Mariner Personal Safety Database Analysis for Human Risk-taking Behaviors
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Key Words: Risk-taking Behavior, Risk Tolerance, Safety, Incident Reports, Mariner Personal Safety Database

1. INTRODUCTION
The maritime industry experiences incidents ranging from near misses to major accidents. Incident investigations reveal the significant role of the human element. In 2013, the International Maritime Organization (IMO) revised its Guidelines for Formal Safety Assessment to include guidance on Human Reliability Analysis (HRA) and has placed increased importance on human factors engineering. Despite these efforts, incidents are still occurring with human error identified as a significant contributor. Human error includes risk-taking behaviors and heightened risk tolerance levels. These variables are the focus of this research because humans take risks in many situations, sometimes out of necessity or due to inexperience or unfamiliarity with a task or process. This research investigates incident reports in the Marine Personal Safety (MPS) Database. The database contains incidents shared by industry partners participating in the ABS Mariner Safety Project. Through statistical and quantitative analyses, a model of risk-related behaviors and potential countermeasures such as training, ergonomic design criteria, and improved safety culture are being developed.

2. METHODS
2.1 What is Risk-taking Behavior?
Humans often take risks, knowingly or unknowingly, out of necessity or due to inexperience or unfamiliarity with a situation, task, or process. Little knowledge or guidance related to risk-taking characteristics is available or how this information can be applied to a vessel’s design or work methods and procedures. The risk topic of interest in this research centers on risk-taking and risk tolerance in the context of performing routine and day-to-day activities, and risks taken with full choice and knowledge of the “risky” behavior.

Understanding human capabilities and limitations is a primary means to overcome opportunities for human error. The most preferred approach to mitigate human error in the workplace is to design out the potential for human error. This approach will help reduce the frequency of errors, and also reduce the consequences to an acceptable level once an error does occur. The other approaches are more demanding to humans such as reducing risk-taking behaviors and task uncertainty. These variables also play an important role because the reduction of incidents may never be achieved without appropriate changes in human behavior.

While risk-taking behaviors and risk tolerance have been discussed widely in various research areas, there is no consensus definition. Accordingly, in this research, “risk-taking behavior” is defined as: 1) Behaviors involving some potential for danger or harm while also providing an opportunity to obtain some form of reward ¹). “Harm” here is considered to be to a person, a piece of equipment, or the environment, and 2) Behaviors taken whether or not a person knows of an existing risk in that specific situation or circumstance.

2.2 Risk Tolerance Factors
Risk tolerance refers to a person’s capability to accept a certain amount of risk. For example, some people continue to smoke cigarettes, some people skydive, and some people engage in scuba diving. Risk tolerance is tied to risk perception, the ability of an individual to discern a certain amount of risk (and willingness to assume that risk) ²) and may be driven by personal sensitivities (or preferences) to either the opportunities for gain or the threat of the potential loss involved ³).

There are two different situations where an individual takes risks: 1) they perform an action/activity without the knowledge of an existing risk or 2) they recognize the risk, and are willing to intentionally assume the risk ⁴). These situations are based on different internal decision-making processes which cannot be externally monitored. It is important to point out that sometimes the results of the person’s actions may complete the task in a safe manner even though a different internal decision-making process was applied (e.g. not following established procedures). These behaviors are actions, inactions, or reactions taken as a response to internal or external stimuli. The decision-making process (to do something or not to do something) and risk tolerance level are considered examples of internal stimuli.

In this research, the term “Risk Tolerance Factor” is introduced and defined as internal or external stimuli motivating risky behaviors and high-risk tolerance. This factor also helps explain contributory causes of incidents.

2.3 Identification of Risk Tolerance Factors
In order to identify Risk Tolerance Factors, incident reports were randomly selected and reviewed from two data sets: A) Authority Databases (e.g., UK Marine Accident Investigation Board (MAIB), Australian Transport Safety Bureau, etc….) (a total of 23 reports) and B) the ABS MPS Database (299 fatality reports, 100 injury reports and 100 near miss reports).

