2016

Human Factors at the Core of Total Safety Management: The need to establish a common operational picture

Maria Chiara Leva
Technological University Dublin, maria.leva@tudublin.ie

Tom Kontogiannis
Technical University of Crete

Nora Balfe
Trinity College Dublin, Ireland

See next page for additional authors

HUMAN FACTORS AT THE CORE OF TOTAL SAFETY MANAGEMENT: THE NEED TO ESTABLISH A COMMON OPERATIONAL PICTURE

M. Chiara Leva[1], Tom Kontogiannis[2], Nora Balfe[1], Emmanuel Plot[3], M.Demichela[4]

[1]Centre for Innovation in Human Systems – Trinity College, Dublin, Ireland
[2]Dep. of Prod. Eng. & Management – Technical University of Crete Greece
[3]INERIS Parc Technologique Alata - BP 2 60550 Verneuil-en-Halatte France
[4]Department of Chemical Engineering–Polytechnic of Turin Italy

The Total Operations Management for Safety Critical Activities (TOSCA) project is aimed at developing a safety management framework that integrates best practices, tools and methods for functional analysis, risk assessment, interactive emergency scenarios analysis, performance monitoring, design review, training and knowledge management. The TOSCA approach is described by a T-model based around a central 'Common Operational Picture' (COP) that holds information regarding the operational system, and is used to support risk assessment and management. The information held in the COP may be represented in different ways but should be accessible to all stakeholders in order to analyse and communicate risk, and to support training and procedure design.

Total Safety Management

Over the recent past, the accumulation of major mishaps, crises and accidents have made it clear that organisations must still improve their capabilities to address safety not as a stand-alone activity that is separate from the main activities and processes of the organisation but as an integrated part of total performance management. Total Safety Management uses the basis of Total Quality Management to drive safety within an organisation (Herrero et al, 2002), but in contrast to quality management, Total Safety Management influences performance, quality and safety resulting in a much wider beneficial effect (Cooper & Phillips, 1995).

It is essential that we understand how weaknesses in the technical processes combine with flaws in organisational interfaces and give rise to significant losses and major industrial accidents. The traditional fields of practice, such as risk analysis (RA) and probabilistic safety assessment (PSA), have often been rooted in simplified accident models and failed to conduct a functional analysis that takes into account any dependencies between technical, human and organisational processes. In addition, traditional RAs and PSAs have not

provided robust solutions because they have not been embedded within a 'total operations' or 'performance management' framework to deliver solutions that are both innovative and safe. It is not sufficient that production systems are reliable (i.e., their failure probability is acceptably low) but they must also be resilient and capable of recovering from irregular variations, disruptions and degradation of working conditions. It is often the case that system vulnerability and resilience arise from the same interactions between socio-technical dimensions. Thus, the mechanisms that create vulnerabilities and resilience cut across traditional disciplinary borders, e.g., engineering, sociology, psychology and political science.

In the last decade, there has been an increasing interest in occupational health and safety in Small and Medium Enterprises (SMEs) accompanied by many European projects supporting their viability (see European Agency for Safety and Health at Work Report 2005). The majority of studies in the literature have found that SMEs have an increased risk of accidents compared to large enterprises. However, Sørensen et al. (2007) found that this relationship only holds for SMEs that are independent; in contrast, for SMEs that are part of larger organizations, the work environment does not seem to present more hazards than the large enterprises. Another survey conducted in Italy (i.e., 84 small-sized and 25 medium-sized enterprises responded to a questionnaire) reported on the importance of SMEs' perception of safety and identified current safety management priorities and methods. Micheli and Cagno (2009) found that, although 80% of SMEs claimed that safety was among their main priorities, they reported problems in planning safety interventions because of limited financial resources, lack of management tools and a burden of compliance with regulations and codes. SMEs focused their investments on issues associated with purely regulatory or legislative aspects, that is, (1) training and information of workers on safety, (2) upgrading installations to comply with safety standards, and (3) introducing safer production technologies and personal protective equipment. A tendency was observed among SMEs to outsource safety management to compensate for the lack of specific competences within the enterprise; this tendency was greater in small-sized enterprises. Therefore, SMEs can gain a lot of benefits in safety and performance by developing a capacity to risk assess actual operations with a practical and resilient methodology as well as a capacity for monitoring operational data in a solution embedded in their everyday data collection process.

The Total Operations Management for Safety Critical Activities (TOSCA) project is a European Project within the context of the 7th Framework Program aimed at developing an innovative approach to integrate and enhance safety, quality and productivity, especially for SMEs in the process industry. The scope of TOSCA is to establish an economically suitable framework in which the most innovative tools and techniques (e.g. advanced 3D software, virtual reality, innovative theoretical models, updated information exchange protocols, etc.) are used together in order to take advantage of possible synergies in processing

human factors requirements, fulfilling regulations, improving safety and enhancing productivity.

