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T29 Transport, Environmental Impacts and Safety: Week 2

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Lecture schedule

Week	Time	Topic	Staff
06	13:00-15:00	Safety theory: the principles of a safety management system (SMS)	AM
	15:00-16:00	Tutorial: lecture on safety indicators	Studic
07	13:00-15:00	Accident and incident investigation	AM
	15:00-16:00	Tutorial: lecture on safety data	Psyllou
08	13:00-15:00	System safety and details of the SMS	AM
	15:00-16:00	Tutorial: analysis of an accident using the Reason model	AM
09	13:00-15:00	Quantified Risk Assessment. Safety culture, safety climate and safety data	AM
	15:00-16:00	Tutorial: lecture and project questions	AM
10	13:00-16:00	Group presentations	MS + AM

Lecture objectives

To follow the evolution of the safety management system, it is necessary to:

- Understand what accidents and incidents are
- Develop their relationship
- Assess models of accident causation

Lecture plan

Evolution of the safety management system into a structured and systematic process needs:

- Definitions and their difficulties
- Accident => Incident relationship
- Accident models
  - ✓ Sequential
  - ✓ Reason

What is an accident and an incident?

Confusion:

- Consensus about accident meaning within the safety community.
- Various industries use the same criteria that emphasise the damaging and observable outcome aspect.
- Ignores occurrences related to security aspects.

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Why do definitions matter?

- Critical to the establishment of official statistics to avoid potential misinterpretations.

- Benchmarking purposes - statistics about the number of accidents in the world.

- Definitions of the type of occurrences accounted for and the type of normalisation can lead to many different interpretations:

  - absolute number increasing while the rate decreasing considering the augmentation of operations.

ICAO Accident Definition

"an occurrence associated with the operation of an aircraft which takes place between the time any person boards the aircraft with the intention of flight until such time as all such persons have disembarked, in which a person is fatally or seriously injured; the aircraft sustains substantial damage or structural failure; or the aircraft is missing or is completely inaccessible"

Accident, the outcome translates into evident physical damage (or disappearance) to person(s) or infrastructure.

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What does the maritime industry say?

The UK's 2012 Merchant Shipping (Accident Reporting and Investigation) Regulations provides specific accident classifications.

Used by Maritime Accident Investigation Board.

Classifications resemble those established by:

- European Union – European Maritime Safety Agency
- International Maritime organisation – equivalent to ICAO

MAIB Definition of an accident

An event or sequence of events which has resulted in:

- the death or serious injury of an individual;
- loss of individual from a ship;
- loss or presumed loss of a vessel;
- material damage to a vessel;
- the stranding or disabling of the vessel,
- involvement of vessel in collision (with another vessel or external object);
- damage by a vessel to external marine infrastructure endangering safety of vessel or external individuals/vessels;
- pollution or potential of pollution caused by damage to vessel.

ICAO incident definition

- Criteria more vague

- Assumes that incidents are less severe than accidents.

Definition

"an occurrence, other than an accident, associated with the operation of an aircraft which affects or could affect the safety of operation".

ICAO incident defintion

Features:

- relatively ambiguous compare to the one of an accident,
- both unexpected and unforeseen; and result in unwanted outcome.
- characterisation of the outcome different.
- incident, the safety of the operations has been affected and jeopardised but no physical damages observed.

Serious incidents - ICAO

"an incident involving circumstances indicating that an accident nearly occurred".

•"nearly" => existing relationship between accident and incident.

•Key relationship to the development of a safety analytical methodology based on incident analysis for the identification of precursors to accidents, as it provides criteria for the classification of causes

Accidents and incidents

Accident and incident relationship has two features:

•common cause concept, which assumes that similar underlying causes generate incidents and potentially accidents; and

•identification of various levels of severity within both accident and incident categories.

The common cause

First proposed in the 1930s, by Heinrich (1931).

Empirical findings from the review of industrial accident reports, he estimated that in an industrial workplace (e.g. steel industry):

- for every 300 unsafe acts there are 29 accidents with minor injuries and one accident with major injury.

- Heinrich pyramid, which serves to illustrate Heinrich's theory of accident causation: unsafe acts lead to minor injuries and, over time, to major injury

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Heinrich Pyramid

(a) Heinrich pyramid (Heinrich, 1931)

(b) Adapted Heinrich pyramid

https://www.youtube.com/watch?v=GgDu3Kc3MbI

Heinrich Pyramid (2)

- Implies same common causes are at work throughout the triangle
- Address more common place safety occurrences that cause minor or no injuries then prevent accidents that cause injuries.
- Theory links accidents to serious incidents and even less severe safety occurrences by assuming a statistical relationship between their rate of occurrence.

Maritime industry and the triangle

- Shipping companies are expected to investigate near-misses as a part of the IMO Codes
- EMSA and MAIB classify them as “marine incidents.”