The identified factors had been further investigated to confirm that the factors are appropriate in scope to cover the risk-taking behaviors observed onboard vessels in all incident types for all severities from fatality to near miss and to further clarify their definitions. For each report reviewed, at least one risk tolerance factor was identified, with the exception of those reports that were incomplete or where there was a lack of...
information. Based on the review of the reports in A) and B), seventeen (17) Risk Tolerance Factors have been identified. These are shown in Table. 1. These factors were then broken down into four (4) categories, 1) Individual, 2) Organization, 3) External and 4) Others.

Table. 1 List of Risk Tolerance Factor

<table>
<thead>
<tr>
<th>Category</th>
<th>ID</th>
<th>Risk Tolerance Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual</td>
<td>1</td>
<td>Risk perception</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Ambiguity/Situation Awareness</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Bias</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Complacency / Vigilance</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Forgetting</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>Fatigue</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>KSAs* / Training</td>
</tr>
<tr>
<td>Organization</td>
<td>8</td>
<td>Time constraint</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>Workload</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>Competing objectives</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>Safety climate / BRM / ERM**</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>Safety culture*** / Management</td>
</tr>
<tr>
<td>External</td>
<td>13</td>
<td>Bad design / Ergonomics</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>External condition</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>Equipment failure</td>
</tr>
<tr>
<td>Others</td>
<td>16</td>
<td>Others (incl. illness)</td>
</tr>
<tr>
<td></td>
<td>17</td>
<td>Unable to identify</td>
</tr>
</tbody>
</table>

* KSA: knowledge, skill and ability  
** Safety climate**: a unique shipboard environment peculiar to each individual ship within a fleet into which the safety culture is received and integrated.  
*** BRM / ERM (Bridge/Engine room resource management)**: the effective use by a vessel’s bridge/engine team (officers, crew and pilot / engineers) of all available resources – information, equipment and personnel – to safely operate the vessel.  
**** Safety culture**: a product of individual and group values, attitudes, perceptions, competencies and patterns of behavior that determine the commitment to, and the style and proficiency of, an organization’s health and safety management.

2. 4 Mariner Personal Safety (MPS) Database

The ABS Mariner Safety Project is a collaborative endeavor between ABS, Lamar University (Beaumont, Texas, USA) and maritime industry partners (i.e., vessel owners and operators). The goal of this project is to create an international database of maritime injury and near miss reports. The MPS Database project has collected more than 100,000 injury and near miss reports. Due to the confidentiality of the information contained therein, the reports are submitted to Lamar University for sanitization where all the confidential data which can uniquely identify the incident, such as date/time, sea area, name of vessels, individuals and involved organizations, etc., are eliminated. The sanitizing effort is ongoing for approximately 25,000 reports (as of July 2015). The sanitized reports are published in the MPS portal which is open to all available resources – information, equipment and personnel – to safely operate the vessel.

2. 4. 1 Statistical Analysis Results

From the latest MPS Database, a new data set for review was prepared with 300 fatality reports, as well as 300 reports randomly selected for each severity of reportable and first aid incidences. Records were first broken down and analyzed by: 1) incident type, 2) task being performed, 3) event as a cause of fatality / injury, 4) rank of the person involved in the incident, and 5) location of the incident.

(1) Incident type

Three categories for incident type have been created: 1) “occupational” (e.g., slips, trips, falls, etc.), 2) “process” (a system safety-related incident includes collision, fire / explosion, flooding, grounding, capsize) and 3) “leisure” (an incident related to leisure, not to duties by crew / workers, and are not subject to detailed analysis in this paper). Most of the fatalities and injuries fall into the occupational incident category and very few in the process incident category, as shown in Fig. 1.

(2) Task on duty at the time of incident

Most incidents for all severities occurred while on duty; fatality (77%), reportable injury (94%) and first aid injury (97%). Fig. 2 shows the type of on duty tasks performed at the time of the incident. The most frequently occurring task for fatalities is line handling. The most frequently occurring task for reportable and first aid incidents is maintenance / repair activities.

