Human Factors in Nuclear Power Plant Safety Management: A Socio-Cognitive Modeling Approach using TOGA Meta-Theory

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Abstract

Coping with socio-cognitive risks in large critical technological infrastructures, for instance when dealing with safety management in a Nuclear Power Plant (NPP), is a crucial topic in today's large systems technology. In such complex and not transparent humans-computers networks, each human activity can be associated with a hardly assessed but non-negligible probabilities of human errors. In NPPs, management of human cognitive factors closely relates to safety monitoring and control of a whole plant by plant operators and managers. The aim of this work is a preliminary demonstration of how a systemic methodological socio-cognitive approach can be used for modeling complex human-technology activities in the frame of Integrated Safety Management (ISM) strategies in Large Complex Critical Infrastructures (LCCIs), such as energy networks or NPP systems. Top-down Object-based Goal-oriented Approach (TOGA) has been applied as a meta-modeling framework.

Socio-Cognitive Engineering (SCE) is an emergent systemic and cognitive initiative in the field of common human technological and cultural interdisciplinary activity. It is based on a shared top systemic conceptualization and ontology. This engineering field requires - especially in high-risk situations - functional computational models of the two basic socio-cognitive interactions: "Human Intelligent Agents (HIAs) - technological systems" and "HIAs - human organization", both relating to the efficiency of a human decision-making.

In human organizations, efficiency plays an essential role in the mitigation of disasters, calamities, nuclear incidents, and other large-scale emergencies. Vulnerability in emergency management organizations is a critical, yet usually not well visible factor under the normal (i.e. not extreme) everyday conditions. Long periods without crisis and dangerous events can be the cause of an illusion of safety. The probability of human errors in large human-technology systems becomes the dominating parameter in the assessment of their reliability. Human factor depends on cognitive attributes as: vagueness, uncertainty, incompleteness of knowledge, variable accessibility to information, emotions, irrationality, ethical preferences, organizational and socio-cultural factors, which do not exist in classical engineering problems. All of them do influence socio-cognitive human decisional processes during the identification and removal of individual (i.e. plant operators, managers and policymakers) and organizational cognitive vulnerabilities. In order to face so complex domain and objectives, a robust and reliable methodology must be chosen. TOGA is a goal-oriented knowledge ordering computational tool for complex systems analysis and design. It includes an upper ontology and its application methodology. It assumes a top-down observation point of view. On the other hand, every problem is seen as an interaction of a pre-selected AIA with its Environment (*En*). After the first level sketch, it goes on a formal step-by-step goal-directed decomposition/specialization of the models and concepts involved in a triple (*AIA*, *En*, *In*), where In represents a basic model of AIA-En Interaction. This type of decomposition can be done for the tasks specification of NPP operators and other staff members.

Complexity of social safety problems in NPP systems strongly requires new third generation systemic research approaches (and therefore integrated conceptual tools), such as TOGA multi-factor problem representation and parallel modeling, as well as the development of Intelligent Decision Support Systems (IDSSs) for managing huge amounts of information and facing unexpected situations. SCE requires ontological and methodological frames for a quantitative assessment (e.g. computer simulations of social risks and impacts caused by intrusions and mismanagement), as well as for the modeling of artificial intelligent organizations embedded in such complex human-technology aggregates (e.g., plant-operator-manager-organization-society). The above mentioned conceptualization platform has to be based on theoretical foundations and, as a consequence, on a conscious, wise and socio-ethical responsible decision making. This is particularly true in all those systems having a psycho-social impact on citizens who definitely are the main stakeholders in deciding on controversial social issues (e.g. if and where developing nuclear power plants). Therefore, such studies also help to persuade the public opinion that the risks of using nuclear fission as a power source can be offset through the development of new technology together with novel Integrated Safety Management (ISM) strategies.