# *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*

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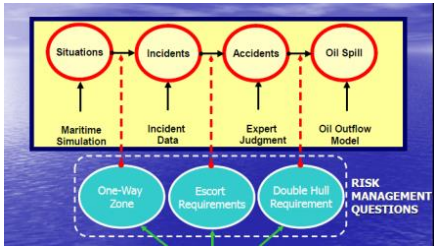
National Academies Marine Board
Fall Meeting
Washington, DC
*29 October 2014*

*Passing in Houston Ship Channel*
*http://pixdaus.com/pics/1285391280WU3sTdJ.jpg, Retrieved 24 October 2011*

# Maritime Risk


- **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

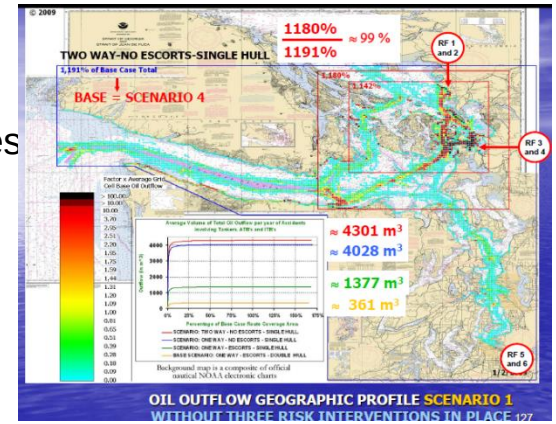



- **Evaluate Risk Mitigation measures → Recommendations**

- **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

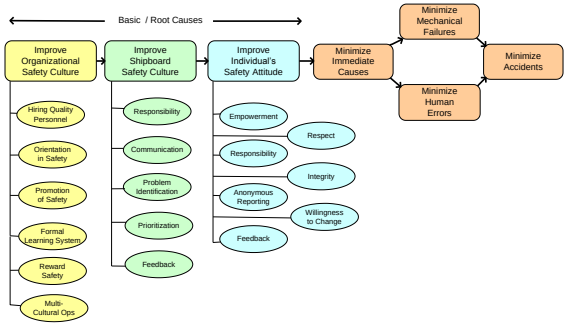
- **American Bureau of Shipping,**
- **U.S. Coast Guard,**
- **3 shipping companies**
  - ***1 U.S. domestic tanker operator***
  - ***1 International tanker operator***
  - ***1 International container operator***


http://www.shipspotting.com/modules/myalbum/photo.php?lid=72482. Retrieved 9 Dec 2007

# Safety Culture, Performance

## Safety factors

- *Characteristics, artifacts of culture*
- *Interviews, data gathering*

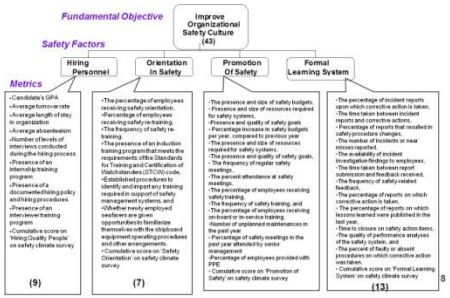



## Safety performance data

- *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**



http://www.menkent.dk/cliffpics/lookout.jpg, retrieved 9 December 2007

# Safety Factor Model

*Senior Executive interviews* ← *Vessel Leadership interviews* → *Safety, Health & Environmental Vetting interviews*

Basic / Root Causes

- Improve Organizational Safety Culture
  - Hiring Quality Personnel
  - Orientation in Safety
  - Promotion of Safety
  - Formal Learning System
  - Reward Safety
  - Multi-Cultural Ops
- Improve Shipboard Safety Culture
  - Responsibility
  - Communication
  - Problem Identification
  - Prioritization
  - Feedback
- Improve Individual's Safety Attitude
  - Empowerment
  - Respect
  - Responsibility
  - Integrity
  - Anonymous Reporting
  - Willingness to Change
  - Feedback
- Minimize Immediate Causes
  - Minimize Mechanical Failures
  - Minimize Human Errors
- Minimize Accidents

