Content

• Introduction to Human Factors
• Accidents and accident causation models
• Accident analysis methods
• Case study analyses
• Future directions
What is Human Factors?
Human Factors

- “the scientific study of the relationship between man and his working environment” (Murell, 1965)

- “the study of how humans accomplish work-related tasks in the context of human-machine systems” (Meister, 1989)

- “applied information about human behaviour, abilities, limitations and other characteristics to the design of tools, machines, tasks, jobs and environments” (Sanders & McCormick, 1993)

- Studying and enhancing the performance of sociotechnical systems
Accidents and accident causation
Accidents

• Latin verb ‘acciadere’ = ‘to happen’
• ad + cadere = ‘to fall’
• “a short, sudden, and unexpected event or occurrence that results in an unwanted or indesirable outcome” (Hollnagel, 2004)
• Event or occurrence directly or indirectly the result of human activity
Human error

• “a generic term to encompass all those occasions in which a planned sequence of mental or physical activities fails to achieve its intended outcome, and when these failures cannot be attributed to the intervention of some chance agency” (Reason, 1990, p. 9).
Theoretical perspectives

- **Person approach (or old view)**
  - Errors at the ‘sharp end’
  - Errors result from psychological/physical factors within individuals
  - Individual focussed strategies and countermeasures

- **Systems approach (or new view)**
  - Error as a systems failure
  - Human error as a consequence of latent conditions residing throughout the system
  - Systems-based strategies and countermeasures
Systems versus person perspectives
“Complex systems cannot be understood by studying parts in isolation. The very essence of the system lies in the interactions between parts and the overall behaviour that emerges from the interactions. The system must be analysed as a whole” (Ottino, 2003)
Swiss Cheese model of human error (Reason, 1990)

Accidents happen because (Reason, 2008)

- **Universals** – ever present hazards, create

- **Conditions** – latent factors that collectively produce defensive weaknesses that

- **Causes** – permit the chance conjunctions of local triggers and active failures to breach all the barriers and safeguards
Rasmussen’s risk management framework

- Government
  - Laws
  - Regulators, Associations
- Company
  - Regulations
  - Company Policy
- Management
  - Company Policy
  - Plans
- Staff
  - Plans
- Work
  - Action
- Hazardous process

Factors影响:
- Changing political climate and public awareness
- Changing market conditions and financial pressure
- Changing competency levels and education
- Fast pace of technological change

Other elements:
- Public opinion
- Boundary to unacceptable workload
- Boundary defined by official work practices
- Adverse events
Herald of Free Enterprise Zeebrugge disaster

- March 6\textsuperscript{th} 1987
- Ferry capsized
- 150 passengers & 38 crew killed
- Ferry set sail with inner bow doors open
Herald of Free Enterprise Zeebrugge disaster

- Assistant bosuns
- Failure to shut bow doors
- Captains leaves port with bow doors open
- Choppy sea
- Pressure to depart early
- ‘Not my job’ culture
- Inherent unsafe ‘top heavy’ ferry design
- Poor rostering
- Negative reporting culture
- Fatigue
- Failure to install bow door indicator

Unsafe Acts

Fallible Board Decisions and Policy

Latent and Active Failures

Accident Research Centre
Systems approach predictions (Rasmussen, 1997)

- Safety is an emergent property impacted by decisions of all actors, not just front line workers alone
- Threats to safety are caused by multiple contributing factors, not just a single catastrophic decision or action
- Threats to safety can result from a lack of vertical integration across levels of a complex sociotechnical system, not just from deficiencies at one level alone
- Lack of vertical integration is caused, in part, by lack of feedback across levels of a complex sociotechnical system
- Work practices are not static, the migrate over time and under the influence of financial and psychological pressures
- Migration occurs at multiple levels of complex sociotechnical systems
- Migration of work practices cause system defences to degrade and erode gradually over time, not all at once. Accidents are caused by a combination of this migration and a triggering event(s)
Other complex safety critical domains?

