Integrating Human and Organizational Factors in the Analysis of Safety and Risk

Paul R. Schulman
Center for Catastrophic Risk Management
University of California, Berkeley U.S.A.

FONCSI Human and Organizational Factors Seminar
Paris, France
24-26 January, 2018

Main topics in this presentation

1. The problem of integrating – really integrating -- organization and management variables into risk analysis and organizational management

2. An important part of this problem is the character of the research process and the knowledge base adressing organization and management factors.

3. Strategies for increasing the utility of HOF research for application to risk assessment and safety management

- Instead of thinking of both the organizational and technical dimensions together as part of socio-technical systems many designers and managers think of them as technical systems with human and organizational error factors.

- The American Petroleum Institute in its statement on “Pipeline Safety Management Systems Requirements” defines a pipeline as follows:
- “that which includes physical facilities through which hazardous liquids or gas moves in pipeline transportation, including pipes, valves, fittings, flanges (including bolting and gaskets), regulators, pressure vessels, pulsation dampeners, relief equipment and other appurtenances attached to pipes, pumps and compressor units, metering stations, regulator stations and fabricated assemblies.”

- Nowhere in this definition is there any mention of people or organizations -- including installers, maintainers, operators nor requirements to keep the operation of the pipeline within limited temperatures and pressures.

- The API report does define separately a “pipeline operator” as follows:
- “an organization that operates a pipeline.”

- Findings in accident analysis
- A major dilemma: how, given the diverse analytic domains of physical models vs human and organizational factors do we find a way to combine them in an *additive* way to improve our understanding, management and regulation of safety and risk in complex technical systems?
- We are currently far away from this objective, with a mutual ignorance, indifference, or even hostility, between researchers in these two domains.

Finding an additive analytic strategy?

- "If you open the plates of a circuit breaker, you will eventually have an arc. You don't want the electrons to arc, but no engineer would say that the electrons that formed the arc were lazy or complacent: if you don't want the arc, you engineer the system around the constraint. Human factors engineering operates according to the same principle; identify the constraints in the interactions between the employees and the workspaces, tools, and technology, and engineer around it."

  (Remarks by human factors engineer Michael Leggatt, founder and CEO of Resilient Grid, at a California Public Utilities Commission Public Safety Meeting (2016).

What’s wrong with this statement?

1. Human factors can be a support and not only a constraint (engineers can make design errors humans can correct e.g. in “work arounds”)
2. Human behavior is less predictable and has more variance than the physical laws and principles engineers design within
3. Engineers should incorporate human factors within designs not simply design “around them”
4. Engineers cannot design “damned fool” proof systems
5. We also now have to worry about willful assault on those designs

Why are social science findings hard to merge with engineering into safety research and risk management?

- It isn’t by oversight that HO variables are often neglected, particularly in risk research.

- Large technical, methodological, practical and political divides exist between human and organizational factors and the performance and risk variables typically attended to by commercial organizations and the regulatory agencies that oversee them.

Technical Differences

- HO factors such as leadership, authority, centralization, decision-making, motivation, mindfulness, stress, culture and even “safety” itself are grounded in concepts and expressed in *natural language* with all of its ambiguities and imprecision. These are difficult to translate into measurable variables.

- Concepts and definitions of physical or mechanical variables are largely agreed-upon and formally expressed through stipulated meanings in artificial language such as physical descriptions or mathematical models and formulas. Most are measured along continuous scales.

Methodological differences

- Organizational and managerial variables are often defined as nominal categories (e.g. “high reliability” organizations), or described as opposites in binary pairs such as flexibility/ridigity or centralization/ decentralization, or well or ill-structured problems rather than expressed in continuous scales of measurement.
- the measurement of organizational and management variables is likely to be more subjective and controversial than those of physical or mechanical factors. (e.g. compare HO vs physical measures of “stress”)
- Much safety and accident research is in the form of case studies whose descriptions are difficult to compare and aggregate across diverse cases

Practical Challenges

- Because organization and management variables are likely to be categorical and not continuous, it is difficult to connect analysis of these variables with physical and mechanical variables for purposes of modeling their relationships in affecting the safety or performance of an organization.

