Three Questions of Risk Analysis

- What can go wrong?
- What are the consequences?
- How likely are they?
- How can we anticipate and manage risk?
Precursors and Leading Indictors: Anticipating Safety Performance In Marine Transportation

Martha Grabowski
Le Moyne College
Rensselaer Polytechnic Institute
grabowsk@lemoyne.edu
http://web.lemoyne.edu/~grabowski
Twitter: grabowsk2

National Academies Marine Board
Fall Meeting
Washington, DC
29 October 2014
Simulation, Human Error Models, Oil Outflow

- 10-year vessel traffic simulation, what-if analyses
  - AIS, VTS, wind, ice, visibility, data, pilot routes
- Accident-incident database drives simulation, human error
  MISL, State, Pilot, Local, Company data

Evaluate Risk Mitigation measures → Recommendations

Sponsors: CG HQ/MSEP, COTP, Harbor Safety Committees, States/Parishes, Industry, Stakeholders, RCAC, Public, NOAA, USACOE

Peer reviewed by National Academies

PAWSA Model
- Washington State Office of Marine Safety, Wash State Ferries
- Lower Mississippi River, Port of Houston,
- San Francisco Fast Ferry
- Prince William Sound Risk Assessment
  Tanker Traffic in Puget Sound/BP* -- Tug Escorts
Anticipating Safety Performance

Simulation, Human Error Modeling, Oil Outflow Models, FMEA, Influence Diagrams and…

Examine the linkage between safety culture and safety performance in the maritime industry

Partnership between
- American Bureau of Shipping,
- U.S. Coast Guard,
- 3 shipping companies
  - 1 U.S. domestic tanker operator
  - 1 International tanker operator
  - 1 international container operator

Safety Culture, Performance

**Safety factors**

- Characteristics, artifacts of culture
- Interviews, data gathering

**Safety performance data**

- Accidents, incidents, near misses, conditions of class, port state deficiencies, LTI >= 3 days
- Survey data – perceived safety
- Validation data
  - US Coast Guard Marine Safety Mgmt System (MSMS), MISLE, MSIS, MinMod, CASMAIN, etc.
  - National Transportation Safety Board (NTSB) reports
  - UK MAIB database, Paris, Hong Kong MAIB
  - Lloyd’s List, Equasis, NOAA oil spill databases
  - Coastal state, local, pilot, environmental, native data
  - Open source, proprietary, company-sensitive data

**Safety factor metrics**

*Measuring characteristics of culture*

Integration

3 companies
1764 participants
102 vessels

Safety Factor Model

Minimize Human Errors
Minimize Mechanical Failures
Minimize Immediate Causes
Minimize Accidents

Improve Individual’s Safety Attitude
Empowerment
Respect
Responsibility
Integrity
Willingness to Change
Anonymous Reporting
Feedback

Improve Shipboard Safety Culture
Responsibility
Communication
Problem Identification
Prioritization
Feedback

Improve Organizational Safety Culture
Hiring Quality Personnel
Orientation in Safety
Promotion of Safety
Formal Learning System
Reward Safety
Multi-Cultural Ops

Senior Executive interviews
Vessel Leadership interviews
Safety, Health & Environmental Vetting interviews

• 20 interviews over 3-year period
• Gather safety factor metrics and data
• Validate existing safety culture surveys – nuclear, chemical, aviation, offshore, medical
• Pilot test shipboard, shoreside safety culture surveys

Initial Research Framework

Organizational Safety Factors
- Hiring Quality Personnel
- Safety Orientation
- Promotion of Safety
- Formal Learning System
- Reward Safety
- Multicultural Operations

Organizational Safety Performance
- # accidents
- # incidents
- # near losses
- # of conditions of class
- # of port state deficiencies
- # LTI>=3

Vessel Safety Factors
- Responsibility
- Communication
- Problem Identification
- Prioritization of safety
- Feedback

Vessel Safety Performance
- # accidents
- # incidents
- # near losses
- # of conditions of class
- # of port state deficiencies
- # LTI>=3

Individual Safety Factors
- Empowerment
- Responsibility
- Anonymous Reporting
- Feedback
- Respect
- Integrity
- Willingness to Change

Individual Safety Performance
- Perceived safety

Safety Factor Metrics

Fundamental Objective

Improve Organizational Safety Culture (43)

Safety Factors

Hiring Personnel

Orientation In Safety

Promotion Of Safety

Formal Learning System

Senior Executive Interviews

Metrics

- Candidate’s GPA
- Average turnover rate
- Average length of stay in organization
- Average absenteeism
- Number of levels of interviews conducted during the hiring process
- Presence of an internship training program
- Presence of a documented hiring policy and hiring procedures
- Presence of an interviewer training program
- Cumulative score on ‘Hiring Quality People’ on safety climate survey