(3) Event (direct cause of fatality / injury)

Fig. 3.1 shows the “event” and the report’s identified cause of the fatality / injury. The events of “fall” and “struck by” are observed as the most frequently occurring for all severities. For fatalities, the most frequently occurring event is fall (28% of fatalities), then medical condition (22% of fatalities) and then struck by (21% of fatalities). The category “Medical Condition” includes nine (9) sub-category items (alcohol, asphyxia, burn, drowning, drug, hypothermia, illness, inhalation and missing). The most frequent Medical Condition for fatalities is drowning (8%) and then asphyxia (4%), missing (4%) and illness (3%). Very few cases of Medical Condition were observed for reportable or first aid injuries.

There are some reports identifying several events for one fatality / injury case and a combination of the events demonstrate a scenario of how the fatality / injury occurred.
For example, there are 11 reportable injuries with the selected events of “fall from a different level” and “slip/foot”. This combination of events demonstrates a scenario such as slipping on stairs/ladders or from a height (e.g., while standing on a stair, ladder, etc.), then falling to a lower level. This scenario teaches us the avoidance of slips can eliminate the possibility of falls and the countermeasures against slips can also be effective for fall incidents. These combinations show the prioritized events for which the countermeasures are required.

Fig. 3.2 shows the sub-category of the event “fall”. Three events, “fall into water”, “fall from a different level” and “fall from same level”, are observed most frequently. For fatalities, the most frequently occurring is “fall into water” (67 cases) followed by “fall from a different level” (32 cases). For reportable and first aid injuries, “fall from a different level” occurs most frequently (40 cases and 23 cases), then “fall from same level” (25 cases and 13 cases).

Fig. 3.3 shows a cross table for the event “fall” and location of the incident. This table was created to illustrate the different locations associated with the event “fall”. Exposed areas (e.g., weather deck / topside areas) was the location where fall incidents occurred most frequently for all severities. Injuries due to falls also occurred frequently in interior working spaces.

(4) Rank of injured persons
Fig. 4 shows the rank of the injured person “on duty”. For all severities, “rating” is the rank with the highest risk. For first aid injury, non-crew workers (defined as workers onboard, but not crew, e.g. pilot, barge/towing/mooring/drilling operator, etc.) is the rank with the 2nd highest risk of injury.

(5) Location on ship
For all severities, exposed areas are the location where incidents occurred most frequently, then interior working spaces and accommodation areas. This is illustrated in Fig. 5. When looking within “interior working space”, the cargo area shows the highest number of fatalities (18 cases). For reportable and first aid injuries, the engine room shows the highest number of incidents (28 cases and 41 cases, respectively). “NA” has been selected for process incidents since it was not possible to determine the location of the incident, such as in case of capsize, collision, etc.

(6) Quality of reports in MPS Database
The accuracy and reliability of the analysis greatly depends on the quality of the reports in the MPS Database. These reports were prepared by the vessel crew or by onshore safety support personnel. In many instances, these individuals are not highly trained incident investigators. As a result, the incident reports have a high degree of variability and comprehensiveness, however they contain useful information to understand an internal decision-making process, such as the reporter’s emotions and honest opinions, which were not obtainable from the official incident reports.

An interesting finding when looking at the MPS reports is that the number of words contained in the reports is proportional to the severity of the incident being reported. The average number of the words contained per report is 210 for a fatality, 88 for a reportable injury and 74 for a first aid incident. This implies that reports for more serious incidents...
are conducted in a more comprehensive manner to capture as much information as possible to develop lessons learned and potential corrective actions so that this event does not occur again. However, the number of cases identified as “unknown” are the highest in the fatality reports for “incident type”, “task”, “event” and “risk tolerance factor”. They are so marked due to a lack of information in the reports. It is presumed that the details were unknown for the fatalities since the involved person(s) were deceased, missing, or the incident was not witnessed by another crew member. However, the reports for fatality generally contain more information compared to less severe injuries and provide more details, especially on risk tolerance and risky behaviors. Accordingly, the quality of the reports are considered to be satisfactory in order to achieve our research purpose.

