Resilience Engineering as a way to manage trade-offs

Kolloquium Flugführung 2015 "Interdependencies of KPIs in ATM”
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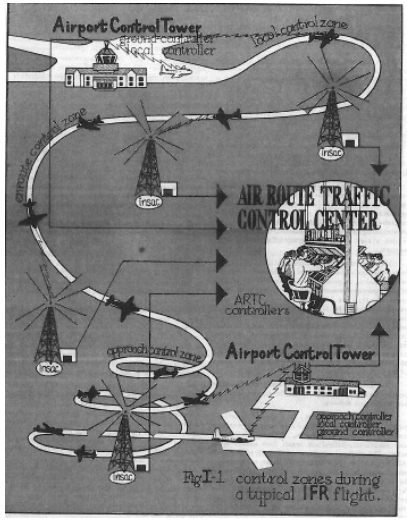
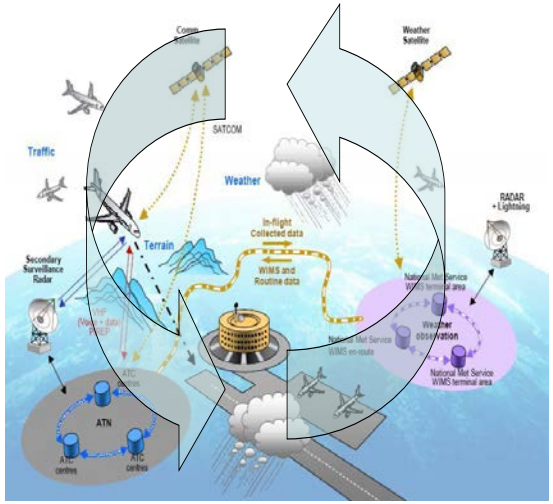
Outline

- Need and premises
- Resilience and Resilience Engineering
- Resilience abilities and trade-offs
- Conclusions

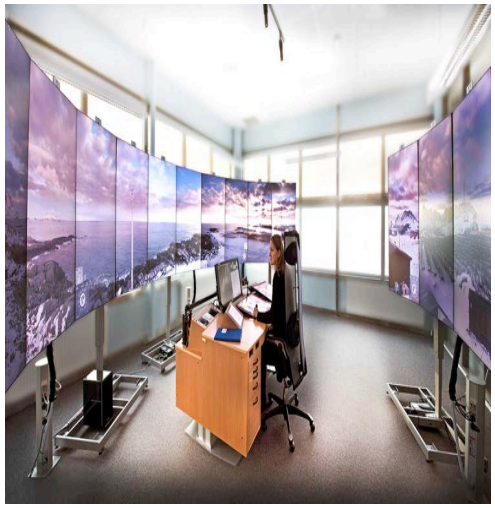
Simple linear…complex linear… complex interactions…increase of interdependencies



Human engineering for an effective air navigation and air traffic control system
Ref.: Fitts, 1951,

