Leading Indicators of Safety in Virtual Organizations

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Leading Indicators of Safety

“In the aftermath of catastrophes, it is common to find prior indicators, missed signals, and dismissed alerts, that, had they been recognized and appropriately managed before the event, might have averted the undesired event.

Indeed, the accident literature is replete with examples, including the space shuttles Columbia (Columbia Accident Investigation Board, 2003) and Challenger (Vaughan, 1996), Three Mile Island (Chiles, 2002), The Concorde crash (BEA, 2004), the London Paddington train crash (Cullen, 2000), and American Airlines flight 587 to Santo Domingo (USA Today, May 25, 2003), among many others (Kletz, 1994; Marcus & Nichols, 1999; Turner & Pidgeon, 1997).

Virtual Organizations

- Organizations comprised of multiple, distributed members
- Temporarily linked together for competitive advantage
- Share a common value chain and business processes via distributed information technology
Virtual Organizations

- Health maintenance systems of distributed physicians, medical societies, managed care systems
- Fire and emergency medical service units
- Danish wind farm consortia
- Global telecommunications alliances providing 99% of the world’s secure interbank transactions
- International offshore oil and gas consortia
- Oil spill response teams
Characteristics of Virtual Organizations

- Members are not co-located
- May occasionally meet face-to-face as well as electronically
- Success depends on shared, interdependent business processes to achieve shared objectives
Characteristics of Virtual Organizations

• Creation of a common value chain among the members

• Temporary linkages between members

• Business processes supported by distributed information technology

Several common features….
Risk Propensity in Large-Scale Systems

- Tasks
  - Mining
  - Medicine
  - Manufacturing
  - Transport

- Technology
  - Heavy Equipment
  - Lasers, Chemicals
  - Sensor Systems
  - Information Technology

- People
  - Human Error
  - Bounded rationality
  - Information overload
  - Cognitive errors
  - Poor d-making

- Organizations
  - Organizational Errors
  - Lack of safety systems
  - Reporting structures
  - Impossible standards

- Culture
  - Risk Taking Cultures
  - Latent conditions
  - Environmental factors

Leading Indicators of Safety in Virtual Organizations

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Risk Propensity in Virtual Organizations

- Mining
- Medicine
- Manufacturing
- Transport

Tasks
- Human Error
- Bounded rationality
- Information overload
- Cognitive errors
- Poor d-making

Technology
- Heavy Equipment
- Lasers, Chemicals
- Sensor Systems
- Information Technology

People
- Mine
- Medicine
- Manufacturing
- Transport

Organizations
- Organizational Errors
- Lack of safety systems
- Reporting structures
- Impossible standards

Culture
- Latent conditions
- Environmental factors
- Risk Taking Cultures

Virtual Organizations:
- Distributed system—risk migration
- Autonomy & temporary alliances—Shared reliability culture difficult
- Interdependence & autonomy—Inherent tensions
- Large-scale complex interactions—Long incubation periods, Leading indicators difficult
Leading Indicators

• Conditions, events or measures that precede an undesirable event and have some value in predicting the arrival of the event

• Associated with proactive activities that identify hazards and assess, eliminate, minimize or control risk
Leading Indicators of Safety

“In high reliability industries, where significant hazards are present and rarely realized, organizations and their regulators pay considerable attention to safety assessment and risk mitigation.

In recent years, there has been a movement away from safety measures based purely on retrospective data or ‘lagging indicators’ such as fatalities, lost time accident rates and incidents, towards so called ‘leading indicators’ such as safety audits or measurements of safety climate…”

It has been argued that these are predictive measures enabling safety condition monitoring (Flin, 1998) which may reduce the need to wait for the system to fail in order to identify weaknesses and to take remedial action. This can also be conceived as a switch from ‘feedback’ to ‘feedforward’ control (Falbruch & Wilpert, 1999; Flin, Mearns, O’Connor & Bryden, 2000, p. 177).”