Capturing near-misses data is vital in modern maritime safety theory as the IMO has stated: “*Learning the lessons from near-misses should help to improve safety performance since near-misses can share the same underlying causes as losses*” (IMO, 2008).

Is it true?

Note the context in which Heinrich worked: factory environment not transport!

- 1920s – were reporting systems present?

Recent research: in systems with robust safety defences (such as in aviation) for every accident there are dozens of incidents and hundreds of innocuous occurrences

Heinrich in ATM

Ratio between accidents and incidents:

- Ambiguous and has not yet been proposed.
- Ratio numbers uncertain due to proportion of unreported incidents.
- Incidents have the potential to go unnoticed, some may not be reported to the appropriate authority and therefore not counted.

Heinrich and helicopters

Situation for helicopter transport to offshore oil rigs reveals another facet of Heinrich

http://www.dailymail.co.uk/news/article-2401782/North-Sea-helicopter-crash-Super-Puma-helicopter-flights-oil-rigs-suspended.html

Heinrich and helicopters (2)

Evidence from North Sea accidents 1997-2010 reveals:

- incidents reported in the 2 years preceding the accidents could not have indicated the type of failure that was about to strike.

- potential sudden failures?
  - require an alternative theoretical framework

- under-reporting of incidents?

Heinrich and helicopters (3)

- Complete dissociation between accidents and incidents?
- Accidents in complex ultrasafe **sociotechnical** systems are characterized by multiple, rare, and nonlinear combinations of factors that are often not evidenced in routine incidents – different mechanism?

Incidents of lesser severity cannot numerically predict the higher severity accidents:

- that tackling the former does not ensure avoidance of the latter.

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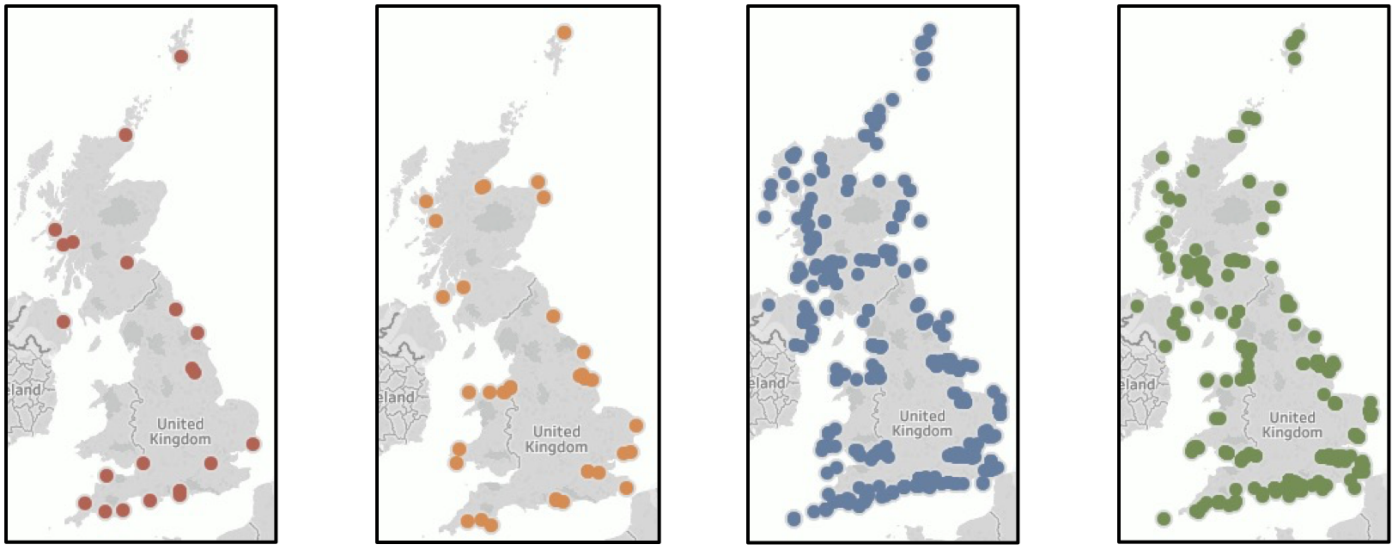
Heinrich and maritime (1)