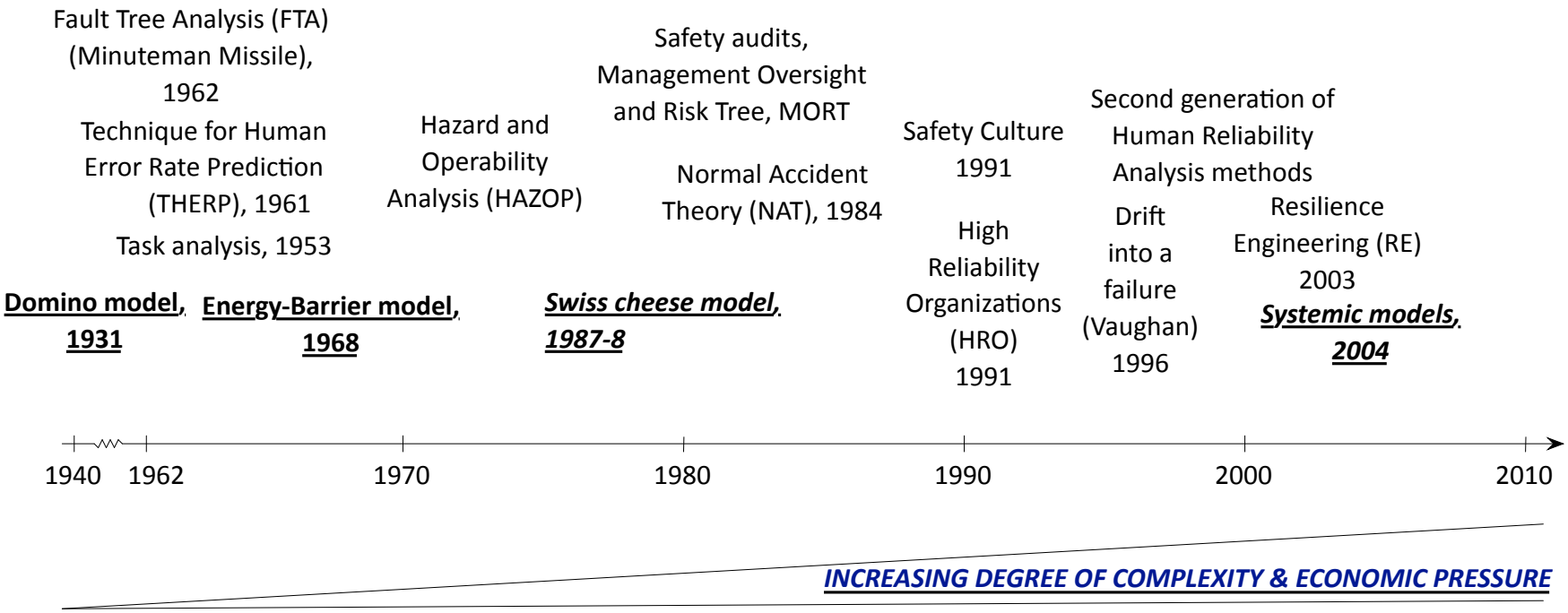


Single European Sky System
Wide Information Management System (SWIM)

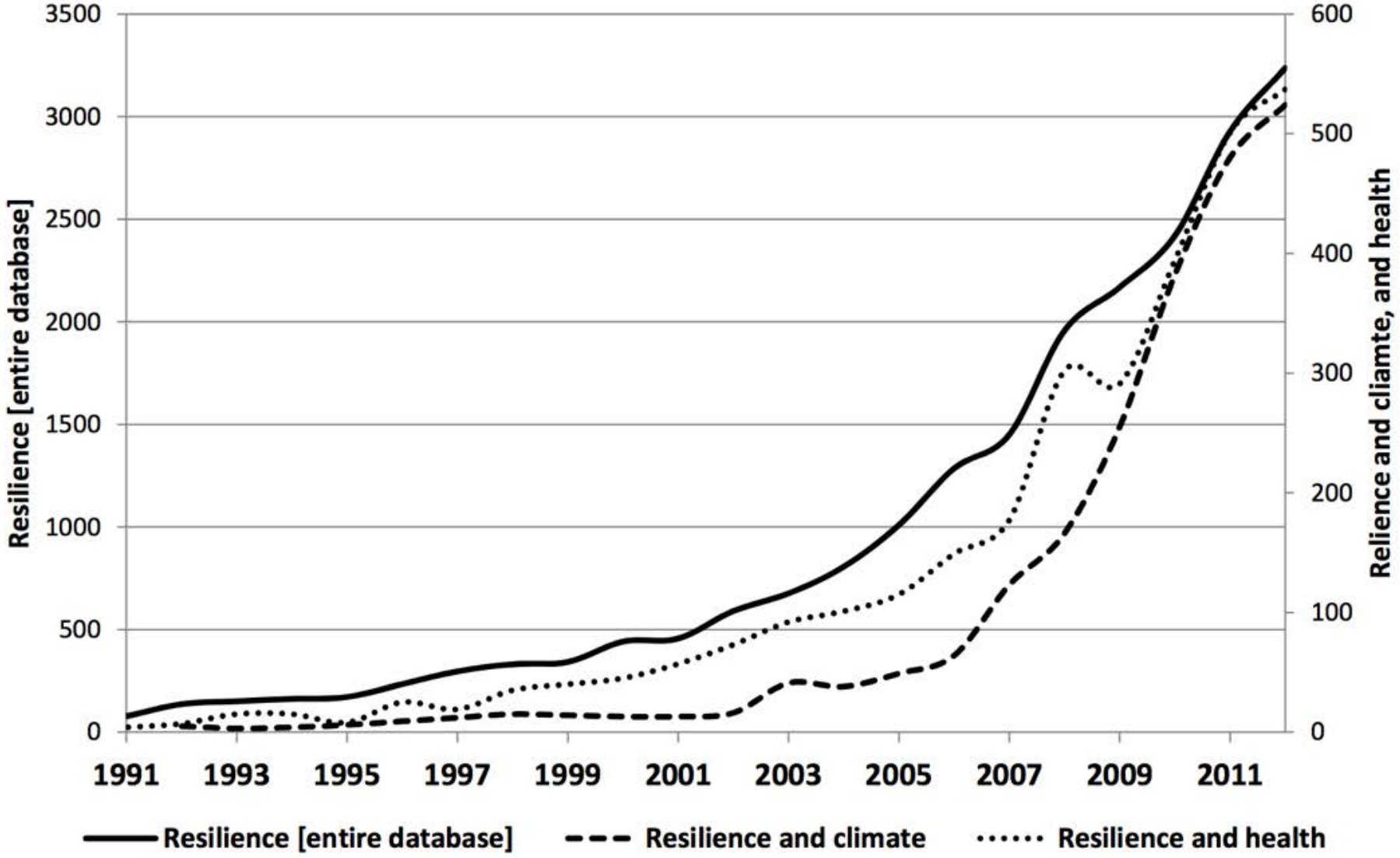


Multiple Remote Tower Center
for Røst and Værøy at Bodø, Norway.
Ref.: AVINOR, SESAR

Simple linear…complex linear…complex interactions



Resilience as topic, in the Web of Science, 1991-2012



Hyper popular

- Resilience as rebound ” the capacity of a system or organization as a whole to simply “**bounce back**” (Wildavsky, 1988)”; resilience as robustness (**include more** well modelled events) **(linear simplifications**, Woods, 2015)

- ”The ability of an organization (system) to **keep, or recover quickly to a stable state**, allowing it to continue operations during and after a major mishap or in presence of continuous significant stresses” (Wreathall, 2006).

