# Towards a Framework for Definition of Enterprise Safety Indicators

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**Abstract**

Safety of enterprises, as well as socio-technical systems in general, is due to several factors and can be considered an emergent property, depending on non-linear and symbiotic interactions between humans and technical systems taking places in collaborative business processes. The safety-II perspective promotes assessing and gathering meaningful knowledge about normal work, and its effect on safety and productivity. We aim at providing a support to this activity, proposing a three-phases framework for the definition of indicators on enterprise safety performance. This framework includes collection of knowledge on work-as-imagined (WAI) business processes, ontology-based modelling of work-as-done (WAD) business processes and some guidelines to define indicators taking into account the actual needs and implicit knowledge of sharp-end operators by means of the Functional Resonance Analysis Method (FRAM).

**Keywords**

FRAM, Safety indicators, Socio-technical systems, Ontologies, Semantical models, Knowledge Elicitation.

## 1. Introduction

The growing complexity of business processes, unpredictable interactions of humans and failures of interoperability services could generate enterprise incidents and, hence, casualties, injuries, and economic losses. Enterprise modelling and simulation are widely recognized as valuable tools to reduce the number of these incidents and, hence, increase enterprise resilience. However, a further issue is due to the fact that business processes are usually conceived and codified by blunt-end operators (e.g., managers, advisors) that sometimes discard or ignore the real operational conditions of sharp-end operators and the actual safety flaws.

The safety-II principle gives a new perspective on socio-technical safety by focusing on information about normal work, and its effect on safety and productivity rather than on inherent hazards and risks. To support the activity of sharp-end operators' knowledge gathering and safety-II analysis, we propose an ontology-based framework aimed at assessing enterprise resilience by means of the $H(CS)^2I$ indicators (i.e., Human-Centred Safety Crowd-Sensitive Indicators).

The ontology-based framework aims at gathering and making interpretive sense of organizational performance, relying on the use of the Functional Resonance Analysis Method (FRAM) [1], which is a recently introduced method for modelling complex behaviors and non-linear properties of socio-technical systems. In particular, the framework supports knowledge collection for FRAM analyses [2], which overcomes traditional top-down theoretical assessment following artificial varieties of work, i.e. work-as-imagined (WAI), towards a bottom-up approach focused on normal operations, i.e. work-as-done (WAD). The framework relies also on an innovative gamified approach for knowledge gathering in order to isolate functional areas of concern. The final aim is to define safety performance

Proceedings of the Workshops of I-ESA 2020, 17-11-2020, Tarbes, France

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metrics: the above-mentioned $H(CS)^2I$ indicators. These latter are expected to support sharp-end workers in self-assessment of their own work activity, helping middle managers and top managers to interpret weak signals (both positive and negative) about system performance, supporting at large organizational decision-making at different organizational levels.

The framework is currently under development in the $H(CS)^2I$ project (2019-2021) funded by INAIL under 2018 SAF€RA EU funding scheme.

The rest of the paper is organizes as follows. Section 2 presents the overall framework. Section 3 describes the three main phases aimed at defining $H(CS)^2I$ indicators and Section 4 provides some conclusions and future research directions.

## 2. The $H(CS)^2I$ Framework

The core of the $H(CS)^2I$ framework is a three-phases process for the development of Human-Centred Safety Crowd-Sensitive Indicators in Enterprises (see Figure 1). The first phase (Phase 1) addresses the collection process of WAI knowledge in an industry. The second phase (Phase 2) focuses on the development of a socially validated ontology [3] [4] and crowd-sensitive FRAM models of the WAD starting from the business processes concerning WAI and from gamified interviews. The third phase (Phase 3) addresses the development of the $H(CS)^2I$ indicators.

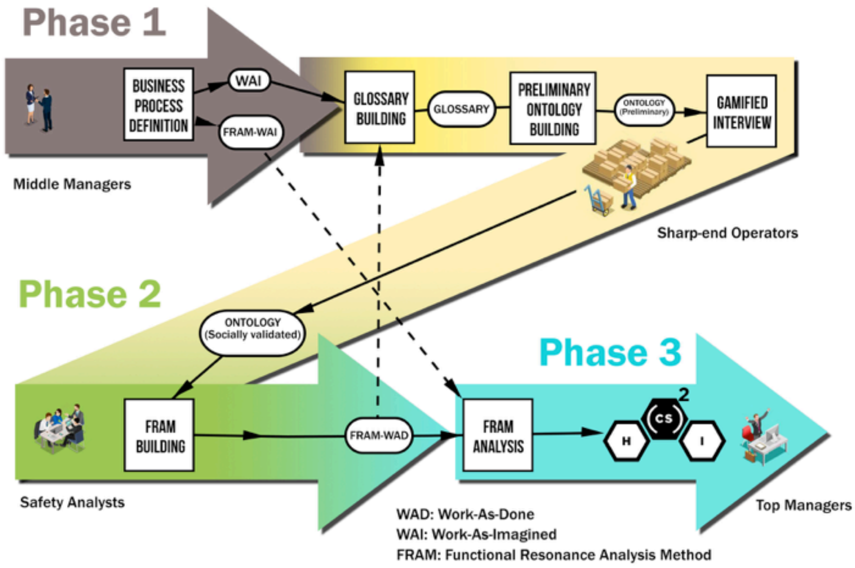


**Figure 1**: Overview of the $H(CS)^2I$ framework

### 2.1. Phases of the $H(CS)^2I$ Framework

#### 2.1.1. Developing Knowledge of Industrial Production Processes

This knowledge collection phase provides for initial characterisation of organisational information for use in subsequent gamified data collection. The aim is to model a WAI business process both by gathering existing documentation or through middle manager interviews, model it in a standardized format (e.g., UML or BPMN) and by using the FRAM notation. This task clearly identifies the theoretical building blocks for later supporting the determination of any inconsistencies or flaws, which require adaptation in order to provide for successful work outcomes, either documented or practiced (WAD).

