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Review

A critical review of methods and models for evaluating organizational factors in Human Reliability Analysis

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A B S T R A C T

This work makes a critical evaluation of the deficiencies concerning human factors and evaluates the potential of quantitative techniques that have been proposed in the last decades, like THERP (Technique for Human Error Rate Prediction), CREAM (Cognitive Reliability and Error Analysis Method), and ATHEANA (A Technique for Human Event Analysis), to model organizational factors, including cognitive processes in humans and interactions among humans and groups. Two important models are discussed in this context: STAMP (Systems-Theoretic Accident Model and Process), based on system theory and FRAM (Functional Resonance Analysis Method), which aims at modeling the nonlinearities of socio-technical systems. These models, however, are not yet being used in risk analysis similarly to Probabilistic Safety Analyses for safety assessment of nuclear reactors. However, STAMP has been successfully used for retrospective analysis of events, which would allow an extension of these studies to prospective safety analysis.

1. Introduction

Organizational factors are addressed in first generation models of human reliability analysis by means of performance shaping factors such as training, experience, procedures, management, communication and culture. Several individual psychological and physiological stressors for humans are also treated by such factors. Organizations are made up of humans and these models suffer from a chronic deficiency in terms of modeling the cognitive processes in humans. Human error is treated similarly to a physical component error. These models lack a cognitive architecture of human information processing, with cognitive error mechanisms, Swain (1990), Kantowitz and Fujita (1990), Cacciabue (1992), Fujita (1992), Hollnagel (1998).

Second generation HRA methods have some kind of cognitive architecture or cognitive error mechanisms. Organizational factors are taken into account by performance shaping factors. The evolution here was to establish a mapping between these factors and the error mechanisms being influenced or triggered in a given operational context, since not all performance shaping factors influence a specific error mechanism. Thus, one can generate tables of influences between performance shaping factors and error mechanisms and between these and specific types of human errors associated to a given operational context for each stage of information processing (detection, diagnosis, decision making and action). In fact, ATHEANA contains comprehensive tables with such interrelationships, NRC (2000). CREAM (Hollnagel, 1998) proceeds similarly.

Although the above methods have evolved in matters relating to human cognition, organizational factors do not have a proper model that can highlight social, political and economic processes that influence such factors in a similar way as error mechanisms in human cognition. Such processes involve complexity that models of first or second generation cannot handle properly, Qureshi (2008).

Digital technology systems require an analysis that takes into account complexity not found in analog technology. Digital systems may be at intermediate fault modes before reaching a final failure state that will be revealed to human operators in the human–machine interface. These intermediate states are mostly invisible to operators and can move the system to often catastrophic conditions, where human beings do not have consciousness or information on what the system is doing, NRC (2008).

In addition to digital systems, complex systems deal with social, political and economic levels of individual, group and organization