To achieve this, the project is developing a theoretical framework for Total Safety Management in the process industry, particularly focused on SME applications. The aim is to better define and highlight the needs of the industry regarding the development of an integrated methodology for assessing safety, quality and operations management.

Safety Management

Safety management has traditionally focused on correcting safety concerns, problems, or hazards and taking the necessary steps to bring the system back to normal operation. Existing safety approaches seem to rely on what is commonly known as closed-loop feedback control. Therefore, we need to develop a new approach that not only solves out discrepancies between safety goals and current states but also helps us understand the current state of operations and risks involved in a plant. If stakeholders are able to develop a common picture of operations and risks then they are in a better position to anticipate the effects of corrective actions and risk mitigations. In order to develop this anticipatory or proactive capability, our safety approach should rely on an internal model of the process that predicts the future state of the process and compares alternative actions in terms of effectiveness and cost. This type of model-driven feedback control enables safety analysts to cope with an overload of information and direct attention to critical events in a timely fashion. Safety practitioners should be able to monitor what could become a threat in the near-term and what could impair their abilities to respond (internal performance). This monitoring capability is supported by a common picture of how the technical process works, how people organize their jobs and how the environment can affect the process and the people.

Several activities that are critical from a safety or productivity perspective may require a strong coordination between many agents (e.g., safety managers, supervisors, operators and external contractors) as well as communication of information regarding possible side-effects, threats and escalation of events. This ‘knowledge transformation’ process requires that data and information are systematically managed and integrated with people’s knowledge of the functioning of the system. Building a common picture of opportunities and threats will allow different agents to understand the systemic causes of safety issues and provide a basis for suggesting practical interventions.

The requirements for safety management in existing and upcoming standards and regulations (example ISO 31000 and its related upcoming revisions, Seveso II directive etc.) call for a proactive strategic approach, demonstrating a capacity to anticipate risks and keep safety at the centre of changes driven by commercial competition as well as ensuring that evidence collected through risk analysis becomes an effective driver of innovation and change. This is particularly

important for Major Hazardous Activities where prevention and mitigation are necessary for survival and where the complexity of organizations requires a 'system of systems' perspective. However, there is currently a gap between the principles stated in the available standards and regulations and the actual roadmaps to their implementation. Organisations, especially the safety critical ones, find it difficult to integrate their different functional units in a common programme of operations management.

COMPRIS

A Common Operational Picture is a single source, usually a display, of relevant operational information. The term originates from the military domain where it is used to describe the complete graphical picture of the battlefield used by commanders to make effective command decisions (Looney, 2001). The aim of a common operational picture is to share situation awareness among distributed stakeholders and the concept has also been applied in emergency management and humanitarian crisis management (McNeese et al, 2006). TOSCA applies this concept to safety management, and is developing a *Common Operations Management and Risk Information System* (*COMPRIS*). COMPRIS provides a representation of information and knowledge about the operational system that can be used to support risk assessment and safety management. The information may be represented in different ways, but should be accessible to all stakeholders involved in a project in order to analyse and communicate risk, and to support training and job design.

In terms of control theory, COMPRIS is a 'mental model of how the system works' that guides the application of a safety management system (SMS) in everyday practice. In this respect, COMPRIS is a 'mental model' of how a specific SMS works, what risks are significant at a particular area, what methods should be used to assess risks, what uncertainties exist in a risk evaluation, and what risk mitigation measures can be chosen to reduce risk to acceptable levels.

Establishing COMPRIS, or a 'risk picture', involves a useful synthesis of the risk assessment, with the intention to provide understandable information to the relevant decision-makers and users about the risk and the risk assessment performed. The 'risk picture' shall be understandable by all relevant personnel, decision makers as well as engineering and/or operating personnel. This may be achieved with the use of tailored documentation and presentations to different groups of internal and external stakeholders. The presentation and documentation of the risk picture shall be a comprehensive, balanced, many-facetted and holistic picture of the risk associated with facilities and operations.

