ABS Review and Analysis of Accident Databases

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Abstract

ABS undertook a project to identify publicly available databases of marine accidents, review the database structures, and analyze the contents. The objective of the project was to better understand the role of the human in accident causation and consequence mitigation. With this knowledge, it is believed that the American Bureau of Shipping (ABS) and vessel designers and operators can 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 in the second year of the project.

Based on two years of review, certain conclusions were drawn:

- Human error continues to be the dominant factor in marine accidents.
- Failures of situation awareness and situation assessment overwhelmingly predominate accidents, these being a causal factor in up to 70% of the recorded accidents attributed to human error. There is a high consistency of this finding among the data and reports within the US, UK, Canada, and Australia.
- Human fatigue and task omission are closely related to failures of situation awareness and human errors and accidents that result.
- For all accidents over the reporting period, approximately 80 to 85% of the accidents analyzed involved human error. Of these, about 50% of marine 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 mitigate it's consequences. In other words, conditions that should have been countered by humans were not adequately addressed.

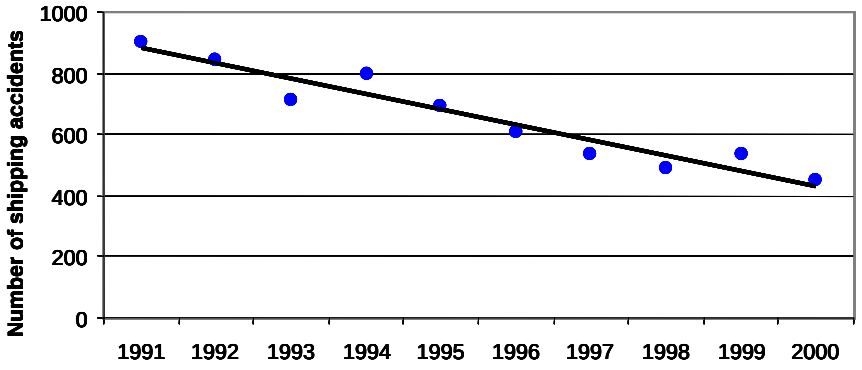
This paper will provide information with regard to findings from the various databases that were reviewed over the last two years. It will emphasize data related to the various human and organizational factors cited with accident reports.

1.0 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 has sparked the writing of new laws or amendments to existing laws and international conventions.

FIGURE 1

Shipping Accidents from 1991 to 2000



(Transportation Safety Board of Canada, 2001)

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 marine incident / accident databases to identify causal factors and trends associated with those marine 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 Risk & Human Factors Group within Corporate Technology. Under an on-going research project, this group 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.

The objective of the accident database 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 marine industry might direct efforts with regard to rulemaking and standardization, and future research and development efforts.
- Offer a information regarding the contribution of the human element in marine accidents and incidents.

Part of 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. Accident data from Australia, Canada, and the UK were also reviewed and analyzed.

2.0 Review of ATSB Accident Reports

ABS acquired 150 accident reports from the web site of the Australian Transportation Safety Bureau (ATSB). Over 100 reports and summaries were read and there was an attempt to codify the causal factors of each accident. Based on that review, causal factors were identified. These are contained in Table I, Causal Factors of Shipping Accidents per Review of ATSB Accident Reports.

In Table II, Accident Causation by Qualitative Grouping for ATSB Data, causal factors were qualitatively grouped according to the judgment of ABS staff in order to place causes into relevant subject areas such that common patterns amongst the various causes would be highlighted.

3.0 Review of TSB Canada Reports

ABS acquired approximately 100 accident reports from the web site of the Canadian Transportation Safety Board (TSB Canada). These reports and summaries were read and the causal factors of each accident codified in the same manner as the ATSB reports. Based on that review, the data in Table III, Causal Factors of Shipping Accidents per Review of TSB Canada Accident Reports, were identified as primary or contributing root causes. Note that these results 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, Accident Causation by Qualitative Grouping for TSB Canada Data, the 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.

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

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%

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

ABS acquired 100 accident reports from the United Kingdom Marine Accident Investigation Board (MAIB). These reports and summaries were read and the causal factors of each accident codified in the same manner as the ATSB and TSB Canada reports. Based on that review, the data in Table V, Causal Factors of Shipping Accidents per Review of MAIB Accident Reports, were identified as primary or contributing root causes. Note that these are also consistent with the findings of the analysis of USCG MINMod data, the ATSB data, and the TSB Canada data. In Table VI, the MAIB 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, Percentage of Accident Causation by Qualitative Groupings for MAIB, TSB-Canada, and ATSB Data, summarizes and compares the accident data from these three databases.

5.0 Review of USCG MSMS / MINMod Reports

Ten years of USCG MSMS Database and MINMod Data were also reviewed as a part of this project. Figure 3, Top-Level Accident Cited Causation for USCG MSMS Database**,** shows the overall accident causation data for 71,470 accidents in the database over the period 1991 to 2001. The data suggest that human error was *primarily* responsible for approximately 46% of marine accidents. Figure 4, Top-Level Breakdown of Near Root Causes for Human Error Induced Accidents, presents accident data for the same period for those accidents and incidents cited as being primarily caused by human error. Review of Figure 2, Percentage of Accident Causation by Qualitative Groupings for ATSB, TSB Canada, and UK MAIB Data, shows a consistent pattern with 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 from the other databases.