- *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*



http://www.menkent.dk/cliffpics/lookout.jpg, retrieved 9 December 2007

# Initial Research Framework

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

P1-P6

**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

P7-P11

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

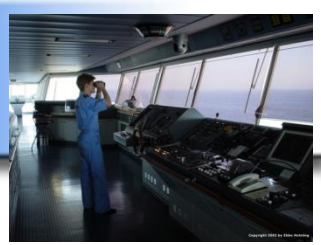
**Individual Safety Factors**
Empowerment
Responsibility
Anonymous Reporting
Feedback
Respect
Integrity
Willingness to Change

P12-P18

**Individual Safety Performance**
Perceived safety

http://www.menkent.dk/cliffpics/lookout.jpg, retrieved 9 December 2007

# Safety Factor Metrics



*Fundamental Objective*

**Improve Organizational Safety Culture (43)**

***Senior Executive Interviews***

*Safety Factors*

**Hiring Personnel**

**Orientation In Safety**

**Promotion Of Safety**

**Formal Learning System**

*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

**(9)**

- 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 'Safety Orientation' on safety climate survey

**(7)**

- 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

**(14)**

- 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

**(13)**

# Safety Performance

| Organization | Accidents | Incidents | Near Losses | Port State Deficiencies | Conditions Of Class | LTI >=3 |
|---|---|---|---|---|---|---|
| Industry Partner 1 | 1* | N/A | 60 | 6* | 1* | 7* |
| Industry Partner 2 | 31* | N/A | 40 | 15* | 16* | 25* |
| Industry Partner 3 | 47 | 73 | 174 | 23* | 39* | 10* |
| Total | 79 | 73 | 274 | 44 | 56 | 42 |

** = 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*

*Passing in Houston Ship Channel*
*http://pixdaus.com/pics/1285391280WU3sTdJ.jpg,*
*Retrieved 24 October 2011*

# 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*
*http://www.marinelink.com/images/show.aspx?aid=3953&width=310&height=500&/american-progress2_web.jpg*

# 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**

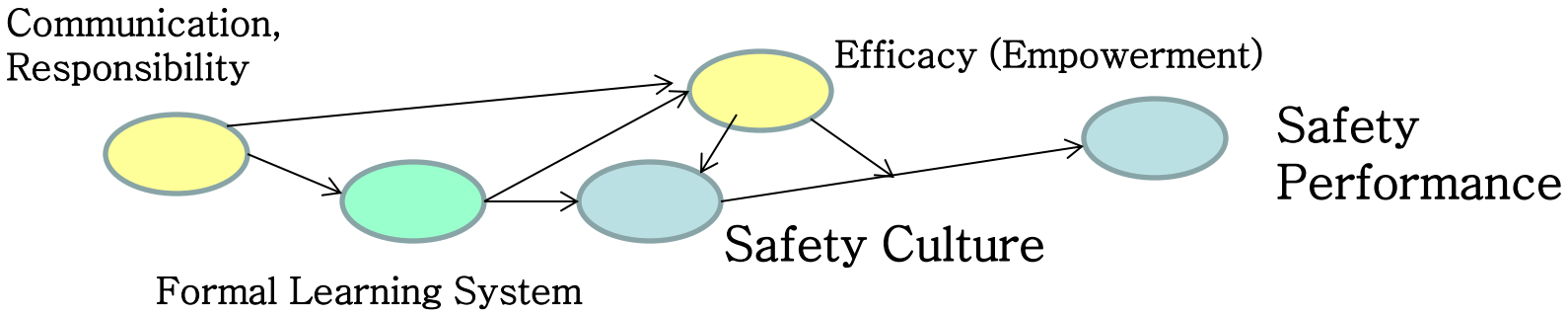


http://t0.gstatic.com/images?q=tbn:ANd9GcQDMElQOYAF7oL-TUY1TkBmwHBchrJulPVeQ17ovstAVreH0-BZQO1IplJ

Retrieved 24 October 2011

# Secondary Analysis *(2011-2014)*

- ***Network* of safety culture influences** *(SF's for vessel, org)*
  - *(DeJoy, et al., 2004; Neal, et al, 2000; Zohar, 1980; 2003).*