Analysis based on MAIB database from 2013-2105

- For ports only
- From very serious, serious, less serious and marine incidents



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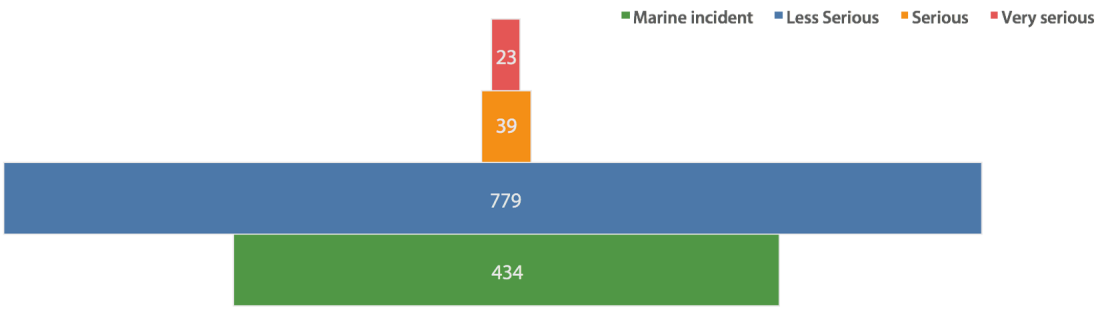
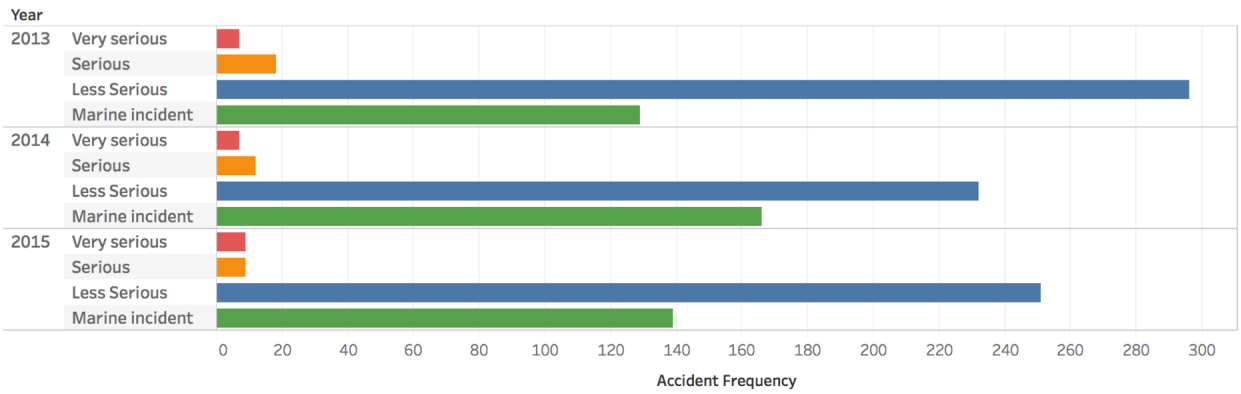
Heinrich and maritime (2)

Figures 8.1 – Total Accidents Reported by Severity, Overall (2013-2015) and by Year





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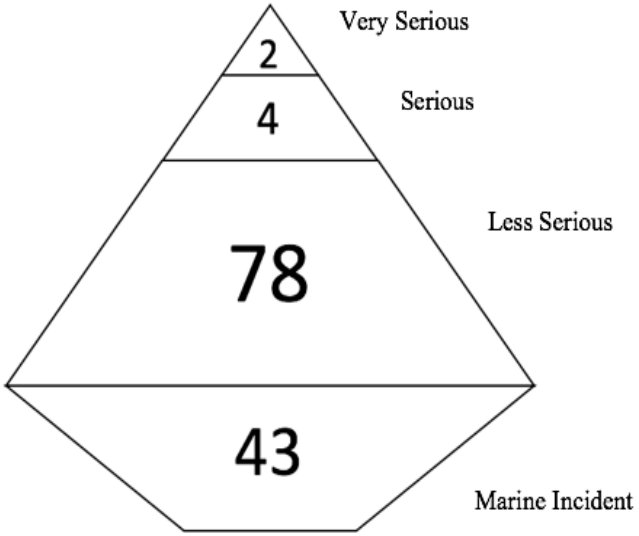
Heinrich maritime results – cluster analysis



- Most accidents tended to occur in rather safe sounding conditions, such as clear visibility and daylight.
- Large role human error plays in accidents.
- High amount of “unknown” data, undermines the ability to calibrate the Heinrich pyramid to the maritime sector.

Can we find precursors?

Assuming that:

- accidents and incidents share the same path of causation
- incident did not produce an accident because the path deviated at some point,

Then understanding incident causation can help understand the precursors to accidents.

Precursors?

More confusion:

- “an initiating event that could lead to accident conditions” in the nuclear industry, or
- as “an event in the accident chain”

So always use as:

precursor in conjunction to a defined safety occurrence.