Figure 5, Ten-Year Trend in Accidents Categorized as Attributable to Human Error, shows a ten-year trend in accidents categorized in MSMS. 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 marine 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.

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 ATSB, TSB-Canada, and UK MAIB Data

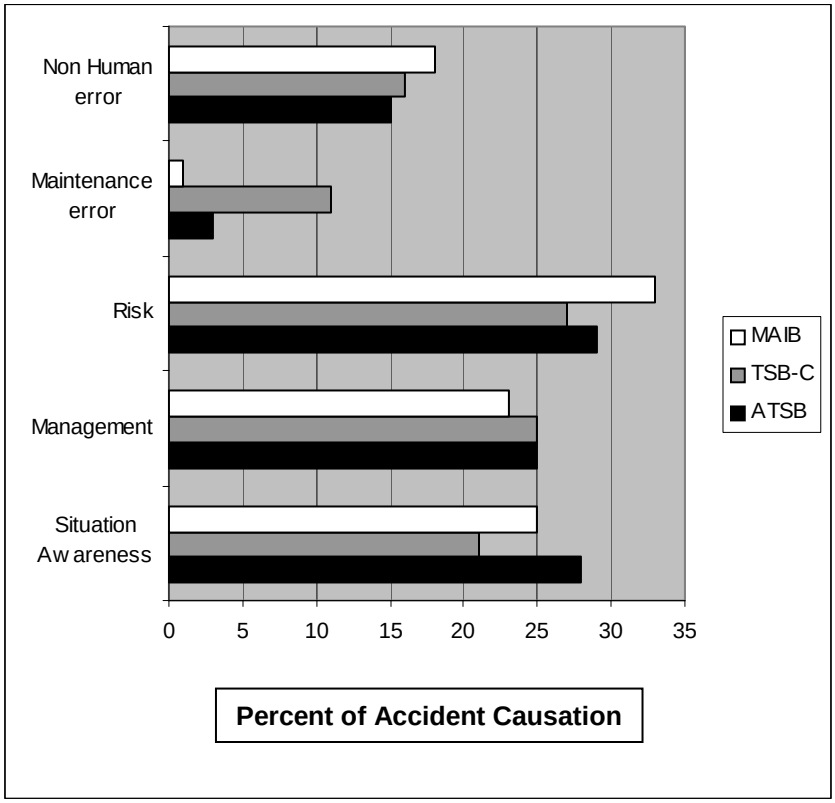


FIGURE 3
Top-Level Accident Cited Causation for USCG MSMS Database

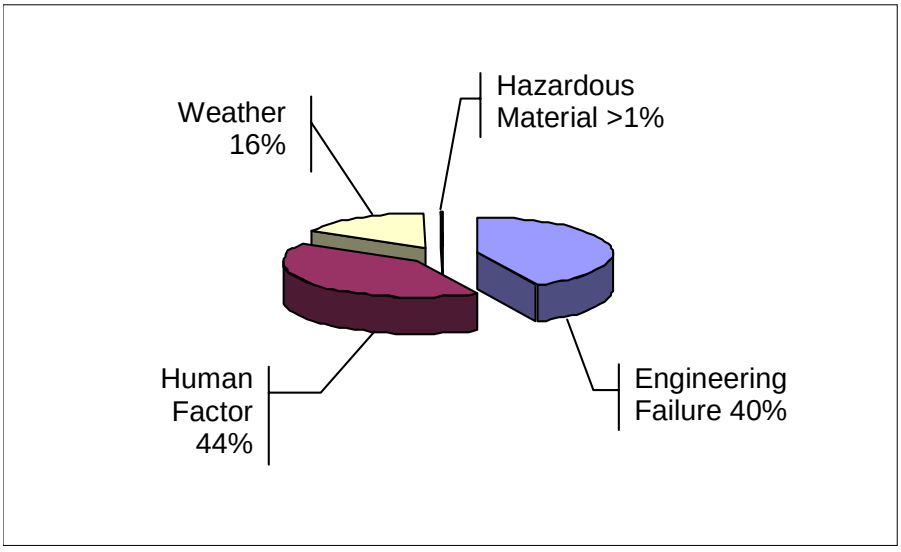


FIGURE 4

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

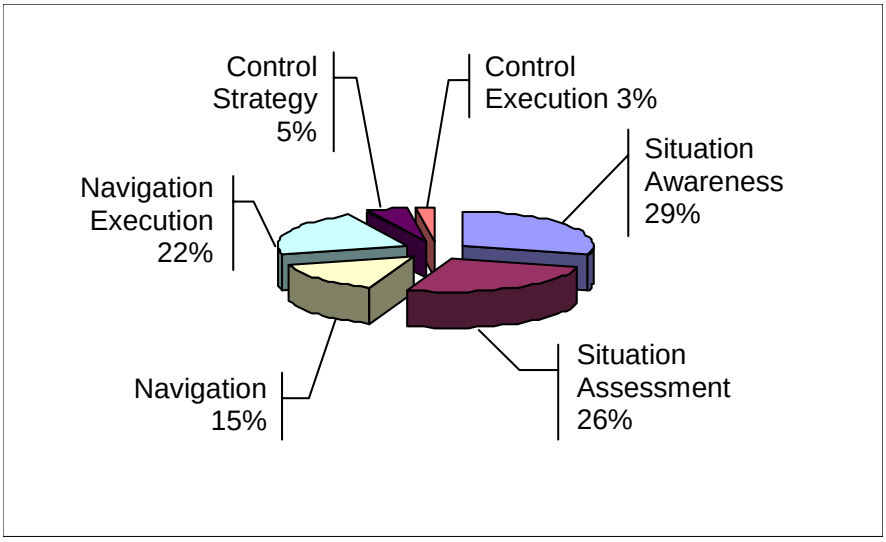
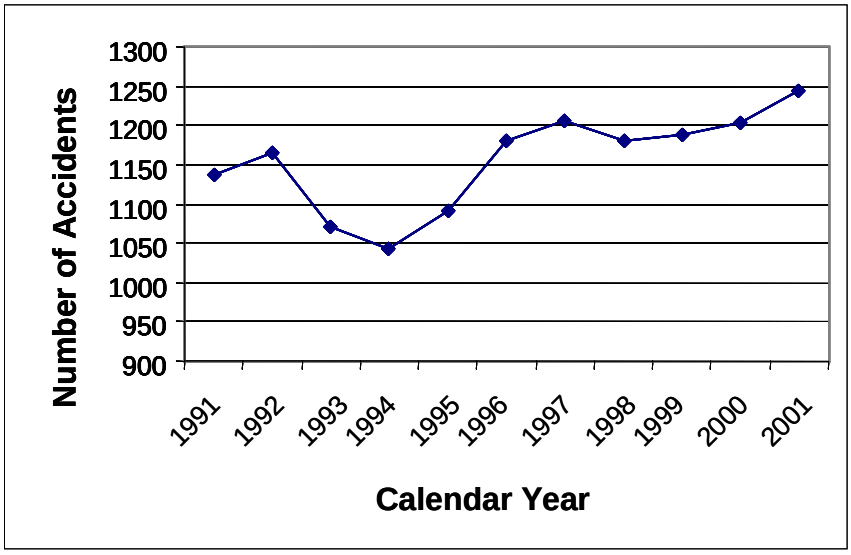


FIGURE 5

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



6.0 Discussion

Comparing the findings of the reviews of ATSB, TSB Canada and the UK MAIB 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 (ATSB, TSB Canada and UK MAIB). 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 findings of the USCG MSMS, failures of situation awareness (29%) and assessment (26%) are credited with about 55% of all human errors. For ATSB, TSB Canada and UK MAIB 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 database, 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 ASTB, TSB Canada, and MAIB 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, Knowledge, Skills and Abilities (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 ATSB, TSB Canada and UK MAIB 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 knowledge,skills or abilities (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 USCG 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.

7.0 Conclusion

Human error continues to be the dominant factor in marine 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, Australia, Canada, and UK.