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Leading Indicators--Examples

- Economic leading, lagging and coincident indicators
- Health systems
- Electric power industry
- Near hit reporting in anesthesia management
- Nuclear safety precursor management
- Offshore oil & gas hazard analyses

http://www.eagle.org/default.html
Lagging Indicators--Examples

- Measures of a system taken after an event
- Measure outcomes and occurrences

- Recordable injury frequencies
- Lost time frequencies
- Lost time severity
- Vehicle accident frequencies
- Workers’ compensation losses
- Property damage costs
- Numbers & frequency of accident investigations
Leading Indicators of Safety in Virtual Organizations

Types of Indicators

• Indicators with **direct links** between signals and adverse events
  --causal link (presence of an individual)

• Indicators with **correlations** between signals (or clusters) and adverse events

• **Proxy** or surrogate indicators
Criteria for Selecting Indicators

[Chrvala & Bulger, 1999]


- Indicators should be worth measuring,
- Indicators can be measured for diverse populations,
- Indicators can be understood by people who need to act,
- Information will galvanize action,
- Actions that can lead to improvement are known and feasible, and
- Measurement over time will reflect the results of action.
Pilot Study

• Identify, analyze & evaluate a set of leading safety indicators in marine transportation

• Initially, domestic tankers (2004-2006)

• Data analysis & structuring

• Partnerships with industry
Value-Focused Thinking

Fundamental Objectives

Basic/Root Causes

- Improve Organizational Safety Culture
- Improve Shipboard Safety Culture
- Improve Individual’s Safety Attitude
- Minimize Immediate Causes

Minimize Mechanical Failures
Minimize Human Errors

Strategic Objective

Leading Indicators

Minimize Accidents

Lagging Indicator
Initial Safety Factor Structure

Fundamental Objectives

- Improve Organizational Safety Culture
  - Senior Management Interview
  - Hiring Quality Personnel
  - Orientation In Safety
  - Promotion Of Safety
  - Formal Learning System
- Improve Shipboard Safety Culture
  - Ship Operations Interview
  - Responsibility
  - Communication
  - Problem Identification
  - Prioritization
  - Feedback
- Improve Individual’s Safety Attitude
  - Safety, Health & Environmental Interview
  - Empowerment
  - Responsibility
  - Anonymous Reporting
  - Feedback
- Minimize Immediate Causes
  - Minimize Mechanical Failures
  - Minimize Human Errors

Strategic Objective

- Minimize Accidents
  - Lagging Indicator
  - Vetting Personnel Interview

Leading Indicators

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Leading Indicators of Safety in Virtual Organizations
Research Model

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

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

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

Individual Safety Factors
- Empowerment
- Responsibility
- Anonymous Reporting
- Feedback

Individual Safety Performance
- Degree of perceived risk
- # accidents
- # incidents
- # near misses
- # LTI>=3

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

H1-H4
H5-H9
H10-H13
## Hypotheses

<table>
<thead>
<tr>
<th>Organizational Hypotheses</th>
</tr>
</thead>
<tbody>
<tr>
<td>H1</td>
</tr>
<tr>
<td>H2</td>
</tr>
<tr>
<td>H3</td>
</tr>
<tr>
<td>H4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Shipboard Hypotheses</th>
</tr>
</thead>
<tbody>
<tr>
<td>H5</td>
</tr>
<tr>
<td>H6</td>
</tr>
<tr>
<td>H7</td>
</tr>
<tr>
<td>H8</td>
</tr>
<tr>
<td>H9</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Individual Hypotheses</th>
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</thead>
<tbody>
<tr>
<td>H10</td>
</tr>
<tr>
<td>H11</td>
</tr>
<tr>
<td>H12</td>
</tr>
<tr>
<td>H13</td>
</tr>
</tbody>
</table>
Method

Subjective measures

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

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

Individual Safety Factors
- Empowerment
- Responsibility
- Anonymous Reporting
- Feedback

Objective measures

Organizational Safety Performance
- # accidents
- # incidents
- # near misses
- # of conditions of class
- # of port state deficiencies
- # LT1>=3

Vessel Safety Performance
- # accidents
- # incidents
- # near misses
- # of conditions of class
- # of port state deficiencies
- # LT1>=3

Individual Safety Performance
- Degree of perceived risk
- # accidents
- # incidents
- # near misses
- # LT1>=3

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Leading Indicators of Safety in Virtual Organizations
Method

- Subjective measures
- Objective measures

- Subjective measures—safety factor surveys (Flin, Mearns & O’Connor 2000, 2001)
  --5 point Likert scale
  --Strongly agree to Strongly disagree
  --Employee perceptions of the importance of safety factors in safety performance