- Aviation Safety Reporting System
- NTSB accident database
- Theoretically underpinned, systems-based accident analysis e.g. HFACS
- Systems-based countermeasures
- Boeing Safety Management System
Figure showing the paths between the categories across the four HFACS levels. Bold lines denote associations that are highly statistically significant (p<.005), while dashed lines represent associations at the conventional level of significance (p<.05). All associations represent positive correlations, aside from that between physical environment and violations, which is negative.
Exploratory case study analyses
Aim

• To ascertain whether systems approaches are applicable in the led outdoor activity domain

• To determine which of three approaches is the most suitable for analysing, and learning from, led outdoor activity accidents and incidents
HFACS (Shappell & Wiegmann, 2003)

- Aviation accident investigation approach
- Based on Reason’s Swiss Cheese model
- Applications in a range of domains
  - General aviation
  - Maritime
  - Mining
  - Rail
  - Road transport
  - Construction
**Pre-conditions for Unsafe Acts**

- Environmental factors
- Personnel factors
- Physical environment
- Technical environment
- Human resource management
- Personnel readiness
- Physical & mental stresses

**Unsafe Supervision**

- Unsafe supervision
  - Inadequate supervision
  - Failed to correct a problem
  - Supervisory violations

**Organisational Influences**

- Resource management
- Organisational climate
- Organisational process

**Unsafe Acts**

- Errors
  - Skill-based errors
  - Perceptual errors
  - Decision errors
- Violations
  - Routine
  - Exceptional

**Psychological Precursors of Unsafe Acts**

- Line Management Problems
  - Fidibility Board Decisions and Policy

**Environmental Factors**

- Condition of operators
  - Physical environment
  - Technical environment

**Personnel Factors**

- Human resource management
- Personnel readiness

**Physical & Mental Stresses**

- Physical & mental states
- Physical & mental stressors

**Unsafe Acts**

- Errors
  - Skill-based errors
  - Perceptual errors
  - Decision errors
- Violations
  - Routine
  - Exceptional
<table>
<thead>
<tr>
<th>ERRORS</th>
<th>VIOLATIONS</th>
</tr>
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<tbody>
<tr>
<td><strong>Skill-based Errors</strong></td>
<td><strong>Routine</strong></td>
</tr>
<tr>
<td>• Breakdown in visual scan</td>
<td>• Inadequate briefing for flight</td>
</tr>
<tr>
<td>• Inadvertent use of flight controls</td>
<td>• Failed to use ATC radar advisories</td>
</tr>
<tr>
<td>• Poor technique/airmanship</td>
<td>• Flew an unauthorised approach</td>
</tr>
<tr>
<td>• Over-controlled the aircraft</td>
<td>• Violated training rules</td>
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<tr>
<td>• Omitted checklist item</td>
<td>• Filed VFR in marginal weather conditions</td>
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<tr>
<td>• Omitted step in the procedure</td>
<td>• Failed to comply with departmental manuals</td>
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<tr>
<td>• Over-reliance on automation</td>
<td>• Violation of orders, regulations, SOPs</td>
</tr>
<tr>
<td>• Failed to prioritise attention</td>
<td>• Failed to inspect aircraft after in-flight caution light</td>
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<tr>
<td>• Task overload</td>
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<tr>
<td>• Negative habit</td>
<td></td>
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<tr>
<td>• Failure to see and avoid</td>
<td></td>
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<tr>
<td>• Distraction</td>
<td></td>
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<tr>
<td><strong>Decision Errors</strong></td>
<td><strong>Exceptional</strong></td>
</tr>
<tr>
<td>• Inappropriate maneuver/procedure</td>
<td>• Performed unauthorized acrobatic maneuver</td>
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<tr>
<td>• Inadequate knowledge of systems, procedures</td>
<td>• Improper takeoff technique</td>
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<tr>
<td>• Exceeded ability</td>
<td>• Failed to obtain valid weather brief</td>
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<tr>
<td>• Wrong response to emergency</td>
<td>• Exceeded limits of aircraft</td>
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<tr>
<td><strong>Perceptual Errors</strong></td>
<td>• Failed to complete performance computations for flight</td>
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<tr>
<td>• Due to visual illusion</td>
<td>• Accepted unnecessary hazard</td>
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<tr>
<td>• Due to spatial disorientation/vertigo</td>
<td>• Not current/qualified for flight</td>
</tr>
<tr>
<td>• Due to misjudged distance, altitude, airspeed, clearance</td>
<td>• Unauthorised low-altitude canyon running</td>
</tr>
<tr>
<td>CONDITION OF OPERATOR</td>
<td>PERSONNEL FACTORS</td>
</tr>
<tr>
<td>--------------------------------------</td>
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<tr>
<td><strong>Adverse Mental States</strong></td>
<td><strong>Crew Resource Management</strong></td>
</tr>
<tr>
<td>• Loss of situational awareness</td>
<td>• Failed to conduct adequate brief</td>
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<tr>
<td>• Complacency</td>
<td>• Lack of teamwork</td>
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<tr>
<td>• Stress</td>
<td>• Lack of assertiveness</td>
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<tr>
<td>• Overconfidence</td>
<td>• Poor communication/co-ordination within and between aircraft, ATC, etc.</td>
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<tr>
<td>• Poor flight vigilance</td>
<td>• Misinterpretation of traffic calls</td>
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<td>• Task saturation</td>
<td>• Failure of leadership</td>
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<tr>
<td>• Alertness (drowsiness)</td>
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<tr>
<td>• Get-home-itis</td>
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<td>• Mental fatigue</td>
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<td>• Circadian dysharmony</td>
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<td>• Channelised attention</td>
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<td>• Distraction</td>
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<td><strong>Adverse Physiological States</strong></td>
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<td>• Medical illness</td>
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<tr>
<td>• Hypoxia</td>
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<tr>
<td>• Physical fatigue</td>
<td></td>
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<tr>
<td>• Intoxication</td>
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<tr>
<td>• Motion sickness</td>
<td></td>
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<tr>
<td>• Effects of OTC medications</td>
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<tr>
<td><strong>Physical/Mental Limitations</strong></td>
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<tr>
<td>• Visual limitations</td>
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<td>• Insufficient reaction time</td>
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<tr>
<td>• Information overload</td>
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<tr>
<td>• Inadequate experience for complexity of situation</td>
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<tr>
<td>• Incompatible physical capabilities</td>
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<tr>
<td>• Lack of aptitude to fly</td>
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<tr>
<td>• Lack of sensory input</td>
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<tr>
<td><strong>Environmental Factors</strong></td>
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<td><strong>Physical Environment</strong></td>
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<tr>
<td>• Weather</td>
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<tr>
<td>• Altitude</td>
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<tr>
<td>• Terrain</td>
<td></td>
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<tr>
<td>• Lighting</td>
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<tr>
<td>• Vibration</td>
<td></td>
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<tr>
<td>• Toxins in the cockpit</td>
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<tr>
<td><strong>Technological Environment</strong></td>
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<tr>
<td>• Equipment/controls design</td>
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<tr>
<td>• Checklist layout</td>
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<tr>
<td>• Display/Interface characteristics</td>
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<tr>
<td>• Automation</td>
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</table>
AcciMaps (Rasmussen, 1997)