- Many of the social sciences that analyze human and organizational factors, unlike engineering, are not “design sciences” with research directed toward formal principles and cumulative findings to guide action and application.

Political Challenges

- HO factors often have implications that raises the political temperature surrounding their development and use.
- Business organizations may resist leadership, decision-making or culture analyses because of their potential implications for assessments of managerial competence or effectiveness.
- Regulatory organizations may avoid HO findings because of their vulnerability to political or legal attack if they base regulations and enforcements on what will be challenged as ambiguous or subjective measures and assessments.

Why Seek Additivity?

- We know that complex and potentially hazardous technologies are in essence socio-technical systems. Interaction between HO and physical elements critically affect their performance.
- We know that technical design and human error are interactive: humans can buffer performance against design errors; design errors can induce human error.

- One potential arena for this integration is the analytic process of risk analysis and assessment widely practiced in academic, commercial and regulatory organizations.
- Currently, these analyses focus primarily on physical variables. HO factorss, in particular those of organization and management are neglected and often resisted as subjective, ambiguous, arbitrary and subject to unreliable measurement.

Integrative Approaches to Risk Analysis

- How can we integrate organizational and management factors into risk mdels and formal risk assessments?
- First we have to clarify a number of analytic concepts to lay a foundation for better HO measurement to join those of physical variables in the calculation and assessment of risk.
- At present too many human and HO concepts are underspecified to permit clarity of use and agreed-upon measurement – including *safety.*

Safety vs Risk

- For both researchers and regulators, it should be clear that "safety" is not synonymous with the mitigation of risk.

- "Safety is more than the absence of risk; it requires specific systemic enablers of safety to be maintained at all times to cope with the known risks, [and] to be well prepared to cope with those risks that are not yet known." (Safety Management International Collaboration Group)

- Safety is about assurance; risk is about loss. Safety is in many respects a perceptual property, risk is a calculated one. A number of failures or incidents can occur without invalidating a risk estimate, but a single failure can disconfirm the assumption of safety.

Confusion in the safety concept?

"The San Bruno pipeline explosion was a terrible accident which devastated many people and harmed an entire community. A pipe with a faulty weld was placed in service in 1956, where it performed safely for 54 years. Suddenly, it failed catastrophically."

(Pacific Gas and Electric Company statement in a motion to a U.S. Federal District court concerning a criminal indictment over the San Bruno accident, as quoted in *S.F. Chronicle* 9/4/14.)

Other Underspecified HO Concepts

Resilience

- Unlike safety or risk, "resilience" does not really describe a condition or state at all but rather an unfolding process. It also is underspecified.
- As David Woods points out there are at least four different conceptual meanings attached to the term "resilience" in safety science research
- Four types of resilience can occur across a crisis cycle in critical infrastructures (precursor, restoration, failure and emergency response, and recovery resilience). Each is different.

- Resilience (cont’d)

  -- We have currently no agreed-upon scale of effectiveness for resilience that allows its comparative assessment across organizations and crises.

- High reliability organizations

  -- High reliability organizations (HRO) research was based on descriptions of organizational features found in a small set of organizations which had good reputations for managing very hazardous technical systems.

  -- But the "high" in high reliability was undefined, unspecified and unmeasurable.

- High reliability organizations (cont’d)
  - High reliability was used to categorize a set of organizational features. It was not determined by measured performance or output.
  - Because high reliability was a category there was no way to tell what "higher" or "lower" reliability meant.
  - The absence of interval organizational variables for reliability meant that it was nearly impossible for follow-on researchers to systematically compare organizations, develop causal models for reliability or suggest a developmental track for high reliability organizations.

Risks of underspecification of concepts

- Because of ambiguous or underspecifed concepts little of the research based on them is taken up for use in integrated analysis with other types of variables
- On the other hand, because of their underspecification, HO concepts can be distorted to fit into a variety of prescriptive writings on organization and management
- HRO research has been “applied” as a management fad to medicine, spaceflight agencies like NASA in the U.S., special forces operations (U.S. Navy Seals) and crisis management in general – quite different organizations, technical systems and missions from analyzed HROs.