<table>
<thead>
<tr>
<th>Category</th>
<th>Fatality</th>
<th>Reportable</th>
<th>First aid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incident type</td>
<td>1%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Task</td>
<td>22%</td>
<td>16%</td>
<td>16%</td>
</tr>
<tr>
<td>Event</td>
<td>9%</td>
<td>7%</td>
<td>4%</td>
</tr>
<tr>
<td>Rank</td>
<td>34%</td>
<td>37%</td>
<td>42%</td>
</tr>
<tr>
<td>Location</td>
<td>16%</td>
<td>28%</td>
<td>32%</td>
</tr>
<tr>
<td>Risk Tolerance Factors</td>
<td>44%</td>
<td>27%</td>
<td>25%</td>
</tr>
<tr>
<td>Average of words</td>
<td>210</td>
<td>88</td>
<td>74</td>
</tr>
</tbody>
</table>

### 3.2 Analysis for Risk Tolerance Factors

The high-level statistical analysis results show different tendencies between fatality and injuries as introduced in 3.1. The traditional concept known as Heinrich’s Law states that the predominant causes of non-injury accidents are identical to the predominant causes of accidents resulting in major injuries. This law has been widely referenced and applied to the research on occupational incidents. However, a new paradigm for serious injuries and fatalities (SIF) has recently been proposed, suggesting a different strategy is required to prevent SIFs. This new paradigm suggests that SIFs have identifiable precursors, most frequently associated with basic safety systems integrity and conformance, and also introduces two primary reasons that a reduction in less serious injuries does not necessarily correspond to a reduction in SIFs. The first reason is the causes and correlations of SIFs are often different from those for less serious injuries. The second reason is the potential for serious injury is low for the majority of non-SIF injuries (typically around 80%).

Since the analysis results in 3.1 support this new concept, only the fatality cases have been selected in this paper for detailed investigation in order to develop a model of risk-related behaviors. Two tasks, “enclosed space entry / rescue” and “line handling”, are selected for risk tolerance factor analysis due to their frequency and high fatality rate per case among all task types and possible impact on vessel and system safety.

(1) Enclosed space entry / rescue

Many authorities and organizations have raised alerts concerning the risk of enclosed space entry / rescue and proper use of a gas meter. The IMO has introduced new requirements to The International Convention for the Safety of Life at Sea (SOLAS) in 2015. However, such incidents continue to occur. Our analysis results also reveal that the tasks related to enclosed space show more severe consequences than other tasks. The average fatality rate per case is 1.04 for occupational incidents and 1.61 for process incidents. On the other hand, the fatality rate for an enclosed space incident is 1.75. This value is 1.6 times greater than the average for total cases of 1.09. Due to this fatality rate, this task has been selected for detailed analysis.

(2) Line handling

Anchoring, mooring and docking operations in general pose serious risks to the safety of the seafarers involved in such operations and may result in fatalities and major injuries. Line handling operations have been recognized as one of the highest risk tasks onboard by various researchers, and our analysis results finds 31 (10%) of the fatality cases occurred during line handling operations. Half of these occurred during towing operation and the most frequent event is “struck by”.

### 3.3 Scenario and Model of Risk-related Behaviors

(1) Enclosed space entry / rescue

Based on this study’s results, the following risk-taking behaviors and risk tolerance-related descriptions were revealed:

Complacency (ID 4): Several necessary process / procedural steps have been intentionally skipped, such as entering an enclosed space without pre-entry test, any watchstander, appropriate protections (e.g., properly functioning and calibrated gas meter), use of ventilation and permit to work/entry.

Safety culture/Management (ID 12): 1) no procedures were provided, or the contents of the procedure were not appropriate, 2) proper equipment/protections for safe entry/rescue (e.g., self-contained breathing apparatus (SCBA)) were not provided onboard by the company, 3) training/drills were not carried out and 4) the responsible person(s) for safety...
(master and chief officer) became victims by not following the formal procedure or not knowing or not completely understanding the necessary precautions that needed to be taken for such a task. This demonstrates a less mature safety culture.

