and reports. Using this method and the software tool will allow clients to analyze incidents, monitor trends and take corrective actions to decrease future losses and improve safety, reliability and efficiency.

It can be inferred from the USCG data analysis, when contrasted with the MAIB, ATSB, and TSB Canada analyses, that about:

- 45% of shipping accidents are *primarily* due to human error (i.e., humans initiated the chain of events leading to an accident).
- 35% of accidents are initiated by events or situations other than human error, but where humans failed to adequately respond to those threats.
- 20% of accidents are due to external events or conditions, or mechanical failures that were appropriately attended to by the crew.

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 observations where Masters possessed insufficient KSAs
- Bridge Resource Management failures often tended to be due to 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 MINMod 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 is suggestive of high workload and fatigue on the part of those personnel.

5.0 Concluding Remarks

Human error continues to be the dominant factor in maritime accidents. It has also been supported that among all human error types classified in numerous databases and libraries of accident reports, failures of situation awareness and situation assessment overwhelmingly predominate, being a causal factor in a majority of the recorded accidents attributed to human error. There is a consistency of this finding among the data and reports within the US, UK, Canada, and Australia.

For all accidents over the reporting period, approximately 80 to 85% involved human error. Of these, about 50% of maritime accidents were *initiated* by human error. Another 30% of accidents were *associated* with human error, meaning that 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 mitigate its consequences. In other words, conditions that should have been countered by humans were not adequately addressed.

It seems clear that continued attention to the human element as a means to improve maritime safety is appropriate, and that initiatives to enhance situation assessment, reduce risk tolerance and risk taking behavior, improve awareness, and perform consistent incident investigations would be highly beneficial to the industry.

6.0 References

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