COMPRIS is an internal model that addresses how safety is measured and what 'performance indicators' will be monitored to measure not only the 'final outcome' but also 'antecedents' so that changes are made before undesired outcomes are produced. Performance indicators provide a good basis for integrating measures of safety with productivity and quality control. Figure 1

shows s model-driven safety management system that comprise four functions from resilience engineering (i.e., REPOND – MONITOR - ANTICIPATE and LEARN):

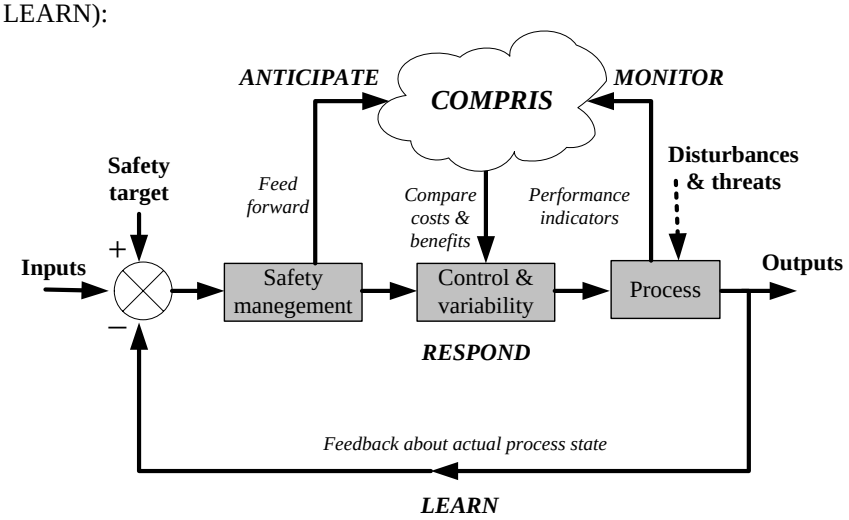

Figure 1: *The role of COMPRIS within a safety management system*

1. Given a specified safety goal, the safety practitioner has to RESPOND take control action that changes the technical process in order to produce the desired output; in turn this is measured by suitable indexes and by feedback (MONITOR).
2. COMPRIS (i.e., the internal model of the process) also needs to enable safety practitioners to ANTICIPATE disturbances so that actions are taken before they occur. The advantage here is that control actions can prevent adverse events from taking place or intervene before their consequences have had time to spread to other parts.
3. Safety practitioners must be also able to control threats from internal variability due to fatigue of personnel, changes in team composition, unavailability of tools and so forth.
4. Safety practitioners must be able to LEARN from experience which includes many changes in the internal model of the process.

Individual companies have different approaches to building their ‘understanding of risks and risk control measures’ depending on the resources invested in safety management. SMEs may have greater problems than large companies in getting an accurate ‘COMPRIS’ (or ‘understanding’) of their risks and the possible measures to control risks. Among other reasons, SMEs are more diversified than large companies and this makes it difficult to draw on what risk information already exists in the specific industry domain they operate. There is a need therefore to examine the scope of COMPRIS in both SMEs and large companies.

Application of COMPRIS

There is limited information on 'what constitutes a common operational picture' in a SMS. There has been a tendency to consider the 'risk registry' and the 'risk acceptance criteria' as a common operating picture so that all stakeholders and operators are aware of the whole spectrum of risks in a company. However, it is interesting to ask whether the common picture should also address the risk analysis tools used to identify risks, their limitations, the kind of analysts participated in the risk analysis, and the influence of the conditions under which the analysis took place. Other issues concern the level of detail that should be presented about risk items such as, the description of risks, the possible risk control measures, the responsible persons etc. Different people have their own boundaries of responsibility and it becomes time consuming to consider any 'risks' in other areas beyond their responsibilities. We can view the common operational picture as a database of risk information that should be accessible to key players but 'who should see what information' remains a challenging issue to be resolved. In TOSCA a set of methods and tools are used to establish the COMPRIS and produce a robust risk assessment (Fig. 2). These include:

- Task design and high-level functional hazard analysis using a participatory approach. This can be achieved with a modified Business Process Modelling (BPM) approach.
- Operational risk screening in order to feed in the results of functional analysis into bow-tie diagrams to identify important technical and human barriers that prevent or control industrial hazards.
- Quantified risk assessment for complex scenarios using tools, such as traditional fault trees or computational fluid dynamics, for consequence and likelihood assessment.