- Objective measures—safety performance data
Your organization is participating in a research project, sponsored by American Bureau Shipping and being conducted by Rensselaer Polytechnic Institute, that is examining employee perceptions of factors responsible for safety performance in the U.S. marine transportation system. This survey is being administered as part of this research project. The researchers will not collect any identifying information from the survey (e.g., IP addresses).
<table>
<thead>
<tr>
<th>Hiring Quality People</th>
<th>Strongly disagree</th>
<th>Slightly disagree</th>
<th>Neutral</th>
<th>Slightly agree</th>
<th>Strongly agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) My colleagues consider safety issues seriously while performing job duties.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b) The hiring process in my organization is effective in identifying the right people for jobs.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Your organization is participating in a research project identifying the factors responsible for safety performance in the U.S. marine transportation system. The attached questionnaire is being administered as part of this research project. It is recommended that the chief safety officer of the vessel or someone who has access to the safety performance data of the vessel answer this questionnaire.
Organizational Safety Performance Questionnaire

TO BE FILLED OUT BY THE CHIEF SAFETY OFFICER OF THE ORGANIZATION

Department of Decision Sciences and Engineering Systems
Rensselaer Polytechnic Institute
Troy, New York, 12180

Your organization is participating in a research project identifying the factors responsible for safety performance in the U.S. marine transportation system. The attached questionnaire is being administered as part of this research project. It is recommended that the safety officer of the organization or someone who has access to the safety performance data of the organization complete this questionnaire.
<table>
<thead>
<tr>
<th><strong>Safety Performance Data</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Organizational Safety Performance</strong></td>
</tr>
<tr>
<td>#accidents per vessel</td>
</tr>
<tr>
<td>#incidents per vessel</td>
</tr>
<tr>
<td>#near-misses per vessel</td>
</tr>
<tr>
<td>#conditions of class per vessel</td>
</tr>
<tr>
<td>#port state deficiencies per vessel</td>
</tr>
<tr>
<td>#LTI&gt;=3 per vessel</td>
</tr>
<tr>
<td><strong>Vessel Safety Performance</strong></td>
</tr>
<tr>
<td>#accidents per employee</td>
</tr>
<tr>
<td>#incidents per employee</td>
</tr>
<tr>
<td>#near-misses per employee</td>
</tr>
<tr>
<td>#conditions of class per employee</td>
</tr>
<tr>
<td>#port state deficiencies per employee</td>
</tr>
<tr>
<td>#LTI&gt;=3 per employee</td>
</tr>
<tr>
<td><strong>Individual Safety Performance</strong></td>
</tr>
<tr>
<td>#accidents</td>
</tr>
<tr>
<td>#incidents</td>
</tr>
<tr>
<td>#near-misses</td>
</tr>
<tr>
<td>#LTI&gt;=3</td>
</tr>
<tr>
<td>Perceived risk</td>
</tr>
</tbody>
</table>
# Participants

<table>
<thead>
<tr>
<th>No.</th>
<th>Organization</th>
<th>Operation</th>
<th>Trade</th>
<th>Fleet</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sea River Maritime Inc.</td>
<td>Oil tanker</td>
<td>Domestic US</td>
<td>7, 2 tugs</td>
</tr>
<tr>
<td>2</td>
<td>Alaska Tanker Company</td>
<td>Oil tanker</td>
<td>Domestic US, Intern.</td>
<td>8</td>
</tr>
<tr>
<td>3</td>
<td>Bouchard Transportation Inc.</td>
<td>Tug-barge</td>
<td>Domestic US, Great Lakes, Intern.</td>
<td>26 B, 19T</td>
</tr>
<tr>
<td>4</td>
<td>Keystone Shipping Company</td>
<td>Oil tanker</td>
<td>Domestic US, TAPS</td>
<td>6</td>
</tr>
<tr>
<td>5</td>
<td>Crowley Maritime Corp</td>
<td>Tug-barge, Oil tanker</td>
<td>Inland</td>
<td>6+</td>
</tr>
<tr>
<td>6</td>
<td>SeaBulk International</td>
<td>Petro. &amp; Chem. tankers</td>
<td>Inland, Intern</td>
<td>10, 26T</td>
</tr>
<tr>
<td>7</td>
<td>Chevron Shipping Company</td>
<td>Oil and LNG</td>
<td>Domestic US, Intern</td>
<td>30</td>
</tr>
<tr>
<td>8</td>
<td>Cononco Philips Polar Tankers</td>
<td>Oil tankers</td>
<td>Domestic US, TAPS</td>
<td>6</td>
</tr>
<tr>
<td>9</td>
<td><strong>Overseas Shipholding group</strong></td>
<td><strong>Oil tankers</strong></td>
<td><strong>International</strong></td>
<td><strong>86+</strong></td>
</tr>
<tr>
<td>10</td>
<td>Shell Shipping</td>
<td>Oil tanker, LNG</td>
<td>Domestic US, Intern</td>
<td>10</td>
</tr>
<tr>
<td>11</td>
<td>AHL Shipping Company</td>
<td>Oil tanker</td>
<td>Domestic US, Gulf Tr.</td>
<td>7</td>
</tr>
<tr>
<td>12</td>
<td>EL Paso Marine</td>
<td>LNG</td>
<td>International</td>
<td>6</td>
</tr>
<tr>
<td>13</td>
<td>American Steamship Comp.</td>
<td>Dry Bulk</td>
<td>Great Lakes</td>
<td>11</td>
</tr>
<tr>
<td>14</td>
<td>Odjfell USA Inc.</td>
<td>Chemical tankers</td>
<td>International</td>
<td>32</td>
</tr>
</tbody>
</table>
Statistical Analysis