KSAs / Training (ID 7): 1) inability to use equipment / protection and 2) unfamiliarity with enclosed space entry process or procedures and rescue operation.

Safety climate / BRM / ERM (ID 11): 1) insufficient maintenance of equipment / protection and 2) insufficient safety management system practices utilized onboard.

From the above results, the enclosed space entry / rescue fatality cases are presumed to occur along the lines of this scenario: “Skipping of necessary steps for safe entry/rescue to enclosed space”. This can be the result of less mature safety culture/management system which can contribute to a less than desirable safety climate and insufficient KSAs / Training for personnel. All of these factors can increase crew misunderstanding of appropriate processes, procedures and complacency.

(2) Line handling

The following risk-taking behaviors and risk tolerance-related descriptions are found:

Equipment failure (ID 15): 1) fittings were broken due to overload and 2) line/ropes were parted/failed.

External condition (ID 14): 1) bad weather / sea state which caused unexpected ship motions and excessive load and 2) line handling work in blind areas from bridge and winch operator.

Safety climate / BRM / ERM (ID 11): 1) while the crew knew that the equipment / fittings were broken, no actions were taken, 2) ineffective communications between bridge and remote working areas and 3) task risk assessments or job safety analyses onboard were inadequately performed or overlooked.

Safety culture / Management (ID 12): 1) proper maintenance/reporting system was not utilized, perhaps not even established, 2) proper procedures were not prepared / provided and 3) improper working conditions for safe task performance.

Bad design / Ergonomics (ID 13): 1) no proper working environments for safe operation (e.g. inappropriate levels of light or no communication system with bridge) and 2) bad design of equipment.

One can infer from our analyses that line handling-related fatalities may occur along the lines of this scenario: struck by line was caused by break of line arrangement due to 1) fittings were broken due to excessive loads caused by following incorrect procedures, 2) equipment failure/bad design, 3) improper maintenance/report of deficiencies, or 4) inappropriate external conditions, such as extreme weather, that usually line handling is not carried out, causing a sudden ship motion.

(3) Countermeasures

The risk tolerance factors in the above scenarios offer potential countermeasures to reduce risk-taking behaviors and adjust risk tolerance levels. Each step in each scenario is related to an identified risk tolerance factor.

Recommendations are suggested for each risk tolerance factor to reduce the related risky behaviors together with its definition and examples. Once the risk tolerance factor is selected, then possible countermeasures and corrective actions may be brought out. The incident report investigation, with risk tolerance factors identified, is method / vehicle to establish countermeasures and corrective actions.

The potential scenarios described for enclosed space entry / rescue and line handling imply that “safety culture” and “safety climate” are key factors. Effective countermeasures to improve safety culture / safety climate include: 1) effective procedures, 2) effective JSA’s, 3) adherence to procedures (permit and a safety watch), 4) appropriate training, 5) improved communication, 6) enhancement of management commitment, 7) improved maintenance / reporting system, etc. as introduced in our Guidance Notes (GNs) on safety 39.

4. CONCLUSION

This research shows the capability of the MPS Database for reliable data analysis for hazard and risk tolerance factors identification. This in turn is assisting in the development of models for risk-taking behaviors and the identification of potential countermeasures.

The analysis for two high-risk tasks, enclosed space entry / rescue and line handling, has revealed that ABS activities, such as our Guides and GNs on ergonomic design 10 & 11, safety culture and job safety analysis 12, are useful as guides for the implementation of the proposed countermeasures.

The next phase of this research effort includes more detailed: 1) risk tolerance factor analysis for other potentially high-risk tasks, 2) further investigation of potential risk mitigation techniques and 3) identification of potential countermeasures associated with each risk tolerance factor.

REFERENCES

9) ABS Guidance Notes on Safety Culture and Leading Indicators of Safety, February 2014