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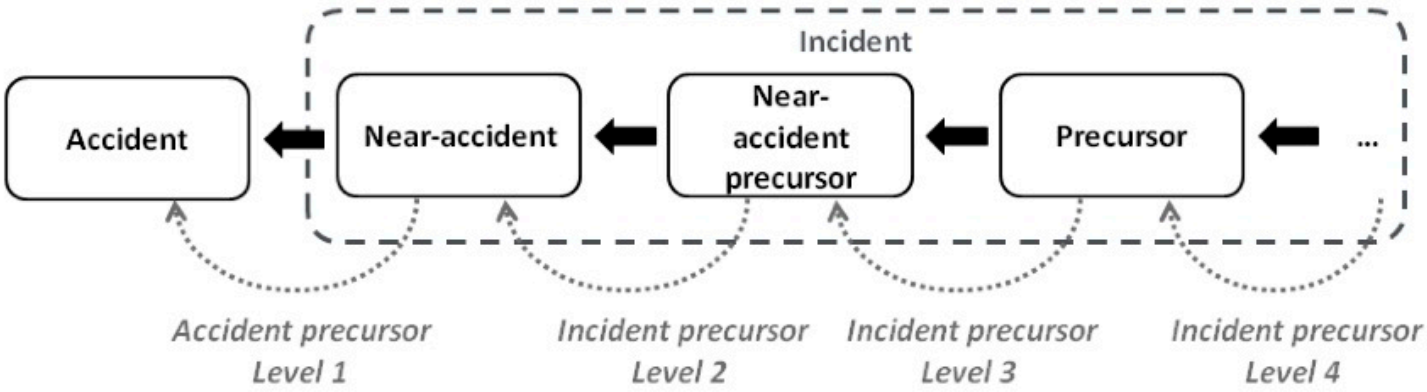
Precursor chain



Severity

Heinrich => explicit severity hierarchy between accidents, serious incidents and other low-level safety occurrences.

- Not all accidents or incidents are comparable
- Significance of their consequences is used to categorise them.

What does ICAO say?

Common severity classification for accidents is based for example on:

(i)Level of damage to the aircraft (destroyed, substantially destroyed, slightly damaged and no damage) and

(ii)Type and number of injuries to human involved in the accident (fatal, serious, minor, none) as proposed in ICAO's Annex 13.

(iii)Larger and more harmful the consequence, the more severe the accident.

What does ICAO say? (2)

But for aviation incidents - consequences are not easily observable.

Severity characterised according to:

- effect on the safe operations of aircraft and their occupants, or
- impact on the system's ability to operate normally.

EUROCONTROL severity

- Serious incident: an incident involving circumstances indicating that an accident nearly occurred (ICAO definition).
- Major incident: an incident associated with the operation of an aircraft, in which safety of aircraft may have been compromised, having led to a near collision between aircraft, with ground or obstacles.
- Significant incident: an incident involving circumstances indicating that an accident, a serious or major incident could have occurred, if the risk had not been managed within safety margins, or if another aircraft had been in the vicinity.

Maritime Accident Investigation Board severity

Very serious: results in total loss of the ship, loss of life, and/or severe pollution

Serious: due to the cause of fire/explosion; collision; grounding; contact; heavy weather damage; ice damage, or a suspected hull defect; results in:

- immobilization of main engines, extensive accommodation damage, severe
- structural damage, such as penetration of the hull underwater, etc., rendering the ship unfit to proceed;
- pollution;
- a breakdown necessitating towage or shore assistance

MAIB severity (2)

- Less Serious: Classification by MAIB for accidents/incidents which do not match categories “Very Serious” or “Serious.”

- Marine Incident: – The least serious, or an “*event or sequence of events other than those listed above which has occurred directly in connection with the operation of a ship that endangered, or if not corrected would endanger the safety of a ship, its occupants or any other person or the environment (e.g. close quarters situations are marine incidents)”* (MAIB, 2016).

What is risk?

Risk and severity – do NOT confuse;

Latter is a component of the former.

- Risk means in general the future's uncertainty.
- Too often the term is used alone while it should be used together with a particular occurrence (e.g. the risk of contracting a virus or the risk of dying from a heart-attack).

Again to define risk?

The risk of an accident, incident or any event has two basic components its:

i)likelihood and

ii)severity.

The risk equation:

$$\text{Risk} = \text{Frequency} \times \text{Severity}$$

probability and severity of the consequences of a safety occurrence or any type of event

Risk classification schemes

- Important to get a correct picture of the risks of certain occurrences => completes the severity classification scheme by taking into account the likelihood effect.

- Attempts to estimate the likelihood of certain events is part of the risk management process and fall under the predictive approach to safety.

- EUROCONTROL Risk Assessment Tool => complete risk classification scheme proposes a tool for consistent and coherent identification of risk elements through a matrix based on severity and repeatability.

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Risk classification schemes

		FREQUENCY				
		Very frequent	Frequent	Occasional	Rare	Extremely rare
SEVERITY	Accident	AA1	AA2	AA3	AA4	AA5
	Serious incident	A1	A2	A3	A4	A5
	Major incident	B1	B2	B3	B4	B5
	Significant incident	C1	C2	C3	C4	C5
	Not determined	D1	D2	D3	D4	D5
	No safety effect	E1	E2	E3	E4	E5

Actual frequency of each of these occurrences:

- enables national organisations to determine the level of effort to be placed into the assessment of the occurrence
- to potentially support the development of trends in safety.