- Graphically represent accident causation trajectories
- Six organisational levels
  - Govt policy and budgeting;
  - Regulatory bodies and associations;
  - Local area Govt planning & budgeting;
  - Technical operation and management;
  - Physical processes and actor activities;
  - Equipment and surroundings.
- Applied to range of accidents including gas plant explosions (Hopkins, 2000), loss of space vehicles (Johnson & de Almeida, 2008), aviation accidents (RAAF, 2001), public health (Vicente & Christoffersen, 2006), and road and rail accidents (Svendung & Rasmussen, 2002; Hopkins, 2005).

Applicable to catastrophic failures in any domain.
Root cause model (Davidson, 2007)

Over load
- Lack of personal capacity
- Poor physical or mental condition
- Ariseal motivation impaired
- Inability to allocate time to the task (Hard soft role)
- Task too large
- Traps in the workplace

Poor concentration
- Actions without thinking
- Forgetting

Misapplication of skills
- Hard soft meta

Poor judgement
- Poor situational awareness
- Inaccurate risk assessment
- Snap decision without considering alternatives
- Poor processing of past feedback
- Failures

Failing to meet judgement responsibilities
- Choosing to take a higher level of risk than needed
- Deferring the judgement to others
- No judgement

Misdirected motivation/attitude
- Breaking policy
- Sabotage

Root causes leading to poor performance or judgment

Over load
1. Lack of personal capacity
   a. Physical
   b. Mental
2. Poor physical of mental condition
   a. Injury
   b. Sickness
   c. Physical fatigue
   d. Mental fatigue
3. Arousal/Motivation Impaired
   a. Drugs/alcohol
   b. Biornhythmic
   c. Menstrual
   d. Bored
4. Mismatch of Skills
   a. Experience to task
   a. Local knowledge
   b. Hard skills
   c. Soft skills
   d. Meta skills
5. Task too large
   a. Hours per day too great
   b. Days without break too great
6. Traps in work environment
   a. Equipment traps
   b. Environment traps
   d. Student traps

Poor Concentration
7. Actions without thinking
8. Forgetting

Misapplication of skills
9. Misapplication of skills
   a. Hard skills
   b. Soft skills
   c. Meta skills

