safety science

some past and recent research areas

including construction

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content

1. introduction

2. asbestos

3. steel

4. theories - models - metaphors

5. management

6. construction

7. predictability of accidents

8. education
red thread of presentation

- from mechanism to risk assessment
- from hazard to culture
- from human factor to socio-technique
- from technology push, cost reduction to disasters
- from risk assessment to design
- from management to accidents
- from rule following to critical reflection
1 introduction

Raphael  School of Athens 16th century
2 asbestos

latency period & mechanism
## 2 asbestos

**occupation and mesothelioma**

<table>
<thead>
<tr>
<th>Industry</th>
<th>risk/100 workers</th>
<th>risk ratio</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>insulation industry</td>
<td>4.7</td>
<td>328</td>
<td>59</td>
</tr>
<tr>
<td>ship building, maintenance</td>
<td>1.2</td>
<td>83</td>
<td>196</td>
</tr>
<tr>
<td>refinery</td>
<td>0.3</td>
<td>24</td>
<td>12</td>
</tr>
<tr>
<td>train/tram building</td>
<td>0.2</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>stone, glass, cement</td>
<td>0.1</td>
<td>9</td>
<td>23</td>
</tr>
<tr>
<td>construction</td>
<td>0.07</td>
<td>5</td>
<td>102</td>
</tr>
<tr>
<td>chemical industry</td>
<td>0.06</td>
<td>4</td>
<td>13</td>
</tr>
<tr>
<td>all other industries</td>
<td>0.01</td>
<td>1</td>
<td>254</td>
</tr>
</tbody>
</table>

we are here to produce

this is a very dangerous plant

we work like this for years

without too much trouble

we do not need procedures,

because we are experienced

everybody is responsible for

his own safety

victims are always to blame

accidents will always happen

Swuste P Hale A Guldenmund F (2002). Changes in a steel works learning from failures and partial successes. in System Safety challenges and pitfalls of intervention Pergamon Adam
4 theories - models - metaphors

Heinrichs’ metaphors statistical correlations

1927 costs: 1 : 4 (direct : indirect)

1928 causes: 88 : 10 : 2 (human : technical : God)

1929 mechanism: 1 : 29 : 300 (serious : minor : no harm)

1931 management: training, selection, safety technique

1941 sequence, dominos:

Heinrich W (1931). Industrial accident prevention, a scientific approach
Heinrich W (1941). Industrial accident prevention, a scientific approach 2nd edition
Heijermans (NI) 1905. Job, working hours, crowded workplaces
Eastman (US) 19010. Dangerous machines, repeated accidents
Home Office (UK) 1911. High workload, industrial fatigue
DeBlois (US) 1926. One learns from risks, hazard ≡ energy
Vernon (UK) 1936. External causes of accidents
4 theories - models - metaphors

complexity of men-machine systems

direct feedback

energy source

logic aid
4 theories - models - metaphors

automation
4 theories - models - metaphors

Aberfan Barry Turner 1978

- rigid risk perception and a strong believe in the organisation;
- focus on underground hazards;
- minimalizing unexpected dangers;
- organisational exclusivity; signals not coming from members, are not taken seriously;
- information, communication problems between departments.

An accident is the result of a complex series of events, related to energy transfer, failing barriers, and control systems, causing faults, errors, unsafe acts, and unsafe conditions and changes in process and organisational conditions.

Johnson W (1970). New Approaches to safety in industry
Bhopal 1984

Tjernobyl 1986

Challenger 1986

Zeebrugge 1987

Piper Alpha 1988

Exxon Valdez 1989

4 theories - models - metaphors

normal accidents

so you want to understand an aircraft carrier? Well, just imagine that it's a busy day, and you shrink San Francisco Airport to only one short runway and one ramp and gate. Make planes take off and land at the same time, at half the present time interval, rock the runway from side to side, and require that everyone who leaves in the morning returns that same day. Make sure the equipment is so close to the edge of the envelope that it's fragile. Then turn off the radar to avoid detection, impose strict controls on radios, fuel the aircraft in place with their engines running, put an enemy in the air, and scatter live bombs and rockets around. Now wet the whole thing down with salt water and oil, and man it with 20-year-olds, half of whom have never seen an airplane close-up. Oh, and by the way, try not to kill anyone. Senior officer, Air Division

4 theories - models - metaphors

people make accidents

organisations cause them

Safety is an dynamic property obtained by the systemic articulation of hazards, environmental, organisational and individual dimensions in high-tech-high-hazard sectors.