- ***Network Effects varied by vessel, company, trade***
  - *Empowerment (Individual)*
  - *Communication (Vessel, Individual)*
  - *Formal Learning System (not Anonymous Reporting)*
  - *Responsibility (Vessel, Individual)*

*Overseas Houston*
http://www.osg.com/siteFiles/SiteManager/108074FE485F3B5B879DD6C3AB711C3A.jpg, retrieved 24 October 2011

# Efficacy's Moderating Effect
## *on Team (Vessel) Performance*

**Safety Culture**

*H1, H2***, H3Alt****

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

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

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

- *Vessel level*
- *Negative binomial regression*
- *Accidents: Zero-inflated negative binomial regression*

**Worker Efficacy**

***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**

| Safety Culture | Low | High |
|---|---|---|
| *High* | • More accidents<br>• More safety suggestns | • Fewer accidents |
| *Low* | • Even more accidents<br>• More safety suggestns | • More unplanned maintenance |

<-----------------  More accidents ----------->

<----------More unplanned maintenance---------->

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

***N = 23 vessels***

*(vs. 102; missing data)*

*Overseas Houston* 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

http://t0.gstatic.com/images?q=tbn:ANd9GcQDMElQOYAF7oL-TUY1TkBmwHBchrJulPVeQ17ovstAVreH0-BZQO1IplJ_

Retrieved 24 October 2011

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*Passing in Houston Ship Channel*
*http://pixdaus.com/pics/1285391280WU3sTdJ.jpg,*
*Retrieved 24 October 2011*

# Appendix

# *Understanding Risk (NRC, 1996)*


- **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).*



http://www.nap.edu/download.php?record_id=5138, *retrieved 21 October 2014*

# Participants

| | Domestic Tanker | International Tanker | Container | Total |
|---|---|---|---|---|
| Shipboard | 77 | 846 | 684 | 1607 |
| Shoreside | 22 | 97 | 38 | 157 |
| Total Individual | 99 | 943 | 722 | 1764 |
| | | | | |
| Vessels | 7 | 39 | 56 | 102 |

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

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were significant for highlighted Performance Measures

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# 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

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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
  - Number of Port State Deficiencies
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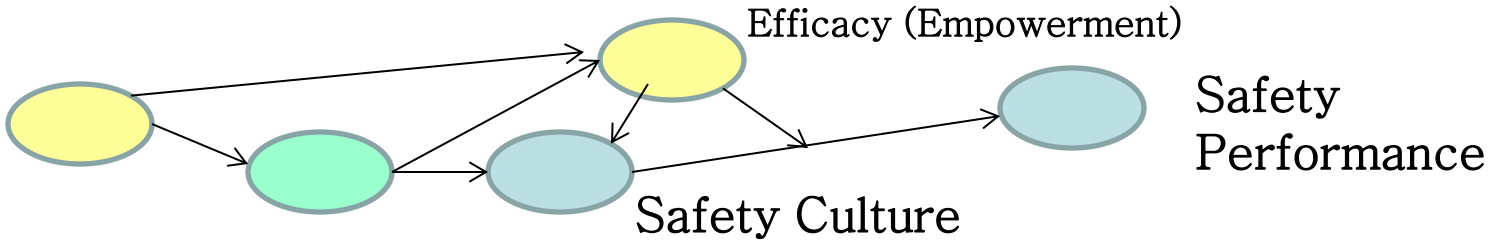


- ***Assumption: When safety culture (climate) high, workers perceive safety as critical***
  - Workers & supervisors actively make causal inferences about safety *(DeJoy, 1994; Hofmann & Stetzer, 1998)*
  - Workers are motivated to be proactive in identifying & correcting anomalies *(O'Dea & Flin, 2001; Parker, et al., 2003; Simard & Marchand, 1995)*

*Overseas Houston* http://www.osg.com/siteFiles/SiteManager/108074FE485F3B5B879DD6C3AB711C3A.jpg, retrieved 24 October 2011