Risk classification schemes

Possibility to classify safety occurrences upon a severity hierarchy is valuable:

- enables to coherently monitor the recurrence of certain accidents and incidents,
- manages the risk.

Risk classification schemes

Determination of the severity of a safety occurrence depends upon:

- analytical methodologies applied to such occurrence.

Different theories explaining how accidents occur.

Accident investigation process

Currently ICAO describes the investigation process in its Annex 13 in four steps:

(i) gathering and

(ii) analysis of information,

(iii) drawing of conclusions, including the determination of causes and, when appropriate,

(iv) making of safety recommendations.

Investigation process assumes linear accident sequence.

Sequential Models

First accident model to be proposed

Accident is a logical sequence of events including human error or component failures

Reliant on the well-defined cause-to-effect concept, where one initial event ("root-cause"):

- leads to another event
- leads again to another event until occurrence reaches its final state – i.e. the "top event".

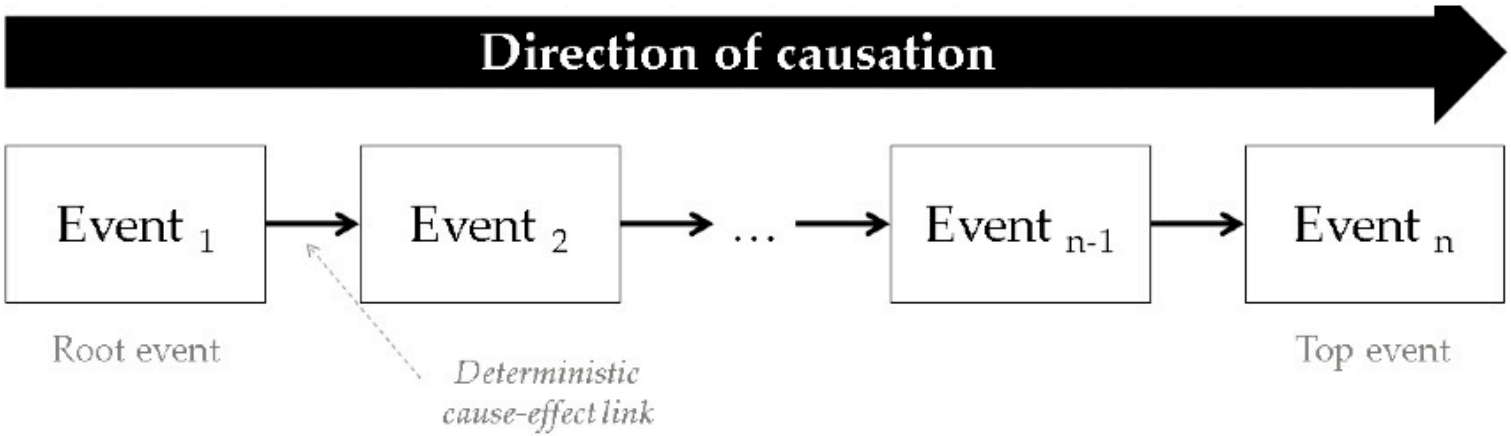
Dominoes

Clear direction of causation:

- domino blocks line up in such a way that if the first one of the series falls, it will knock down all those that follow in a sequence.

- each domino represents a specific accident event or factor, which can be any circumstance that contributes to a specific result.

Dominoes



(a) Single sequential model

Dominoes

Can be a multiple sequence of events in the form of event-trees in which events and factors:

- are arranged in a hierarchical and directed network.
- Top-event is considered as the result of a sequence of several combinations of other events or factors.

Enables:

- characterisation of more complex accidents that cannot be explained by a simple
- single sequence of events.