- “The ability of a system, community or society exposed to hazards **to resist, absorb, accommodate to and recover** from the effects of a hazard in **a timely and efficient manner**, including through the preservation and restoration of its essential basic structures and functions.” (H2020, Secure societies)

- ”The ability of systems, infrastructures, government, business, communities, and individuals to **resist, tolerate, absorb, recover** from, **prepare for**, or **adapt to** an adverse occurrence that causes harm, destruction, or loss of national significance” (DHS 2010)

Resilience Engineering

- ”The ability of the systems to adapt to changing conditions in order to maintain a system property” (Leveson et al, 2006).

- "A system is resilient if it can adjust its functioning prior to, during, or following events (changes, disturbances, and opportunities), and thereby sustain required operations under both expected and unexpected conditions. (Hollnagel, 2014)"

- “Graceful extensibility to stretch near or beyond when surprises occurs, a positive capability. Sustain adaptability to manage and regulate, governance and architect systems/organizations” (Woods, 2015)

Resilience Engineering

- Covers theories, methods and practices to enable a system to adjust its functioning prior, during and after disturbances, challenges and opportunities.

⇨ what architectures allow systems to adapt to changing circumstances?

⇨ what mechanisms allow a system to sustain operations at the boundaries of normal function?

⇨ how systems can be prepared for inevitable surprise while still meeting pressures to improve on efficiency of resource utilization?

⇨ Is the safety management system ready to address anticipation, respond, sustain adaptability (paying less attention to error and deviation)?

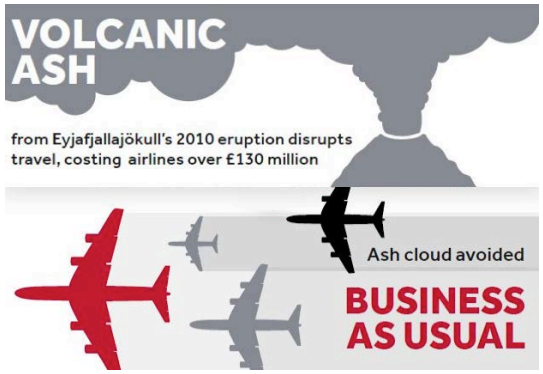
⇨ how adaptive systems fail and succeed in general and across scales?

*Rosness et al, 2010; Woods, 2015

Trade-offs

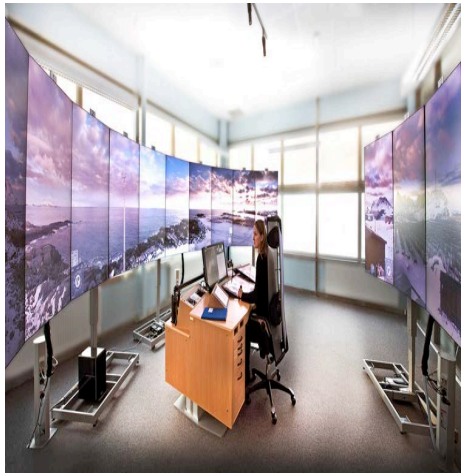
- A balance achieved between two desirable but incompatible features; a compromise
- Is a situation where the outcome of an action means that one quality of an aspect is lost in return for another quality or aspect being gained

Several types of trade-offs



Eyjafjallajökull
(2010, total losses:
approx. 1 billion euros)