Poor judgment
10. Poor situational awareness
    a. Availability
    b. Selective perception
    c. Selective focus
    d. Frequency desensitivity
    e. End of session
    f. Transfered responsibility
    g. Concrete information
11. Inaccurate Assessment of the Risk
    a. Inconsistency
    b. Failure to review
    c. No-risk perception
    d. Perceived as unlikely to happen
    e. Justifying away the risk
    f. Sunny day syndrome
    g. Negative event feedback
12. Illusion of control
    i. Wistful thinking
    j. Illusion of control
13. Risk homeostasis
14. Trap Decision Without Considering Options
    a. Habitual rule of thumb
    b. First impressions
15. Poor Processing of Past Experiences
    a. No accident errors
    b. It must go right next time
    c. Success/failure attribution
16. No Judgement Made
17. Breaks Organisational Policies
18. Sabotage

Failing to meet judgement responsibilities
14. Choosing to take a higher level of risk than needed
   a. Physical comfort ease
   b. Mental ease
   c. Emotion comfort ease
   d. Personal ego needs
   e. Others' needs/values
   f. Personal goals/values
   g. Perceived goals of management
   h. Pressured by timel conditions
   i. Risky shift
   j. Illusions of
   k. Natural risk taker
   l. Gender and other social interactions
15. Deferring Judgement to Others
16. No Judgement Made
17. Breaks Organisational Policies
18. Sabotage
Case study accidents

• Lyme Bay Kayaking tragedy

• Ripswing incident

• Entrapment and near drowning incident
Case study accidents

• Lyme Bay Kayaking tragedy

• Ripswing incident

• Entrapment and near drowning incident
The Lyme Bay Kayaking Tragedy

- Introductory open sea kayak activity
- Initial capsizes
- Group becomes separated and swept out to sea
- High wind and wave conditions lead to further capsizes and abandoning of kayaks
- Delayed rescue
- 4 students drowned
Lyme Bay Root cause model analysis

**Instructor root causes**
- Mismatch of skills/Experience
- Equipment traps
- Environment traps
- Poor judgement
- Inaccurate assessment of risk

**Managerial root causes**
- Poor safety management systems
Lyme Bay incident Accimap

Government policy and budgeting
- No government legislation to control activity centres
- Accreditation body failed to inspect sea activities

Regulatory bodies & associations
- Absence of an outdoor centre - regulation or inspection

Local area Government planning & budgeting, Company management
- Company management ignored letter regarding poor safety

Technical & operational management
- Centre management - inadequate qualified experienced
- Instructor inadequately qualified experienced by
- Exercise not examined
- Exercise not examined
- Students gave inadequate training e.g.
- Students gave inadequate training e.g.
- No advice given on group
- Student's instructor not to infill
- Required ratios of competent instructors in instructions

Physical processes & actor activities
- Teacher capsized canoe
- Teacher capsized canoe
- Students taught inexperienced
- Students teach inexperienced
- Student unable to stay afloat
- Rolling together
- Loss of control between
- Disciplined filled with
- Abandonment of canoe
- Failure to initiate in-wa ter procedures
- Delayed, inadequate search and
- Drowned

Equipment & surroundings
- Failure to supply appropriate equipment for activity e.g.
- Failure to provide rafts
- Failure to provide spray decks
- Failure to provide distress flares
- Failure to provide canoe with spray emergency buoyancy
- Failure to provide towlines
- Failure to provide adequate clothing for students
- Failure to provide survival bag
- Failure to provide whistles for every student
- Failure to provide coloured helmets
- Failure to provide canoe fitted with decklines
- Failure to provide enough boat

Adverse condition

Lyme Bay incident Accimap

Inadequate safety

Inadequate emergency procedures

Failure to supervise centre manager's ensure canoeing was being safely managed

Failure of Devon County Council to inspect sea activities

Southway staff failure to follow handbook for recreational activities

LEA checklist not used by Southway

Company management ignored oral warnings regarding poor safety

Poor communication

Inadequate emergency procedures

Absent of an outdoor centre - regulation or inspection

Company management ignored letter regarding poor safety

Inadequate safety
Systems-based accident analysis?
Validation of Rasmussen’s framework