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Dominoes II

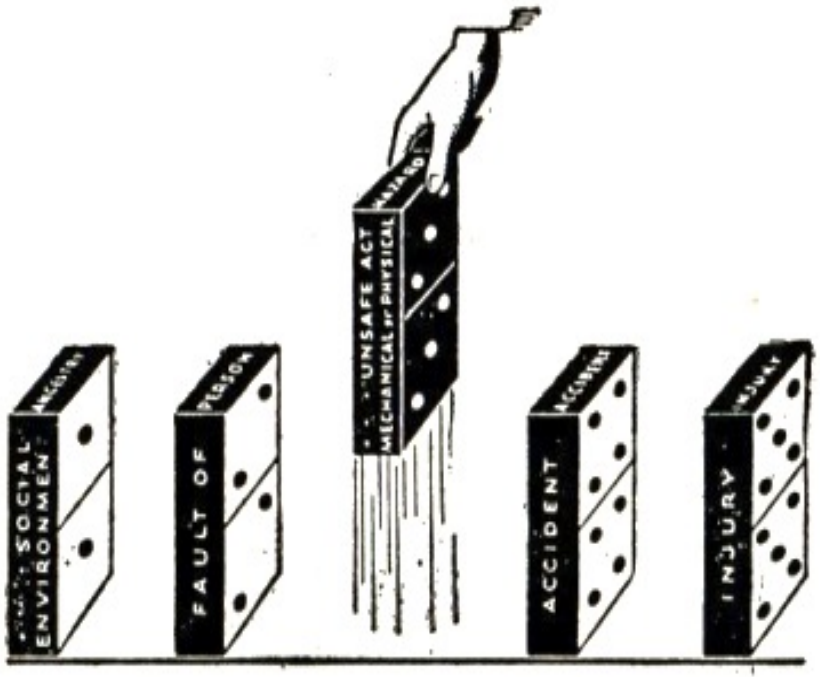

FIG. 4. The unsafe act and mechanical hazard constitute the central factor in the accident sequence.

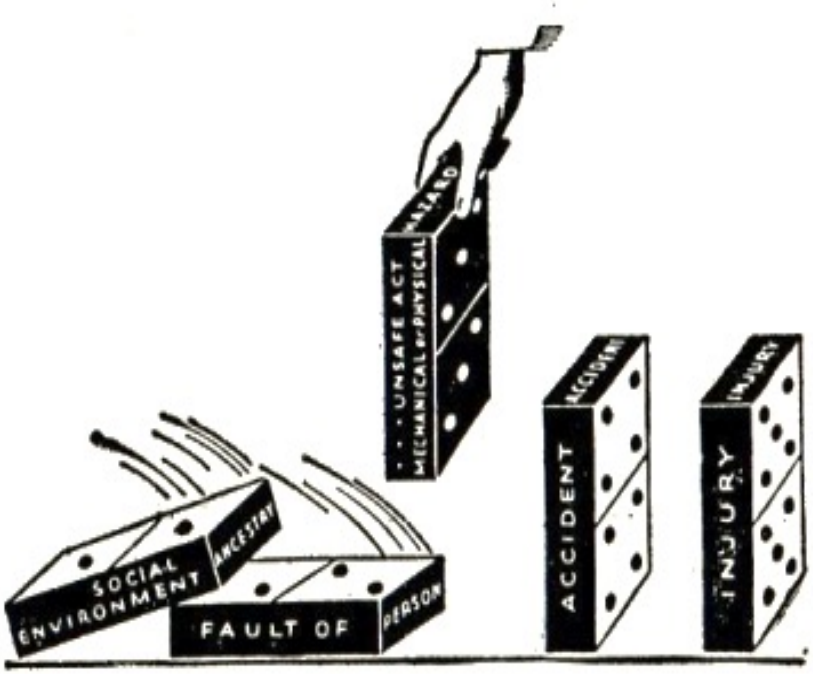

FIG. 5. The removal of the central factor makes the action of preceding factors ineffective.