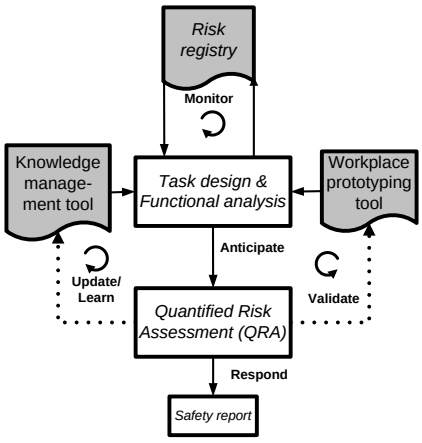

Figure 2: TOSCA methods and tools to establish COMPRIS

The results of risk analysis can be tested in workplace prototyping tools that create virtual workplaces for operators to interact with planned designs or changes in a 3D virtual representation. 3D maps of the site can also be used to display risk information in an accessible format, including critical risk areas and key safety barriers. Many SMEs complain that risk assessment is a complicated process that can be done only once during the design stage. Updating the risk assessment process every time there is a change management program is very cumbersome. For this reason, TOSCA builds a tool for managing and visualizing safety knowledge. Finally, TOSCA builds a risk registry for collecting data, monitoring risks and communicating safety knowledge. The risk registry is based on the concept of building a 'business case for safety' where the values of safety are seen beyond the traditional reduction of risks to establish connections with quality and productivity.

Current applications and future developments.

The TOSCA T-model © describes the Common Operational Picture at the heart of TOSCA safety management, and links this picture to a design loop and an operational loop (Fig. 3). The design loop applies the TOSCA tools to the design of new plant sections, the management of technical and organizational changes, and the risk analysis of critical activities. The operational loops applies the methods and tools to the management of safety barriers, the design of workflows, coordination of teams, and training. Modular products to deliver safety management are under development for each area of the framework

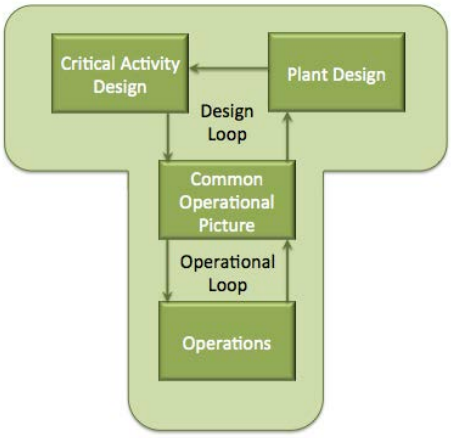

Figure 3: TOSCA Total Safety Management Framework©

To follow up the development and the testing of the TOSCA methodology in the three main sections and the deployment of the tools to support it within the project we have currently chosen to develop five test beds to test the

effectiveness of the proposed approaches in the areas identified. The test beds include the use of process mapping and task analysis to improve risk assessments for a food processing organisation, the establishment of a risk register and a set of KPIs to support hazard identification and risk monitoring in a energy generation company, the development of a 3D risk map to be used as a knowledge and risk management system for a company producing fertilizers, the use of rapid prototyping to optimise a rare testing procedure for a LPG storage organisation, and the use of VR to review and train operators and contractors for loading and unloading of cryogenic liquids. Three of the test beds will be conducted in SMEs, allowing the TOSCA approach to be tailored and tested for small enterprises as well as large ones. The results of the first phase of testing will be used to refine the individual tools and techniques deployed, as well as the overall approach and the concept of COMPRIS.

Acknowledgments

This research has received funding from the European Commission's Seventh Framework Programme FP7/2007-2013 under grant agreement FP7-NMP-2012-SMALL-6-310201 “TOSCA” and it is © copyright of the TOSCA consortium)

References

Cooper, M.D. & Phillips, R.A. 1995. Killing two birds with one stone: Achieving quality via total safety management. Leadership and Organisational Development Journal, 16(8), 3-9.

European Agency for Safety and Health at Work, 2005 Report 2004: ISBN 92-9191-141-0 Promoting health and safety in European Small and Medium-sized Enterprises (SMEs)://osha.europa.eu/en/publications/reports/ag05001.

Herrero, S.G., Saldaña, M.A.M., del Campo, M.A.M., & Ritzel, D.O. 2002. From the traditional concept of safety management to safety integrated with quality. Journal of Safety Research, 33, 1-20.

ISO 31000, 2009 Risk Management – Principles and guidelines.

Looney, C.G. 2001. Exploring fusion architecture for a common operational picture. Information Fusion, 2 (4), 251-260.

McNeese, M.D., Pfaff, M.S., Connors, E.S., Obieta, J.F., Terrell, I.S., Friedenbery, M.A. 2006. Multiple vantage points of the common operational picture: Supporting international teamwork. In Proceedings of the Human Factors and Ergonomics Society 50th Annual Meeting, 467-471.

Micheli, G. and Cagno, E. 2009. Perception of safety issues and investments in safety management in small and medium-sized enterprises: a survey in the Lecco area. Prevention Today, 4(10, 7-18)

Seveso II. 1996. Council Directive 96/82/EC on the control of major-accident hazards.

Sørensen, O.H., Hasle, P. and Bach E. 2007. Working in small enterprises – is there a special risk. Safety Science 45, 1044–1059.