Icing at Gardemoen
1991 – 1998



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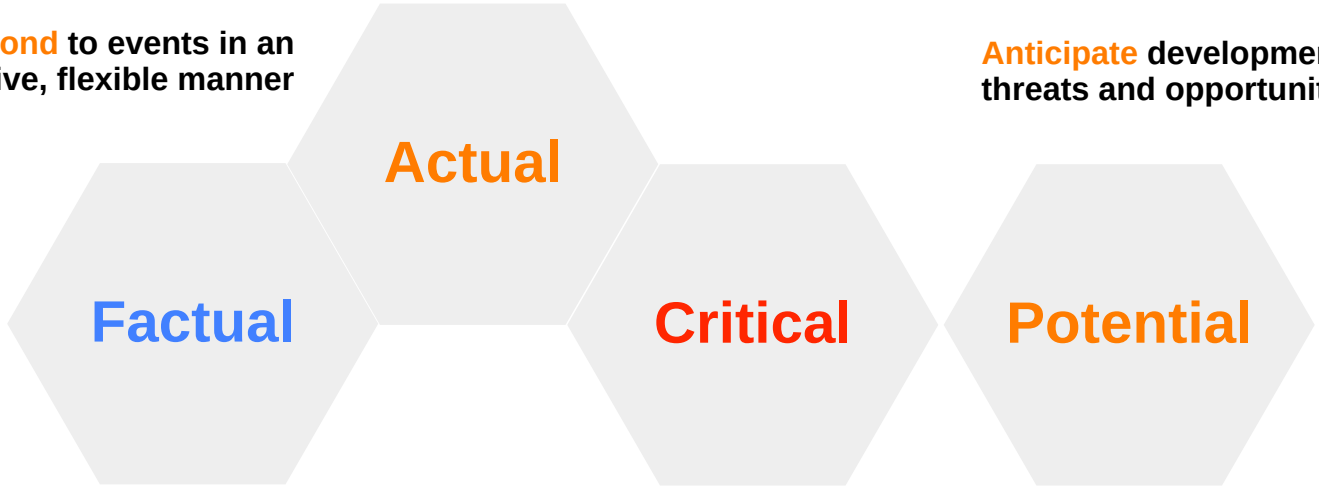
Trade-offs

- Efficiency-Thoroughness (ETTO)
- Safety – economy
- Balancing local adaptation and global goal
- Bounds on perspective

Resilience abilities

Respond to events in an effective, flexible manner

Anticipate developments, threats and opportunities



Learn from experience, right experience.

Monitor system´own performance and changes in the environment

…Everything includes trade-offs

The abilities are interrelated

ETTO supporting the ability to respond

Respond
to events in an effective, flexible manner

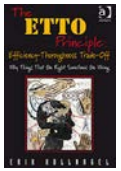
Actual

Knowing what to do and being capable to do it

by adjusting the way things are done or by activating a set of "prêt a porter" responses

Trade-offs
When to respond,
How to respond,
Balancing compliance - flexibility

Efficiency-Thoroughness Trade-Off (ETTO)



Thoroughness:
Time and effort to think and plan

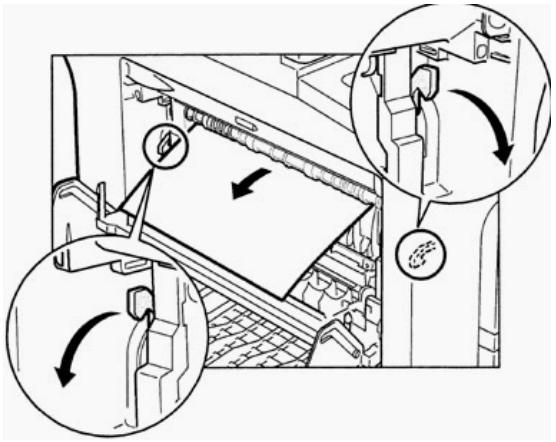
Spent in preparation
Recognizing situation
Choosing and planning

Efficiency:
Time, effort and materials

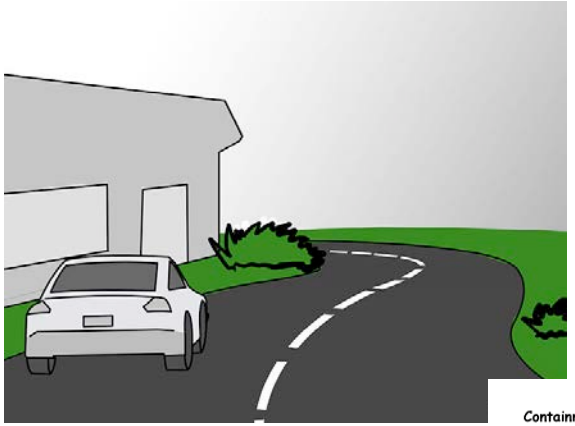
Spent in doing an activity
Implementing plans
Executing actions

Everyday operation
Anticipate & Respond
Supervision
Learning
Responses

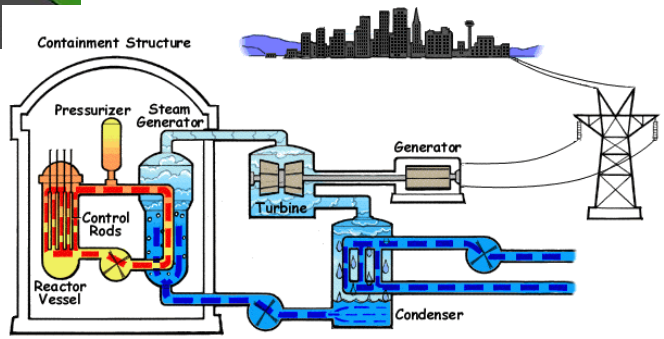
ETTO & The need of performance variability*



Photocopy – paper jams
no/little need for adjustments



Driving to work -
Variability enables
effective
performance



Underspecified systems
Emergency procedures - guidelines
Impossible to describe all possible variations

* The ETTO Principle: Efficiency-Throrougness Trade-Off
Why Things That og Right Sometimes Go Wrong
Erik Hollnagel, 2009

Sources of variability in ATM examples

- Adjust performance to anticipated changes
  e.g aircraft delay, too early

- Contextual – situational variability – adjust to incomplete specification of situation
  e.g. go-around / missed approach, notice changes

- Compensatory – when something is missing
  e.g. failure of one display, one ATCO fainted

- Unexpected situations e.g. sudden increase of diversions around airfield, running out of de-icing fluid

ETTOing and the abilities to anticipate and respond

- Individuals and organisations must adjust to cope with their current working conditions. These adjustments are always approximate because there is always a limited amount of information, resources and time.