For all accidents over the reporting period, approximately 80 to 85% involved human error. Of these, about 50% of marine 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 marine 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.

References

American Bureau of Shipping. (2003). R*eview and Analysis of Accident Databases: 1990 – 1999 Data* (ABS Technical Report Number 2003-01). Houston: Author.

American Bureau of Shipping. (2004). Abs R*eview and Analysis of Accident Databases: 1991 – 2002 Data* (ABS Technical Report Number 2003-01). Houston: Author.

Australian Transportation Safety Bureau. (2003). Retrieved Aug, 2003 from http://www.atsb.gov.au/marine/incident/index.cfm

Canadian Transportation Safety Board. (2003). Retrieved July 16, 2003 from http://www.tsb.gc.ca/en/publications/index.asp

Iarossi, F. J. (2003). *Marine Safety: Perception and Reality*. 17th Annual Chua Chor Teck Memorial Lecture. Singapore. Retrieved May 12, 2003 from http://www.eagle.org/news/speeches/index.html.

Jones, M. (2002). *Review and Analysis of Accident Incident and Near-Miss Databases*. Houston, TX: American Bureau of Shipping. (Internal SAHF Report).

Transportation Safety Board of Canada. (2001). *Ten Year Trend Analyses of Marine, Rail, Pipeline and Air Accident and Incident Data*. Gatineau, Quebec: Author.

UK Marine Accident Investigation Branch . (2003). http://www.dft.gov.uk/stellent/groups/ dft_shipping/documents/sectionhomepage/ dft_shipping_page.hcsp

UK Marine Accident Investigation Branch . *Marine Accident Investigation Branch (MAIB) Annual Report 1999*. Retrieved July 16, 2003 from http://www.maib.detr.gov.uk/ar1999/04.htm

United States Coast Guard Research and Development Center, (2001). *United States Coast Guard guide for the management of crew endurance and risk factors* (Report No. CG-D-13-01). Groton, CN: Author.