Some research approaches to consider:

A. Proxy variables for organizational concepts:

Elements of safety culture (e.g. commitment to safety, care and mindfulness in tasks; continual search for improvement)

- The Institute for Nuclear Power Operators (INPO) does close inspections of work spaces to see if they are clean and if tools are in assigned places. They believe these are indicators of care and systematic management in miniature.

- In HROs managers attempt to maintain a well-orderedness in a variety of operations, even those unrelated to safety -- in cafeteria operations, in the proper functioning of all technical systems, including, lights, copiers and plumbing.

- Number of procedural revisions conducted over a given period

- Safety culture proxies (cont’d)
  - HRO managers and other personnel are conscious of "precursor" conditions which might lead to increased risk of error or failure.
  - A number of these were human and organizational: silence or edginess in an air traffic controller; too much noise or too many people in a control room; backlogs in clearing corrective action reports; the movement into "unstudied conditions" in operations or maintenance activities.

B. Indirect organizational measures and indicators

Communication patterns

-- e-mail tracking software allows communications to be measured across an organization. Who initiates and who receives most e-mail? Is the e-mail distribution net narrow and one-directional or broad and multi-directional? Are there employees or groups isolated from the main distribution patterns? Are lateral communications decreasing relative to vertical ones? Do the communication patterns suggest major departures in practice from formal authority as described in an organization chart?

Resilience

-- simulations have been used to test emergency response communication, decision and problem-solving processes. Are emergency response roles and responsibilities recognized and competently exercised.

-- unannounced experiments can be conducted to guage specific resilience properties such as pattern recognition, free-flowing communication, quality and speed of decision-making, e.g. non-lethal "failure" of computer displays and network systems, power supply, etc. can be induced as a test of elements of resilience.

- These are simply examples of possible measures for organizational and managerial concepts and variables.
- *No single one* of these possible measures, indicators and metrics can be adequate.
- It is up to analysts with the help of practitioners to develop multiple measures to enlarge the reliability with which we can measure and assess variables such as these .

- We can also increase the coverage and utility of human and organizational variables by shifting the *scale*, *scope* and *time* frame of their analysis.
- Here are some examples:

  A. Shifts in scale: micro analysis

  -- e.g. micro task and task psychology analysis (e.g. robotic surgery and its change in roles of surgeons and support groups; personal confidence and resilience of surgeons to deal with unexpected issues; U.S. Navy SEALS high mission variability, low predictability requires a "calming focus" and "comfort with failure“; micro-resilience properties down to individuals)

  -- cognitive work analysis of specific task requirements

Micro analysis (cont’d)

-- role of "reliability professionals" in HROs (internalizing commitment to system reliability; mixing formal deductive and experiential knowledge; ability to see beyond their own job description)

-- role of specific sub-cultures of task in work groups (e.g. mechanical vs I&C maintenance groups; overland vs over-water air traffic controllers)

B. Shifts in scale: Macro-analysis

-- network vs organizational reliability

reliability is increasingly a network property beyond control of single organizations;

inter-connected infrastructure risk

-- sectoral reliability and safety

sectoral "best" practices as standards;

sectoral "drift" toward loss of experience base in infrastructures in workforce retirements;

banking sector drift toward higher risk loans and investments prior to financial meltdown

C. Enlarged time frames

-- analysis of slow motion failures and inter-generational risk

nuclear plant safety vs nuclear waste;