- Individuals and organisations therefore continually seek viable compromises between doing the job efficiently and doing it thoroughly.

Provides understandings of operations and (technical, human or organizational) buffers that can be used if a new demand arises:

When should the system/organization put emphasis on thoroughness and when put emphasis on efficiency? Looking into transitions – performance variability that are critical to both productivity and safety

Safety – Economy and the ability to monitor

Monitor system´own performance and changes in the environment .

Critical

knowing what to look for
actual changes, or could change, so much in the near term that it would require a response

trade-offs
choice of indicators,
when to monitor,
information overload

Navigating complexity

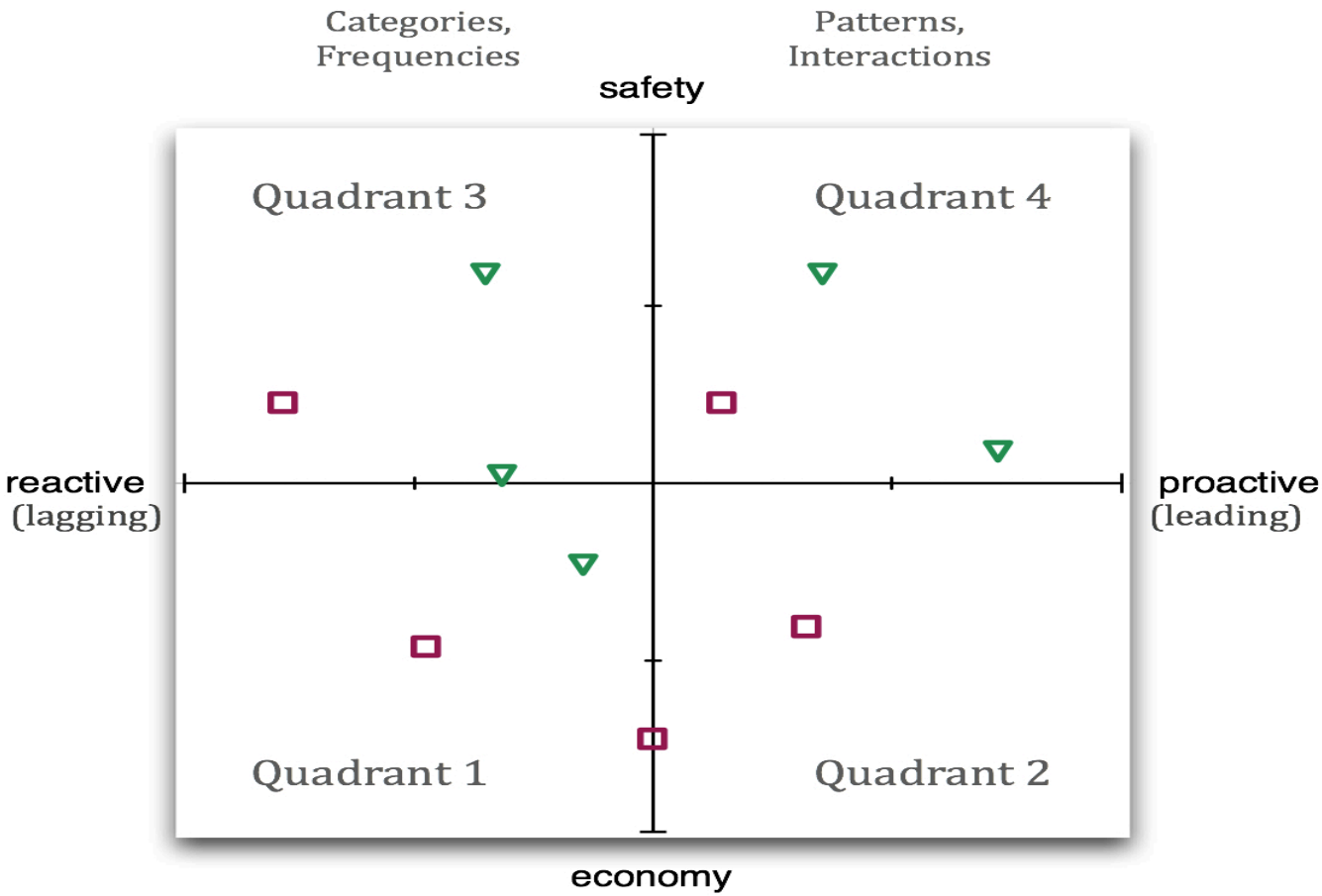
- Functionality of the system depends on interactions
- Dealing with hidden interdependencies
- Handling challenges that produce unintended consequences
- Integrate metrics among different actors
- Integrate trade-offs economy & safety