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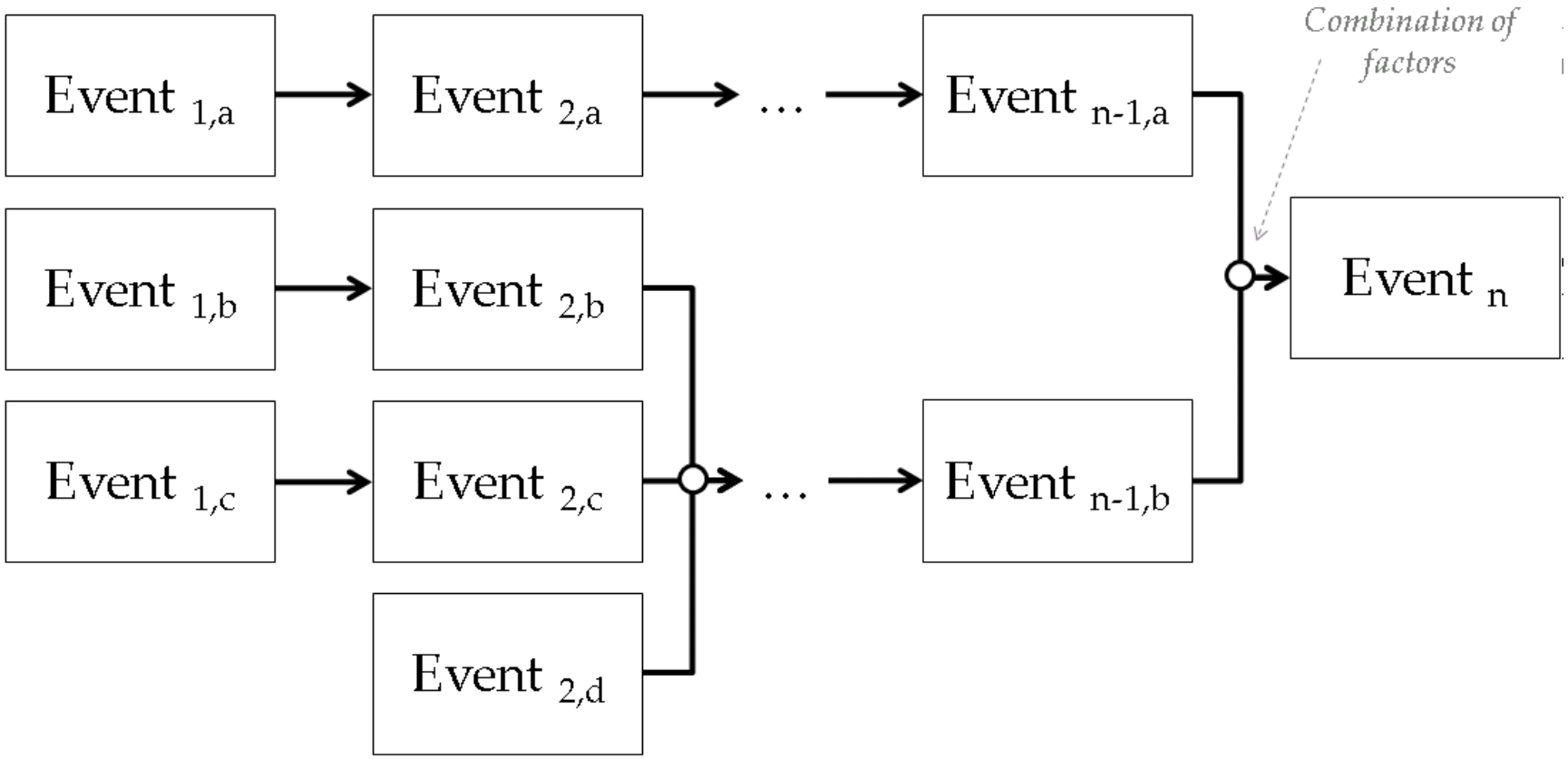
Multiple Sequential Model



Advantages

- describing accidents or incidents as the outcome of series of individual steps in a unique order of occurrence

  - follows a natural line of reasoning.

- Easily graphically represented allowing for a simple and accessible knowledge.

Disadvantages

- Where the reasoning analysis should stop (i.e. what is the first domino?) not always well defined
- can always take analysis one step further back from the last identified base-event
- stop rule for the root-cause identification can be quite arbitrary.
- assumes a relatively simple and deterministic cause-effect relationship between successive events (or combination of events).

Adequately explain accidents in complex systems?

Epidemiological Accident Model

As systems became more complex so did accidents:

- considered differently than singular failures leading to a sequence of events.

Epidemiological accident model allows for:

- deeper analysis of an accident and
- Considers latent conditions behind each failure.

Epidemiological Accident Model

Epidemic analogy compares the accident with a disease, which can strive only if:

- several factors associated with the host (e.g. the living being), the agent (e.g. the virus), and
- environment where the host remains,

manifest in a specific way.

Accidents happen as a manifestation of sufficient underlying factors:

- "latent factors" or "latent conditions"

Epidemiological Accident Model

Model assumes that inherently,

- any system has developed and maintains specific defences against failures.
- defences, also called safety barriers, have the function of deflecting or minimising the consequences of certain events.

Epidemiological model therefore identifies the failure of safety barriers and the possible latent conditions responsible for the barriers' degraded performance.

Epidemiological Accident Model

This model and its concept of safety barriers:

- introduces the idea that accidents may not only arise from the failure of some system's components but
- may also arise from the failure of the system in preventing them

Swiss Cheese Model

Swiss Cheese model:

- Reason (1990) rejected the hypothesis that the safety barriers implemented by an organisation are intact but rather have deficiencies.

- Potential barrier failures, which, when occurring one after the other, permits a “trajectory of accident opportunity”.