- **Correlation analysis** between
  -- indicators and safety factors
  -- indicators and safety performance
  -- Pearson product moment correlation
  -- t-test to test significance of correlation

http://www.eagle.org/default.html
• **Regression analysis** to determine predictive power of leading indicators
  --Safety factors with safety performance
  --Leading indicators with safety performance

  --Distribution of mean errors to validate predictive power of leading indicators
  --Kolmogrov-Smirnoff statistic
**Statistical Analysis**

Factor analysis of safety climate data
--orthogonal and oblique rotations
--is there a common factor structure in all operator organizations?

• Questionnaire reliability

• Logical analysis of data
Safety Factor Results

Factor Analysis:

- Anonymous Reporting
- Hiring Quality People
- Feedback (Individual, Ship)
- Formal Learning System
- Empowerment
- Communication

Principal Component Factor Analysis followed by orthogonal varimax rotation. The factors are chosen on the basis of minimum eigen value criterion.
Feedback vs. Near Losses
Permutation test--Feedback_Ship

Observed coefficient = -0.8589
p-value = 0.0071
Safety Index

Safety Index = \( w_i \times \text{SafetyFactor}_i \)

Weights provided by solution to the following optimization problem

\[
\min_w \text{Corr(Safety index, Near Loss)} \\
\sum w_i = 1 \\
w_i \geq 0
\]
Ship Safety Index

\[ Safety \text{Index} = w_i \times \text{SafetyFactor}_i \]

\[ Safety\text{Index} = 0.326 \times \text{prioritization of safety} + 0.0 \times \text{communication} + 0.036 \times \text{problem identification} + 0.637 \times \text{feedback ship} + 0.0 \times \text{responsibility} \]

\[ \text{Mean NearLoss} = 59.40 - 11.23 \times \text{SafetyIndex} \]
Pilot Study Significant Results --

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

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

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

Individual Safety Factors
- Empowerment
- Responsibility
- Anonymous Reporting
- Feedback

Individual Safety Performance
- Degree of perceived risk
- # accidents
- # incidents
- # near misses
- # LTI>=3

H1-H4
H8, H9
H10-H13
Leading Indicators in Virtual Organizations

- Prioritization of safety and reliability as goals
- Organizational structuring and design
- Shared organizational culture of reliability
- Communication at the organization’s interfaces
- Trust

High reliability organization research

Network, virtual organizations
Virtual Organization Safety Factors

Fundamental Objectives

Basic/Root Causes

Minimize Accidents
Minimize Mechanical Failures
Minimize Human Errors

Strategic Objective

Leading Indicators

Improve Virtual Org Safety Culture
Improve Organizational Safety Culture
Improve Shipboard Safety Culture
Improve Individual’s Safety Attitude
Minimize Immediate Causes

Lagging Indicator

Improve Virtual Org Safety Culture
Improve Organizational Safety Culture
Improve Shipboard Safety Culture
Improve Individual’s Safety Attitude
Minimize Immediate Causes

Leading Indicators

Minimize Accidents
Minimize Mechanical Failures
Minimize Human Errors

Fundamental Objectives

Lagging Indicator
Virtual Organization Safety Factor Structure

Fundamental Objectives

Leading Indicators of Safety in Virtual Organizations

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Revised Virtual Organization Model