Hiring Personnel

- The percentage of employees receiving safety orientation,
- Percentage of employees receiving safety re-training,
- The frequency of safety re-training.
- The presence of an induction training program that meets the requirements of the Standards for Training and Certification of Watchstanders (STCW) code,
- Established procedures to identify and impart any training required in support of safety management systems, and
- Whether newly employed seafarers are given opportunities to familiarize themselves with the shipboard equipment operating procedures and other arrangements.
- Cumulative score on ‘Hiring Orientation’ on safety climate survey

Orientation In Safety

- The presence and size of safety budgets,
- Presence and size of resources required for safety systems,
- Presence and quality of safety goals
- Percentage increase in safety budgets per year, compared to previous year
- The presence and size of resources required for safety systems,
- The presence and quality of safety goals,
- The frequency of regular safety meetings,
- The percent attendance at safety meetings,
- The percentage of employees receiving safety training,
- The frequency of safety training, and
- The percentage of employees receiving on-board or in-service training.
- Number of unplanned maintenances in the past year
- Percentage of safety meetings in the past year attended by senior management
- Percentage of employees provided with PPE
- Cumulative score on ‘Promotion of Safety’ on safety climate survey

Promotion Of Safety

- The percentage of incident reports upon which corrective action is taken,
- The time taken between incident reports and corrective actions,
- Percentage of reports that resulted in safety procedure changes,
- The number of incidents or near misses reported,
- The availability of incident investigation findings to employees,
- The time taken between report submission and feedback received,
- The frequency of safety-related feedback,
- The percentage of reports on which corrective action is taken,
- The percentage of reports on which lessons learned were published in the last year,
- Time to closure on safety action items,
- The quality of performance analyses of the safety system, and
- The percent of faulty or absent procedures on which corrective action was taken.
- Cumulative score on ‘Formal Learning System’ on safety climate survey

Formal Learning System

Senior Executive Interviews
# Safety Performance

<table>
<thead>
<tr>
<th>Organization</th>
<th>Accidents</th>
<th>Incidents</th>
<th>Near Losses</th>
<th>Port State Deficiencies</th>
<th>Conditions Of Class</th>
<th>LTI &gt;=3</th>
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</thead>
<tbody>
<tr>
<td>Industry Partner 1</td>
<td>1*</td>
<td>N/A</td>
<td>60</td>
<td>6*</td>
<td>1*</td>
<td>7*</td>
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<tr>
<td>Industry Partner 2</td>
<td>31*</td>
<td>N/A</td>
<td>40</td>
<td>15*</td>
<td>16*</td>
<td>25*</td>
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<tr>
<td>Industry Partner 3</td>
<td>47</td>
<td>73</td>
<td>174</td>
<td>23*</td>
<td>39*</td>
<td>10*</td>
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<tr>
<td>Total</td>
<td>79</td>
<td>73</td>
<td>274</td>
<td>44</td>
<td>56</td>
<td>42</td>
</tr>
</tbody>
</table>

* = small sample size; t = 1 year; Table 5

- Company proprietary data
- US Coast Guard Marine Safety Mgmt System (MSMS), MISLE, MSIS, MinMOD, CASMAIN, etc.
- Coastal states, pilot organization, environmental groups’ data
- National Transportation Safety Board reports
- UK MAIB, Hong Kong Marine Dept, Paris, Equasis databases
- Lloyd’s List, NOAA spill databases

Open source, proprietary, company-sensitive data
Organizational Safety Results

Safety Factor Categories

- Hiring Quality Personnel
- Safety Orientation
- Promotion of Safety
- Formal Learning System
- Reward Safety
- Multicultural Operations

Safety Performance Measures

- Number of accidents
- Number of incidents
- Number of near losses
- Number of Conditions of Class
- Number of Port State Deficiencies
- Number of LTI ≥ 3 days

Highlighted Organizational Safety Factors were significant for highlighted Performance Measures

SeaRiver American Progress
Initial Study Limitations

- Correlations, not causality
  - Higher order statistical analyses followed (SEM, binomial regression)

- Longitudinal assessments needed
  - Within, and cross-organizational analyses
  - Benchmark results vs. other safety factor studies

- Small # of organizations (n = 3 companies)
  - Trend analyses require further data collection

- Safety factors and metrics provide starting point for measurement over time

Retrieved 24 October 2011
**Secondary Analysis (2011-2014)**

**Network of safety culture influences** *(SF’s for vessel, org)*


- Communication, Responsibility
- Efficacy (Empowerment)
- Formal Learning System
- Safety Culture
- Safety Performance