Monitor to anticipate bottlenecks/opportunities ahead
and prepare for future events

Q4 Balanced framework

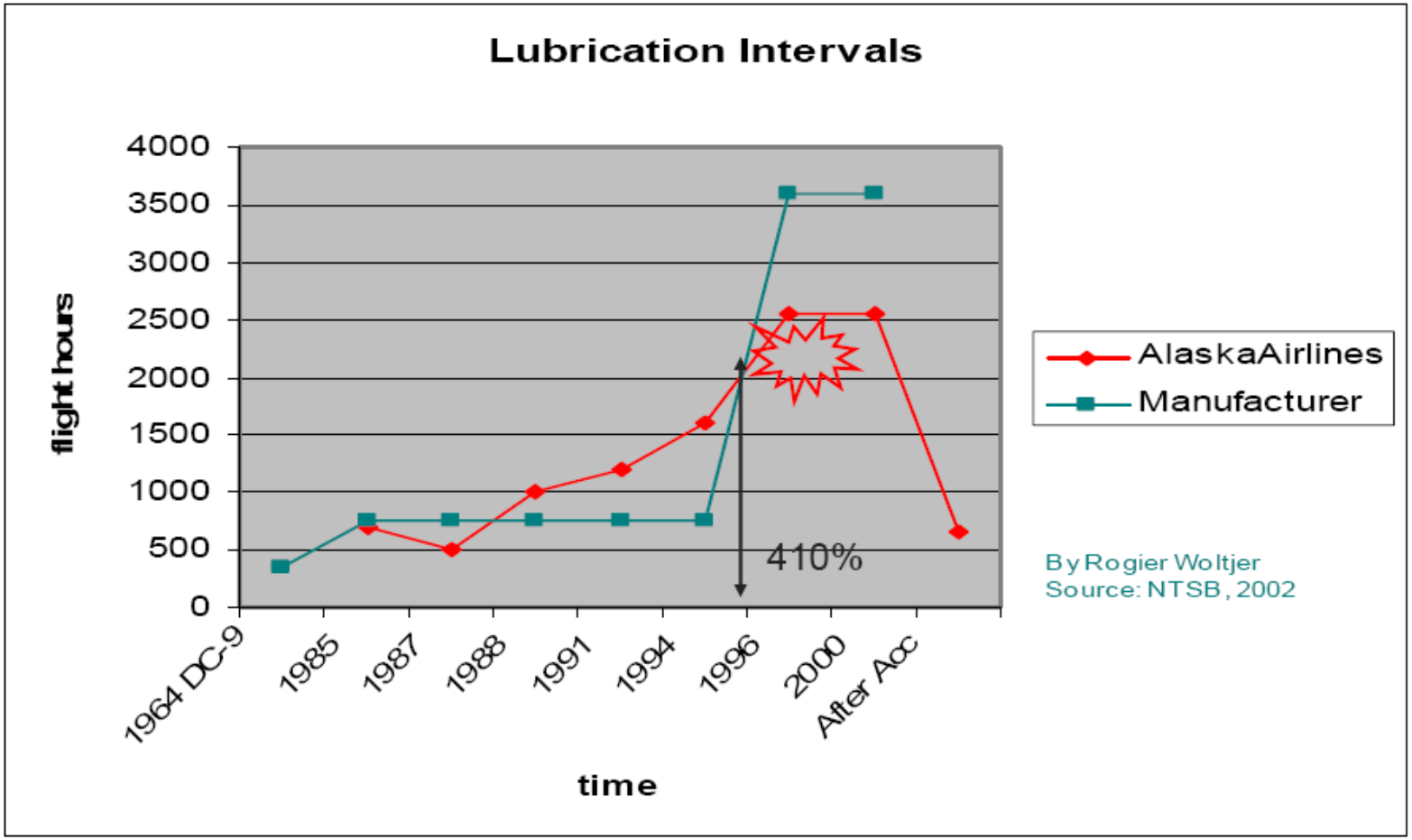
- reactive - lagging indicators, which refer to what has occurred or to system states of the past;
- proactive - leading indicators, which refer to aspects that might be critical- what may occur or to possible system states of the future.
- Safety continue operations in face of opportunities and challenges
- Economy ensure business continuity and sustainability