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List of acronyms

ACCI-MAP	Accident Map
AHP/DEA	Analytical Hierarchical Process/Data Envelopment Analysis
APJ	Absolute Probability Judgment
AOE	Analysis of Operational Events
ASEP	Accident Sequence Evaluation Program
ATHEANA	A Technique for Human Error Analysis
BBN	Bayesian Belief Network
BHEP	Basic Human Error Probability
BN	Bayesian Network
BWR	Boiling Water Reactor
CAHR	Connectionism Assessment of Human Reliability
CESA	Commission Errors Search and Assessment
CBDT	Cause-Based Decision Tree
CC	Common Conditions
CODA	Conclusions from occurrences by descriptions of actions
CPC	Common Performance Conditions
CREAM	Cognitive Reliability and Error Analysis Method
DT	Decision Tree
EPRI-HRA	Electric Power Research Institute – Human Reliability Analysis
ESD	Event Sequence Diagram
FCM	Fuzzy Cognitive Map
FLIM	Failure Likelihood Index Methodology
FRAM	Functional Resonance Accident Model
FT	Fault Tree
GST	General Systems Theory
HCR	Human Cognitive Reliability
HEART	Human Error Assessment and Reduction Technique
HEP	Human Error Probability
HFACS	Human Factors Analysis and Classification System
HF-PFMEA	Human Factors-Process Failure Mode and Effect Analysis
HFI	Human Factors Integration
HOF	Human and Organizational Factors
HORAAM	Human and Organizational Reliability Analysis in Accident Management
HRA	Human Reliability Analysis
HSC	High Speed Craft
IDAC	Information, Decision, and Action in Crew
IF	Influencing Factor
INTENT	Not an acronym
IPSN	Institute for Nuclear Safety and Protection
JHEDI	Justified Human Error Data Information
K-HPES	Korean-Human Performance Enhancement System
LISREL	Linear Structure Relation
MERMOS	Méthode d'Evaluation de la Réalisation des Missions Operateur pour la Sûreté
MTS	Maritime Transport System
NARA	Nuclear Action Reliability Assessment
NPP	Nuclear Power Plant
NRC	Nuclear Regulatory Commission
ORE	Operator Reliability Experiment
PC	Paired comparisons
PRA	Probabilistic Risk Assessment
PSA	Probabilistic Safety Assessment
PSF	Performing Shaping Factors
QRA	Quantitative Risk Assessment
SADT	Structured Analysis and Design Technique
SD	System Dynamics
SHARP1	Systematic Human Action Reliability Procedure (enhanced)
SLIM-MAUD	Success Likelihood Index Methodology, Multi-attribute Utility Decomposition
SMAS	Safety Management Assessment System
SPAR-H	Standardized Plant Analysis Risk-Human Reliability Analysis
STAMP	Systems-Theoretic Accident Model and Process
STEP	Sequential Time Events Plotting
STPA	System-Theoretic Process Analysis
THERP	Technique for Human Error Rate Prediction
TRC	Time Reliability Correlation
UMH	University of Maryland Hybrid

relationships (Leveson, 2004a; Qureshi, 2008). Traditional models are based on a successive chain of events each relating to a previous event causation. This is a strictly linear view of cause–effect relationship. In contrast to sequential models, epidemiological models evolved later, which distinguish latent failures (design, maintenance, management) that can converge to a catastrophic event when using a "trigger", i.e., by combining operational failures (unsafe acts, active failures) and typical system conditions (operating environment, context), Leveson (2004a), Qureshi (2008), NRC (2008), Dekker et al. (2011).

These two classical approaches work well when applied to components of conventional (non-digital) systems that have well-defined failure modes and exhibit linear relationships between these failure modes and their causes, even when not expected in the design since these failure modes are quite "visible". Nonlinear interactions, on the other hand, are unplanned, unfamiliar unexpected sequences of failures and, in addition, invisible and incomprehensible, Leveson (2004a), Qureshi (2008), Dekker et al. (2011).

In complex nonlinear interactions, failures do not arise from the relationship (which may not be exhaustive) of components failure modes and their causes, but "emerge" from the relationships between these components during operational situations. To study these interrelationships, it is necessary to identify the laws that rule them. The only model that can do that is a model based on systems theory, which aims to study the laws that govern any system, be it physical, biological or social Leveson (2004a), Qureshi (2008), Dekker et al. (2011).

Human factors should be evaluated in three hierarchical levels. The first level should concern the cognitive behavior of human beings during the control of processes that occur through the man-system interface. Here, one evaluates human errors through human reliability techniques of first and second generation, like THERP (Swain and Guttman, 1983), ASEP (Swain, 1987), and HCR (Hannaman et al., 1984) (first generation) and ATHEANA (NRC, 2007) and CREAM (Hollnagel, 1998) (second generation). In the second level, the focus is on the cognitive behavior of human beings when they work in groups, as in nuclear power plants. The focus here is on the anthropological aspects that rule the interaction among human beings. In the third level, one is interested in the influence of organizational culture on human beings as well as on the tasks being performed. Here, one adds to the factors of the second level the economical and political aspects that shape the company organizational culture. Nowadays, Human Reliability Analysis (HRA) techniques incorporate organizational factors and organization levels through performance shaping factors.