**VO Safety Factors**
- Prioritization of Safety
- Organizational Design
- Communication @ Interfaces
- Shared Reliability Culture
- Trust

**Organizational Safety Factors**
- Hiring Quality Personnel
- Safety Orientation
- Promotion of Safety
- Formal Learning System

**Unit Safety Factors**
- Responsibility
- Communication
- Problem Identification
- Prioritization of Safety
- Feedback

**Individual Safety Factors**
- Empowerment
- Responsibility
- Anonymous Reporting
- Feedback

**VO Safety Performance**
- # accidents
- # incidents
- # near misses
- # LTI>=3

**Organizational Safety Performance**
- # accidents
- # incidents
- #near misses
- # LTI>=3

**Unit Safety Performance**
- # accidents
- # incidents
- #near misses
- # LTI>=3

**Individual Safety Performance**
- # accidents
- # incidents
- #near misses
- # LTI>=3
## Candidate Leading Indicators

**Soma Neural Nets, 2004**

- #ILO conventions adopted by vessel flag
- Propulsion system availability
- Primary fleet flag
- Co-ownership?
- Country of registry
- Non-IACS class?
- Mean fleet age
- Ship type
- Vessel flag

**Safety Performance**

ADAC score  
# deficiencies per PSC inspection  
# Accidents  
# Immaculate PSC inspections

\[ R^2 = .43 - .61 \]

(Soma, Chapter 4, Figure 5, p 72)

**Principal Components**

(Soma, Ch. 7, p. 126)

---

### Safety Rehearse

<table>
<thead>
<tr>
<th>Soma PCA, 2004</th>
<th>UK HSE, 2000</th>
<th>Mearns, et al., 2003</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety rehearse</td>
<td>Productivity vs. safety</td>
<td>Involvement</td>
</tr>
<tr>
<td>Commitment</td>
<td>Learning organization</td>
<td>Perceived supervisor competence</td>
</tr>
<tr>
<td>Communication</td>
<td>Safety resources</td>
<td>General safety behavior</td>
</tr>
<tr>
<td>Job satisfaction</td>
<td>Participation</td>
<td>Safety behavior under incentive</td>
</tr>
<tr>
<td>Acknowledgement of personal limitations</td>
<td>Shared perceptions about safety</td>
<td>Rules &amp; implementation of safety measures</td>
</tr>
<tr>
<td>Work integrity</td>
<td>Trust</td>
<td>Propensity to report incidents/accidents</td>
</tr>
<tr>
<td>Social integration</td>
<td>Training</td>
<td>Perceived management commitment</td>
</tr>
<tr>
<td>Power &amp; dignity</td>
<td>Management commitment &amp; visibility</td>
<td>Communication</td>
</tr>
</tbody>
</table>

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Leading Indicators of Safety in Virtual Organizations
## Candidate Leading Indicators

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<thead>
<tr>
<th>Soma PCA, 2004</th>
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<th>OCIMF TMSA, 2004</th>
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</thead>
<tbody>
<tr>
<td>- Safety rehearse</td>
<td>- #ILO conventions adopted by vessel flag</td>
<td>- Productivity vs. safety</td>
<td>- Mgmt, Leadership, Accountability</td>
</tr>
<tr>
<td>- Commitment</td>
<td>- Propulsion system availability</td>
<td>- Learning organization</td>
<td>- Recruitment/mgmt of personnel</td>
</tr>
<tr>
<td>- Communication</td>
<td>- Primary fleet flag</td>
<td>- Safety resources</td>
<td>- Reliability &amp; maintenance</td>
</tr>
<tr>
<td>- Job satisfaction</td>
<td>- Co-ownership?</td>
<td>- Participation</td>
<td>- Navigational safety</td>
</tr>
<tr>
<td>- Acknowledgement of personal limitations</td>
<td>- Country of registry</td>
<td>- Shared perceptions about safety</td>
<td>- Cargo, ballast &amp; mooring ops</td>
</tr>
<tr>
<td>- Work integrity</td>
<td>- Non-IACS class?</td>
<td>- Trust</td>
<td>- Management of change</td>
</tr>
<tr>
<td>- Safety training/orientat'n</td>
<td>- Mean fleet age</td>
<td>- Training</td>
<td>- Incident investigation &amp; analysis</td>
</tr>
<tr>
<td>- Mgmt commitment</td>
<td>- Ship type</td>
<td>- Safety training &amp; rehearsal</td>
<td>- Safety management</td>
</tr>
<tr>
<td>- Communication</td>
<td>- Vessel flag</td>
<td>- Management commitment &amp; visibility</td>
<td>- Environmental management</td>
</tr>
<tr>
<td>- Job satisfaction</td>
<td>- Emeg preparedness</td>
<td>- Job satisfaction</td>
<td>- Emergency preparedness</td>
</tr>
</tbody>
</table>