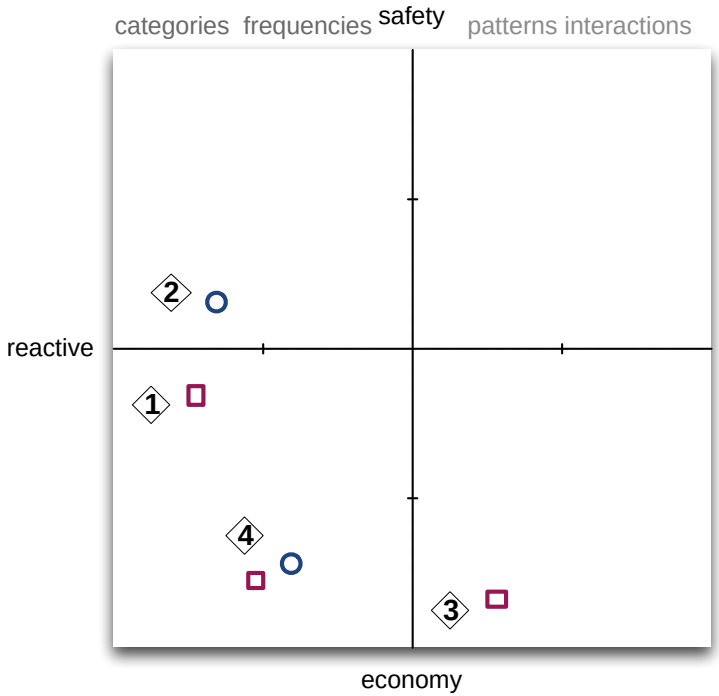
Q4 - Framework

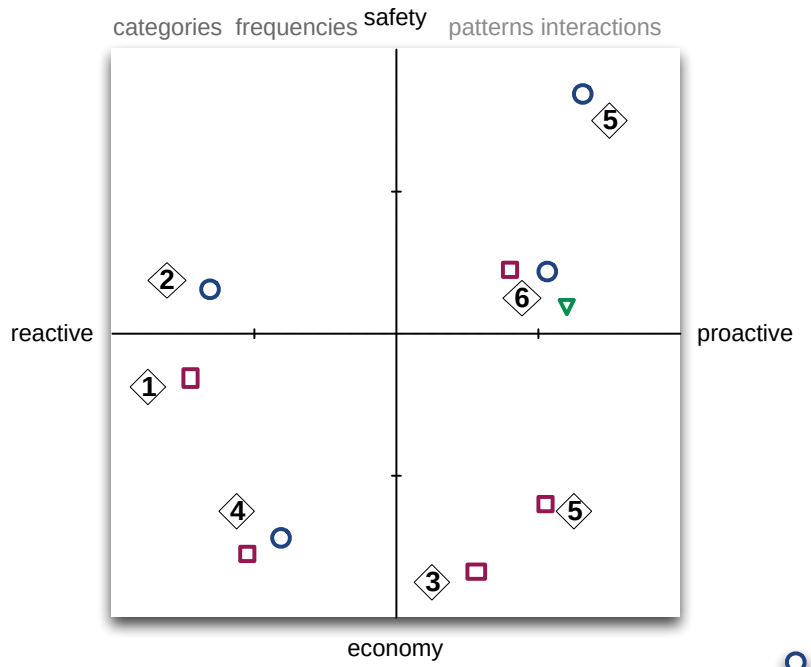


Source: Woods, Branlat, Woltjer, Herrera (2015)

Alaska 261 maintenance problems







1. Staffing - lack of management personnel
2. Staffing - lack of inspectors
3. Fleet Utilization rate - aggressive flight schedule
4. Maintenance intervals - end play and lubrication - optimization

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2. Staffing - lack of inspectors
3. Fleet Utilization rate - aggressive flight schedule
4. Maintenance intervals - end play and lubrication - optimization
5. Use of contractors - forecast - likely to increase
6. Maintenance intervals - optimization against history & design

Regulator
Manufacturer
Airline

Contrasting the use of indicators in the industry prior (left) and after (right) the Alaska Airlines flight 261 accident (based on NTSB, 2003)Woods, Branlat, Woltjer, Herrera (2015)

Q4 balanced framework– and the ability to monitor

- Provides a new path to model the safety-economy goal conflict
- Describes metrics that are currently used by an organization.
- When subsets of metrics in the different quadrants align, the overall picture is consistent, despite the uncertainties associated with each specific metric, so that the organization can make investment decisions with confidence.
- When there is a divergence between reactive and proactive indicators and between safety and economic indicators, organizations can conclude that their ability to balance trade-offs and to assess changing risks has weakened or new risks could arise to threaten organizational performance in the future

Local - global goals and the ability to anticipate

Anticipate developments, threats and opportunities

Potential

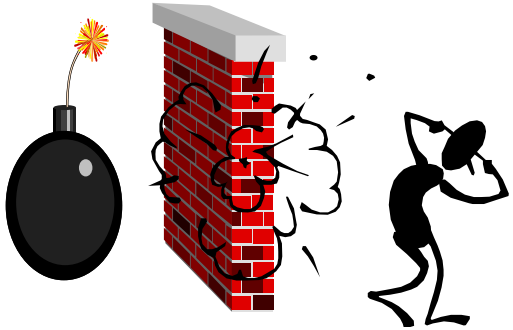
Finding out what to expect all units present local adaptations, recognise short-medium and long term resilience strategies that coexist and sometimes conflict

Local adaptive – global maladaptive

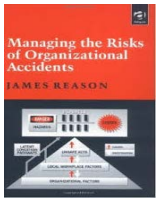
- Towards more resilient and secure networks
- Conflict and inadequate distribution of resources, local responses to external stress
- Examples of addressing resilience at one scale alone may lead to erosion of adaptive capacities at other scale
- **Need to consider different scales to ensure that different adaptations/ transformations at one scale do not come at expense to others considering cascades impacts across scales**
- Need further work in theory an practice to contribute to sustain adaptability within and across scales.