- Safety is an emergent property impacted by decisions of all actors, not just front line workers alone
- Threats to safety are caused by multiple contributing factors, not just a single catastrophic decision or action
- Threats to safety can result from a lack of vertical integration across levels of a complex sociotechnical system, not just from deficiencies at one level alone
- Lack of vertical integration is caused, in part, by lack of feedback across levels of a complex sociotechnical system
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- Migration occurs at multiple levels of complex sociotechnical systems
- Migration of work practices cause system defences to degrade and erode gradually over time, not all at once. Accidents are caused by a combination of this migration and a triggering event(s)
Lyme Bay incident Accimap

Government policy and budgeting
- No government legislation to control activity centres
- Accreditation body failed to inspect sea activities

Regulatory bodies & associations
- Absence of an outdoor centre regulation or guidance

Local area Government planning & budgeting, Company management
- Company management ignored letter regarding poor safety procedures

Technical & operational management
- Centre managers ignored warnings regarding poor weather conditions

Physical processes & actor activities
- Students/teachers inexperienced

Equipment & surroundings
- Failure to supply appropriate equipment for activity e.g.: - Failure to provide radios; - Failure to provide spray decks; - Failure to provide distress flares; - Failure to provide canoes with suppl emergency buoyancy; - Failure to provide life jackets; - Failure to provide adequate clothing for students; - Failure to provide survival bag; - Failure to provide whistles for every student; - Failure to provide coloured hats; - Failure to provide canoes fitted with decklines; - Failure to provide oars and boats.

Adverse conditions
- Delayed, inadequate search and rescue operations

Coastguard given wrong information about missing

Poor communication
- Coastguard notified too late

Oversight of Peach
- Poor understanding of offshore winds & affect on canoes

Exercise not suitable for novices
- Inability to right capsized canoe

Poor equipment
- Failure to initiate in-water procedure

Loss of contact between groups
- Inadequate emergency procedures
- Failure to supervise centre manager to ensure canoeing was being safely managed

Staff handbook for recreational activities
- Failure to provide appropriate equipment for activity e.g.: - Failure to provide radios; - Failure to provide spray decks; - Failure to provide distress flares; - Failure to provide canoes with suppl emergency buoyancy; - Failure to provide life jackets; - Failure to provide adequate clothing for students; - Failure to provide survival bag; - Failure to provide whistles for every student; - Failure to provide coloured hats; - Failure to provide canoes fitted with decklines; - Failure to provide oars and boats.

LEA checklist not used by Southern Management
## Generic failure types

<table>
<thead>
<tr>
<th>Government policy and budgeting</th>
<th>LACK OF LEGISLATION</th>
</tr>
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<tbody>
<tr>
<td>Regulatory bodies &amp; associations &amp; associations</td>
<td>LACK OF REGULATORY BODY</td>
</tr>
<tr>
<td>Local area Government planning &amp; budgeting</td>
<td>INADEQUATE PROCEDURES</td>
</tr>
<tr>
<td>Company management</td>
<td>INADEQUATELY QUALIFIED</td>
</tr>
<tr>
<td>Technical &amp; operational management</td>
<td>INADEQUATELY QUALIFIED</td>
</tr>
<tr>
<td>Physical processes &amp; actor activities</td>
<td>FAILURE TO COMPLY WITH LAW, PROCEDURES</td>
</tr>
<tr>
<td>Equipment &amp; surroundings</td>
<td>INAPPROPRIATE EQUIPMENT</td>
</tr>
</tbody>
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The way forward?
Data challenges

“"In complex systems, event analyses are constrained by the quality of the data gathered, the maturity of the associated reporting system, and the training and background of the investigator and reporter. Such constraints place limits on the adequacy and strength of analyses conducted with the data.""

(Grabowski et al, 2009)
Data challenges

“In complex systems, event analyses are constrained by the quality of the data gathered, the maturity of the associated reporting system, and the training and background of the investigator and reporter. Such constraints place limits on the adequacy and strength of analyses conducted with the data.”

(Grabowski et al, 2009)
Data and analysis challenges

• Standardised incident reporting system
• Standardised accident and incident database
• Systems-based accident analysis method
• Investigator training in HF/systems-based models
• Outdoor activity contributory factor taxonomies
• Instructor/student error taxonomies
• In-depth analysis

• Feasibility study?
Benefits

• Study of accidents widely accepted as a way of acquiring knowledge that can improve safety (e.g. Cassano-Piche et al, 2009)
• Development and application of standardised, universally accepted, theoretically underpinned data collection, storage and analysis approaches will lead to an increase in knowledge, the appropriate application of which is likely to lead to a reduction in safety compromising accidents and incidents
Questions?

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