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### 2.1.2. Gamified Collection of Work-As-Done Knowledge

This phase has two aims. The first one is to build an ontological representation of the business knowledge related to the enterprise production processes, which is required for safety analysis. As an ontology should reflect an ever-changing reality, this ontology development step could be iterated several times to include additional knowledge acquired during the process. For the first iteration, the input consists of the models representing the theoretical representation of work (WAI). For the subsequent iterations, this task requires the process models representing WAD. The sharp-end operators perform the process related to this step. This process encompasses gamification techniques [5] in order to increase the engagement of the sharp-end operators (e.g. by earning points or game rewards) and a computational creativity approach [6] to stimulate their contributions. The ontology extends an ontological upper model derived from the FRAM named FRAM Upper-level Model (FUM) [7]. This latter represents the most relevant FRAM concepts and the ontological relationships linking them. A FRAM-based ontology of enterprise production is built by extending FUM with domain-specific concepts. Furthermore, the FUM facilitates engineering of FRAM-based ontologies to be used to support the process of designing FRAM models. Based on the knowledge gathered in the ontology through the gamified approach, crowd-sensitive FRAM models representing WAD are created by safety analysts.

The quality of identification of WAD knowledge has to be assessed against several dimensions including semantics (i.e., absence of contradictory concepts), syntactic quality of WAD models, completeness, fidelity, relevance and social acceptance by sharp-end operators.

### 2.1.3. Definition of $H(CS)^2I$ Indicators

This phase aims at developing enterprise safety indicators to be used by top managers for enterprise resilience assessment. To this purpose, firstly, the FRAM models, both the one based on procedural work (WAI) developed during the first phase, and the one on normal operational work (WAD) developed during the second phase, are analysed. The initial purpose of this analysis consists in comparing the two developed models to identify discrepancies between WAI and WAD. This is a primary area of concern, since it implies that the system presents relevant design flaws that require thus continuous adaptation to overcome constraint and to work around other unintended consequences. Secondly, knowledge gathered through the ontology-based gamified approach is used to develop a semi-quantitative simulation model based on the FRAM model. Its purpose is to combine different variability states in order to detect the potential for functional resonance. Traditionally, the FRAM modelling approach is purely qualitative, and relies on interviews and observational studies, which could be affected by subjectivity and are normally time-intensive. On the other hand, the simulation model is semi-quantitative since it would relate criticality scores to a numeric scale with the linguistic data reported by the operators through the ontology-based gamified approach. The approach could be based on Monte Carlo simulation [2], as a means to explore the potential combination of variability for the purpose of identifying the functional aspects with the higher potential for functional resonance. The purpose of this task is thus to use the discrepancies as well as data describing adaptive behaviors in order to define indicators based on an increased involvement of operators, as well as the analysis and synthesis of the evolving context of work.

The $H(CS)^2I$ framework aims at defining multiple indicators [8] grouped at different granularity layers to represent criticalities at different abstraction levels. Even though the methodological contribution remains valid in any socio-technical system, the specific framework as well as the indicators are based on the organization-specific data and knowledge. As a matter of example, in a generic industrial plant, indicators could be specifically related to measuring the frequency and quality level of communications among sharp-end operators or inter-level communications between

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middle management and sharp-end operators, or even assessing the presence and status of the tools required for developing a specific maintenance activity.

## 3. Conclusions

The theory of Resilience Engineering [9] supports the trade-off between complexity-oriented theories and pragmatic tools usable for decision-makers to increase system safety. In this context, the H(CS)$^2$I framework aims at enhancing traditional approach for resilience assessment through a methodological contribution based on an innovative ontology-based gamified approach for FRAM. Gamification is used to increase engagement of operators at providing data and increases the capacity of gathering reliable collective data about normal work. Ontology becomes thus necessary to build a reliable formal representation of FRAM model. Hence we propose an innovative Resilience Engineering-oriented gamified approach aimed at capturing bottom-up adaptive behaviors and normal work variability in order to generate database usable for running semi-quantitative simulations and support a systemic analysis of areas of concern. The functional resonance approach, combined with the gamified approach would thus support the definition of proxy measures of socio-technical safety, i.e. the H(CS)$^2$I. These latter are expected to represent holistic performance metrics usable as early warning indicators for system critical transitions in riskier states.

## 4. Acknowledgements

This work is partially supported by the H(CS)$^2$I project, which is funded by the Italian National Institute for Insurance against Accidents at Work (INAIL) under the 2018 SAF€RA EU funding scheme.

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