**Network Effects varied by vessel, company, trade**

- Empowerment (Individual)
- Communication (Vessel, Individual)
- Formal Learning System (not Anonymous Reporting)
- Responsibility (Vessel, Individual)
Efficacy’s Moderating Effect on Team (Vessel) Performance

N = 23 vessels (vs. 102; 239 vessels; missing data)

Safety Culture

H1, H2***, H3Alt***

Worker Efficacy

H4A, H4B***, H4CAlt****

Safety Performance
- # accidents
- # unplanned maintenance
- # safety suggestions

Efficacy (Behavioral proactivity) motivates safety improvements
- fewer accidents
- fewer unplanned maintenance activities
- more (or fewer?) safety suggestions

Efficacy: Perceived ability to exert control over outcomes (Bandura, 1977; 1997)
--measured at individual level, aggregated

Overseas Houston
http://www.osg.com/siteFiles/SiteManager/108074FE485F3B5B879DD6C3AB711C3A.jpg
retrieved 24 October 2011
Safety Culture and Vessel Performance
...moderated by Vessel Efficacy

Vessel Efficacy

<table>
<thead>
<tr>
<th>Safety Culture</th>
<th>Vessel Efficacy</th>
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</thead>
<tbody>
<tr>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>- More accidents</td>
<td></td>
</tr>
<tr>
<td>- More safety suggestions</td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>- Fewer accidents</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>- Even more accidents</td>
<td></td>
</tr>
<tr>
<td>- More safety suggestions</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>- More unplanned maintenance</td>
<td></td>
</tr>
</tbody>
</table>

N = 23 vessels (vs. 102; missing data)

• Negative binomial regression
• Accidents: Zero-inflated negative binomial regression

http://www.osg.com/siteFiles/SiteManager/108074FE485F3B5B879DD6C3AB711C3A.jpg
retrieved 24 October 2011
Implications

- **Networks of safety culture influences**
- **Moderating influence of efficacy/empowerment**
- **Safety culture manifests at different org’l levels**
  - Safety culture metrics, rewards, incentives vary across organizational levels
- **Efficacy/empowerment can be maladaptive**
  - Especially with high safety culture
  - Not particularly helpful – maladaptive-- in uncertain, high stress and reactive problem solving settings
- **Multi-level, network data analyses**
  - Secondary data analysis provides new insights


Get the right science
Get the science right
Get the right participation
Get the participation right, and

Develop an accurate, balanced and informative synthesis (p. 132).

### Participants

<table>
<thead>
<tr>
<th></th>
<th>Domestic Tanker</th>
<th>International Tanker</th>
<th>Container</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shipboard</td>
<td>77</td>
<td>846</td>
<td>684</td>
<td>1607</td>
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<tr>
<td>Shoreside</td>
<td>22</td>
<td>97</td>
<td>38</td>
<td>157</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>99</strong></td>
<td><strong>943</strong></td>
<td><strong>722</strong></td>
<td><strong>1764</strong></td>
</tr>
<tr>
<td><strong>Individual</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vessels</td>
<td>7</td>
<td>39</td>
<td>56</td>
<td>102</td>
</tr>
</tbody>
</table>

- **Domestic US tanker operator** *(Initial and Follow up Study)*
- **International tanker operator** *(Initial study)*
- **International container operator** *(Initial study completed)*

Passing in Houston Ship Channel


Retrieved 24 October 2011
Organizational Safety Results

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SeaRiver American Progress
### Vessel Safety Results

#### Safety Factor Categories
- Communication
- Responsibility
- Problem Identification
- Feedback
- Prioritization of Safety

#### Performance Measures
- Number of accidents
- Number of incidents
- Number of near losses
- Number of Conditions of Class
- Number of Port State Deficiencies
- Number of LTI ≥ 3 days
- Perceived Safety based on Survey results

#### Highlighted Vessel Safety Factors were significant for highlighted Performance Measures

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Individual Safety Results

Safety Factor Categories
- Empowerment
- Responsibility
- Anonymous Reporting
- Feedback
- Respect
- Integrity
- Willingness to Change

Performance Measures
- Number of accidents
- Number of incidents
- Number of near losses
- Number of Conditions of Class
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- Number of LTI ≥ 3 days
- Perceived Safety based on Survey results

Highlighted Individual Safety Factors were significant for highlighted Performance Measures

SeaRiver American Progress
**Secondary Analysis (2011-2014)**

**Network of safety culture influences**


- Workers & supervisors actively make causal inferences about safety (DeJoy, 1994; Hofmann & Stetzer, 1998)
- Workers are motivated to be proactive in identifying & correcting anomalies (O’Dea & Flin, 2001; Parker, et al., 2003; Simard & Marchand, 1995)

**Assumption: When safety culture (climate) high, workers perceive safety as critical**