**Principal Components**

(Soma, Ch. 7, p. 126)

(Soma, Chapter 4, Figure 5, p 72)

- Safety training & rehearsal
- Management commitment & visibility
- Communication
- Job satisfaction and industrial relations
- Safety training & rehearsal
- Perceived management commitment
- Communication
- Satisfaction with safety
- Job satisfaction

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**Leading Indicators of Safety in Virtual Organizations**
Statistical Significance

Correlation between ship characteristics and PSC indicator
\[ R^2 = .58 \]

Correlation between safety culture correlation measure and PSC indicator
\[ R^2 = .53 \]

Correlation between safety culture correlation measure and accidents
\[ R^2 = .65 \]

(Soma, Chapter 6, p 104)
Statistical Significance

Neural Net, Ch. 4

Correlation between NN results and ADAC score
\[ R^2 = 0.43 \]

Correlation between NN results and accidents
\[ R^2 = 0.61 \]

<table>
<thead>
<tr>
<th></th>
<th># Accidents (M = 100)</th>
<th># PSC DEF (M = 51)</th>
<th># IMMAC PSC (M = 51)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADAC Score</td>
<td>( P = 0.15 )</td>
<td>( P = 0.10 )</td>
<td>( P = 0.15 )</td>
</tr>
<tr>
<td># Accidents</td>
<td></td>
<td>( P = 0.36 )</td>
<td>( P = -0.08 )</td>
</tr>
<tr>
<td># PSC Deficiencies</td>
<td></td>
<td></td>
<td>( P = -0.63 )</td>
</tr>
</tbody>
</table>

(Soma, Chapter 4, p 104)
• ‘It is now assumed that having the cultural pattern that is most similar to the others have the most mature pattern.’

• The correlation coefficient between the correlation matrix indicator and the accident indicator was 0.61, and the same figure for the safety inspection indicator was 0.65.

• Even though the values isolated are not statistically significant, it is unlikely that 2 independent analyses [would] produce spurious correlations of this high value.”

(Soma, Chapter 7, p 122)
Validating Leading Indicators

Once candidate leading indicators have been identified….

- Scatter plot analysis
- Multiple regression analysis
- Validation against additional data sets
- Principal components analysis
- Neural nets
- Artificial (hybrid) neural nets
- Logical analysis of data (LAD) [data mining]

… to determine predictiveness of indicators
Cautions

Several cautions associated with leading indicators…

- Safety plateaus—mishap rates stabilize
  --suggests a mix of system- and individual-level leading indicators

- Heedfulness important to identify indicators
- Shared understanding of normal and abnormal
Cautions

Several cautions associated with leading indicators…

http://www.eagle.org/default.html

- Learning from accident precursors and leading indicators is difficult for organizations
  --root cause analyses, incident investigations

- Different subsystems within a large system may have their own cultures
  --different vessels may have different leading indicators
Event Chain for Maritime Accidents

Causal Chain

Stage 1
Basic/Root Causes
- Inadequate skills, knowledge, equipment, maintenance, management
- Human and organizational errors

Stage 2
Immediate Causes
- Operational errors
- Equipment failure
- Hazardous situation

Stage 3
Incidents
- Propulsion failures
- Steering failures
- Human failures

Stage 4
Accidents
- Collisions
- Groundings
- Allisions
- Ice collisions
- Fire & explosion

Stage 5
Consequence
- Oil outflow
- Persons in peril

Stage 6
Impact
- Environmental damage
- Loss of life
- Loss of property

I. Decrease Frequency of Root/Basic Causes
II. Decrease Frequency of Immediate Causes or III. Exposure to Hazardous Conditions
IV. Intervene to Prevent Accident if Incident Occurs
V. Reduce Consequences if Accident Occurs
VI. Reduce Impact if Consequence Occurs

Risk Reduction Interventions

Safety Management Programs
Channel Closure Restrictions
Escort Vessels, Redundancy
Double Hulls
Booming and Containment