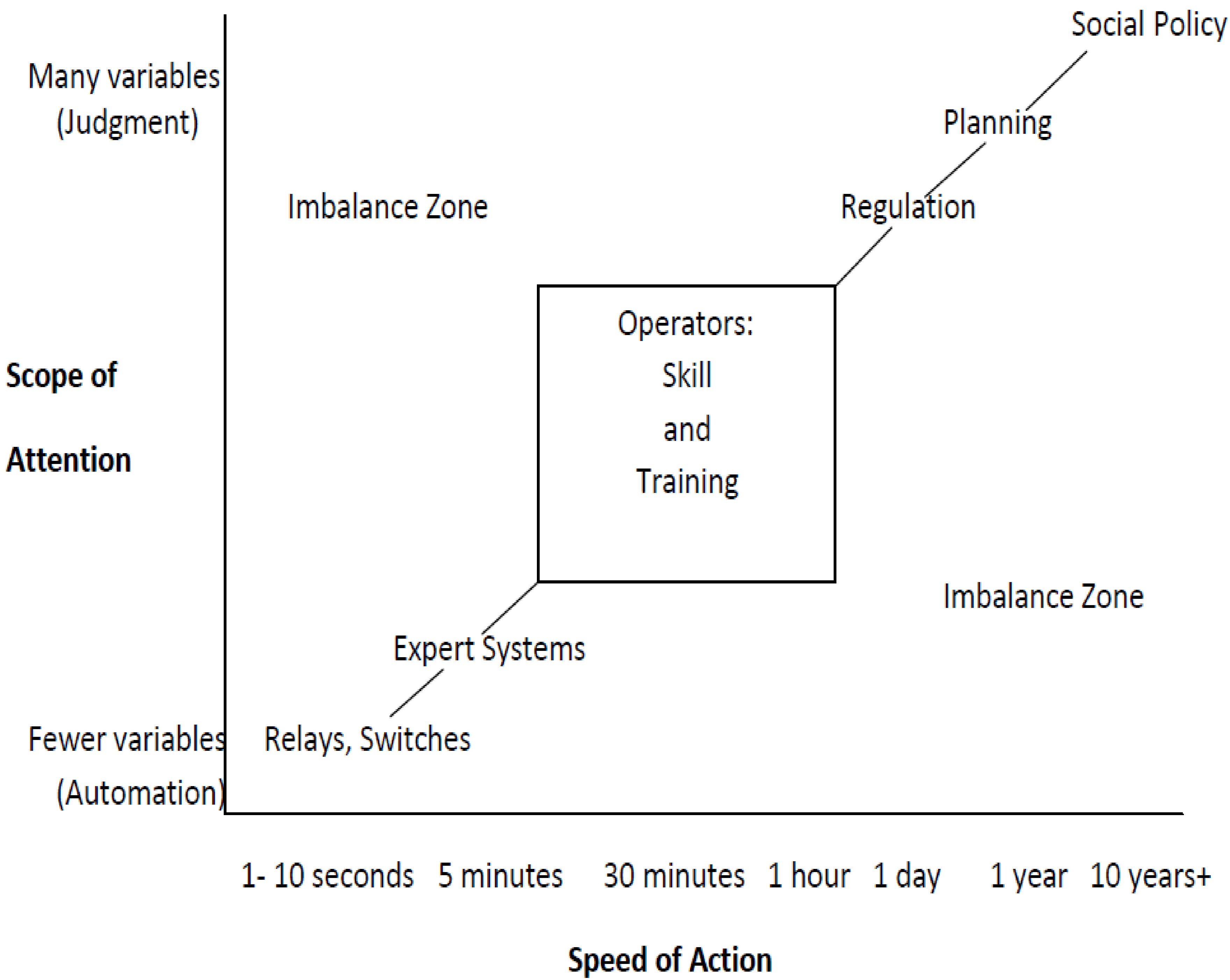
climate change and increasing infrastructure risk

-- search for more and longer leading safety and reliability risks and indicators

specific sustainability problems and strategies;

decline in preventive maintenance investments in favor of innovation investments or a run to failure strategy

- Analyses of safety across these scales and time frames can lead to a higher resolution additive understanding of organizational and managerial factors in safety and reliability, running from macro to micro levels of analysis over long and short-term time frames.
- Then we can analyze the causal interconnections between the levels and time scales -- how what happens or doesn't happen at one level of planning and management scale can affect operating conditions at another.
- The following figure is one integrated illustration of the scale and scope of organizational and managerial attention relation to the time frame needed for action in order to promote safety:


Social Policy
Many variables
(Judgment)
Planning
Imbalance Zone
Regulation
Operators:
Skill
and
Training
Scope of
Attention
Imbalance Zone
Expert Systems
Fewer variables
(Automation)
Relays, Switches
1- 10 seconds
5 minutes
30 minutes
1 hour
1 day
1 year
10 years+
Speed of Action

- Formalizing human, organizational and managerial concepts and variables can help fold uncertainty into analyses of risk and safety.
- Currently many formal risk assessment practices in the United States assume that the risk described in the analysis *is* the uncertainty.
- Often a single value is offered to describe this risk: the product of a probability estimate and a specification of the consequences in money or lives.