This property is obtained through the on-going interaction of in/external actors with technology, mediated by structures and power.

Balancing conflicting goals defined as trade-offs quandaries is at the heart of the vision of safety. The power of safety departments is one of the elements of the quality of these trade-offs.

4 theories - models - metaphors

Swiss cheese

4 theories - models - metaphors

process & occupational safety - bowtie

management

- output
  - procedures
  - equipment
  - ergonomics
  - availability
  - competence
  - communication
  - motivation
  - conflicting goals

barriers

- barrier 1
- barrier 2
- barrier 3
- barrier 4
- etc.

task of management

- purchase
- use
- maintenance
- control

Visser K (1998). Developments in HSE Management in Oil & Gas Exploration, Production
management. Journal of Hazardous Materials 130(3)
4 theories - models - metaphors

Rasmussen drift to danger

Colombia 2003

Texas City 2005

Buncefield 2005

AF 447 2009

Deepwater Horizon 2010

Fukushima 2011

5 management
5 management and design

- Risk evaluation, audits
- Process (re)design
- Maintenance

Accident scenarios

- Production
  - Literature
- Similar sectors
- Expert opinion

Szymberski 1997

Graph showing the ability to influence safety over the project schedule with phases labeled as Conceptual, Detailed Engineering, Procurement, Construction, and Start-up.
5 ideal feedback

Actual feedback:

- Risk evaluation, audits
- Process (re)design
- Maintenance

Accident scenarios

Production Literature
Similar sectors
Expert opinion

5 actual feedback

- Risk evaluation, audits
- Process (re)design
- Maintenance

Accident scenarios

Production Literature
Similar sectors
Expert opinion
6 construction is ‘organic’

Ford Madox Brown 1852-1865

Fernand Léger 1950
6 construction shocks and vibrations

### Direct and Latent Factors in Construction

<table>
<thead>
<tr>
<th>Direct Factors</th>
<th>Latent Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disturbances in materials</td>
<td>Safety-production conflict (time)</td>
</tr>
<tr>
<td>Disturbances in process</td>
<td>Production bonuses</td>
</tr>
<tr>
<td>Inadequate monitoring</td>
<td>Not familiar with scenarios</td>
</tr>
<tr>
<td>Prime focus on human factor</td>
<td>Indifference to safety</td>
</tr>
<tr>
<td>Inadequate accident analysis</td>
<td>No link to safety policies</td>
</tr>
<tr>
<td>Labour, low level of education</td>
<td>Distant from mother company</td>
</tr>
<tr>
<td>Language</td>
<td>Not adequate safety management</td>
</tr>
<tr>
<td>Macho behaviour</td>
<td>Relation design – unsafety</td>
</tr>
<tr>
<td>Low safety knowledge architects</td>
<td>Separation design – execution</td>
</tr>
</tbody>
</table>

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7 are accidents predictable?

1. start with hazards and scenarios, observations, interviews workers & managers, literature, accident reports

2. determine central events, many scenarios, few central events

3. which barriers are present to stop, reduce effects of scenarios

4. how effective are barriers, interviews, accident reports

5. does management control the effectiveness of barriers
8 education competence levels

Skill

Knowledge

Awareness

Receive

Accept

Apply

list
identify
recall
recognise
ask help when needed
explain
define
write down
participate
contribute
translate
describe
apply
analyse
utilise
plan
calculate
demonstrate
I Was Born Intelligent, But Education Ruined Me.
red thread of presentation

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