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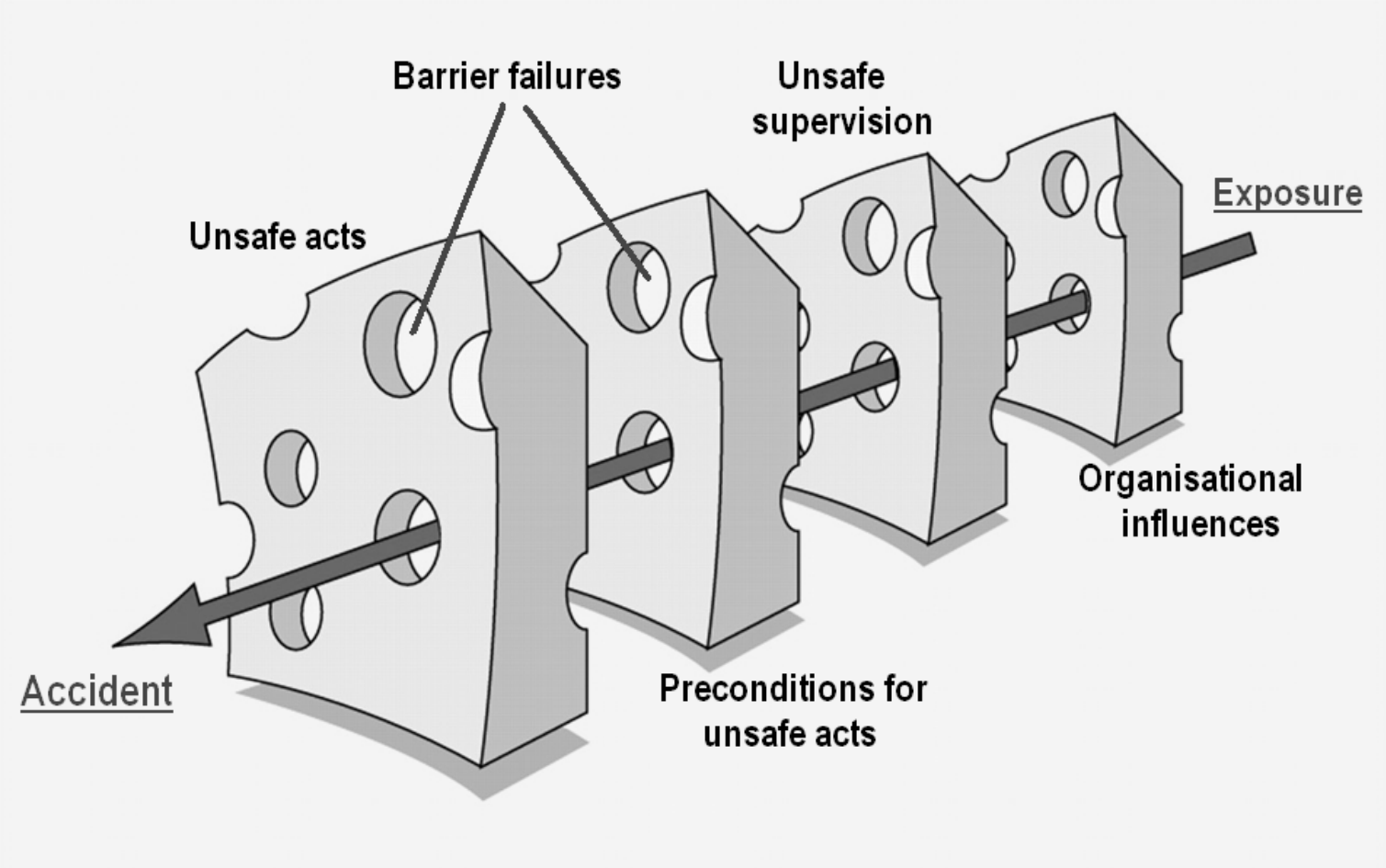
Swiss Cheese Model



Swiss Cheese Model

Swiss cheese represents the system safety barriers:

- Holes of various sizes and positions symbolise each barrier's deficiencies and weaknesses.

When holes are momentarily lined up:

- system permits a specific exposed state to pass through and lead to an unwanted outcome

https://www.youtube.com/watch?v=oOnIisFt5aM

Swiss Cheese Model

- Epidemiological model conforms to the principle of propagation of effects indicating a direction of causation.

- Highlights failures of certain system components – mainly safety barriers.

Swiss Cheese Model

Model opens the discussion on latent factors whose effects are not easily observable and measurable.

Considers the general “health” of the system and can provide insights of possible performance deviations.

Swiss Cheese Model

If context behind these deviations is well understood:

- remedial actions can be taken to correct the root-cause of the problem
- either prevent those latent conditions or
- improve barriers efficiency.

Swiss Cheese Model

Added complexity to explain the accident causation path can:

- sometimes make the model more difficult to spell out,
- graphical representations more complex and less easily understandable.

Swiss Cheese Model

With adequate training:

- very powerful model e.g. aviation safety domain, and ICAO and EUROCONTROL use an adapted version in their international safety management and investigation manuals.

Swiss Cheese Model

These organisations and others have

- worked together to adapt and create a taxonomy for the safety barriers and their corresponding
- conditional, contextual, latent and human factors.

Swiss Cheese Accident Model

- focus on performance deviation formulated with the epidemiological accident
- model also served as a basis for the development of the systemic accident theory
- recently, a major focus has been put on a totally different design of accident model where the causality does not have to be linear.

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Evolution in safety thinking