- This narrow specification is often a false precision, because uncertainty surrounds either the probability or consequence estimate or both.

- Introducing uncertainty surrounding the estimates is resisted because it undermines the effort to arrive at a maximizing or optimizing analytic solution to guide risk mitigation investments.

- But actually identifying the type of uncertainty can be *information* of great importance for risk management.
- It can lead to specific strategies for each type.
- The uncertainty might well be in either likelihood or in consequence estimates and can often be captured in upper and lower range of these estimates.
- If so, this represents a trade-off of precision for accuracy because a single value for risk is likely to be wrong in unspecified ways while at the same time a true value is likely to be contained somewhere within the range of estimates.

Human organizational and managerial variables can help us define the margins of the best and worst-case for risk of failure of physical systems

-- whether these systems are carefully and attentively operated and maintained by well trained and motivated workers and

-- organization and management metrics can be used to support or discount risk mitigation investment analysis

-- whether possible failures are anticipated and planned for, and

-- whether resources, roles and skills are available for rapid and effective responses to these failures

- It will take a large and persistent R&D project to achieve the integration of human, organizational and managerial variables into the physical analysis of technical systems.
- But understanding them as socio-technical systems, across scale, scope and time, is key to our ultimate understanding of how to design and manage them for safety.
- Further addressing human and organizational issues as measurable can be of high value to organizations for more reasons than safety.

- Many safety management elements overlap with those that have been identified as being associated with effective management in general and high productivity levels in competitive business firms.
- A survey of management practice data from 732 medium-sized firms in the United States, France, Germany, and the United Kingdom found that the following management practices – *investment in modern technical processes*; *clear documentation* (with key indicators)*; careful monitoring and performance documentation;* stress on attracting and developing talented people and soliciting and incorporating ideas of lower level employees -- were strongly associated with *firm-level productivity, profitability, high market value, and survival rates*.

Nick Bloom, N. and John van Reenan (2006). "Measuring and Explaining Management Practices Across Firms and Countries". *Center for Economic Performance* Discussion Paper No 716 (March)

Other benefits of good safety management

- In a recent exercise which required 43 teams comprising 345 participants to absorb, interpret and act upon large amounts of information and demanded considerable ability in communication, coordination and adaptability, results showed strong, significant relationships between collective mindfulness (an HRO property), measured by the ‘Mindful Organizing Scale’ (Weick and Sutcliffe 2007) and objective measures of performance particularly significant to the performance of teams pursuing ambitious, high risk strategies.

Nick Oliver, et. al. "Collective Mindfulness, Resilience and Team Performance." *Academy of Management Annual Meeting Proceedings*, (1): (2017).

Key HOF Implementation Questions

- If you wanted to implement these HO indicators and their management in a big organization, operating in different countries, how would you proceed?
- How would you define the combination of indicators that would make sense for your organization? Who could do it?
- What would be the organizational conditions needed to make the introduction and use of HOF indicators successful?
- Would you use a standard approach, a customized approach...?

1. national culture can make a difference within an organization and should be taken into account (e.g. Geert Hofstede research)

2. indicators must make sense to participants throughout an organization

3. the first need is a theory of safety performance – the structures (authority, role specificity or overlap, rule density, communication channels and practices) prevailing attitudes, incentives, cognitive approaches considered foundational for good performance -- that tells you what indicators are important

4. risk indicators and their development should not be the responsibility of a single safety officer or department -- responsibilities for a safety management system, including its metrics should be widely distributed across departments and levels