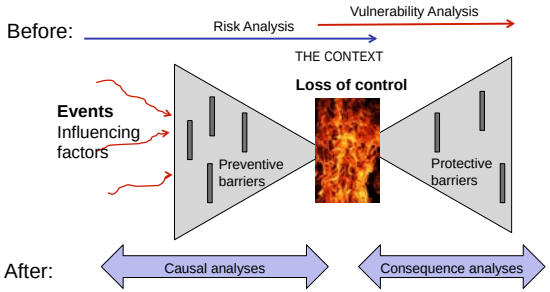
Source: Woods, 2015; Chelleri, 2015

Contrasting perspectives and ability to anticipate and learn

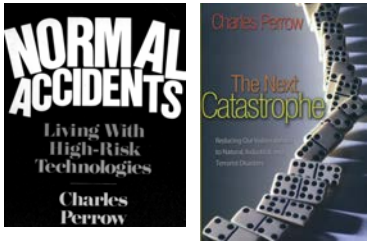


The energy and barrier perspective Haddon, 1970





Defense in depth, Reason 1997

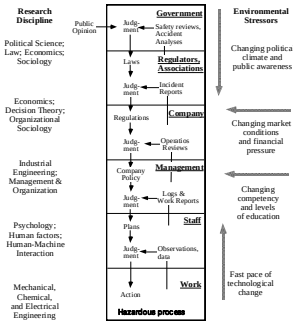


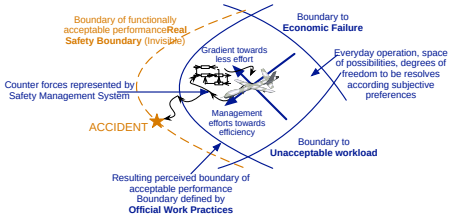
Interactions Coupling	Linear	Complex
Tight	Centralise to handle tight couplings!	Centralise to handle tight couplings! Decentralise to handle unexpected interactions!
Loose	Centralise or decentralise as you like!	Decentralise to handle unexpected interactions!

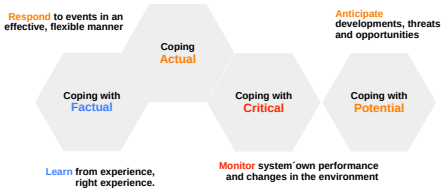
Normal Accident perspective, Perrow 1984

Source: Rosness et al, 2004, 2010

Contrasting perspectives and ability to anticipate and learn







High Reliability Organisations (HRO) (Rochlin et al., 1987, LaPorte and Consolini, 1991)

Information processing (Turner, 1978)
Decision making
Rasmussen, 1998

Resilience Engineering (Amalberti, Dekker, Hollnael, Woods,, 2006)

Source: Rosness et al, 2004, 2010

Conclusions

- Resilience engineering is about supporting the organization's ability to be able to respond to both expected and unexpected conditions
- The abilities provide theoretical underpinnings for improving resilient design and operations.
- Trade-offs need to be taken into account when designing, operating and managing resilient operations.

Arguments for applying Resilience Engineering

- System-organizational oriented
- Not bimodal or linear
- It focuses on interdependencies and ways to balance trade offs
- Take focus away from human error and failures at sharp end

Strenghts and weaknesses

Strengths

+ Multidisciplinary study
+ Helps asking questions before looking into answers
+ Utilizes operational and management experience
+ Take into account technical, human and organizational performance
+ Improves understanding of the system
+ Look system interdependencies

Weaknesses

- Not rigorous, structure and methodological
- Needs improvements on systematic analysis
- No standard on terminologies on-going research, can be confusing
- Requires analyst with RE training and practical experience

Any questions?

Some resilience engineering activities…you are invited…

- The 9th FRAMily workshopwill be held on June 11-12 2015 at the University of Applied Sciences and Arts Northwestern Switzerland (FHNW) in Olten, Switzerland. http://www.functionalresonance.com

- The 6th REA Symposium to be held in Lisbon from 22nd – 25thJune 2015. http://www.rea-symposium.org

- Resilience potential and early warnings for Air Traffic Management in case of system degradation through Enterprise Architecture (SCALES project) (Workshop May 2015 Trondheim Norway) http://www.hala-sesar.net/projects/blog/scales

SCALES

Thank you for your attention

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