

Integration Between Occupational and Process Safety: Existing Approaches and Challenges for an Enhanced Framework

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Occupational safety is traditionally managed distinctly from process safety. The former puts the emphasis on high frequency and low consequence incidents, and refers to hazards that could provoke human consequences. In contrast, the latter focuses on releases of chemicals, energy, or hazardous materials, leading to low likelihood but high consequence accidents with severe negative effects to people, environment, assets, and/or business. However, neither personal safety nor process safety should be compromised, and their common priority should remain the elimination and mitigation of adverse consequences for workers. The aim of this paper is to provide an overview of existing approaches for harmonising the assessments of personal and process safety risks, pointing out the main challenges to be addressed for developing a future enhanced framework. To achieve this aim, a systematic literature review in databases of scientific publications was carried out. The review returned 14 studies, most of which propose a new method or tool (e.g., risk index). The critical analysis of these results indicated the strengths and weaknesses of each approach that represent helpful starting points for an enhanced framework. Such a framework should systematically identify hazards, hazardous events, and exposure conditions that cause harm to employees, and should establish a ranking of the risks according to their criticality for prioritising risk management efforts.

1. Introduction

A current confusion about the differences between occupational safety and process safety is noticed (Aldrich et al., 2015). Leclercq et al. (2018) highlight the existence of a fuzzy perimeter between process and occupational accidents. Moreover, Occupational Safety and Health (OSH) and Major Accident Hazard (MAH) risks have been traditionally analysed separately (Gnoni and Bragatto, 2013).

On one hand, OSH (also referred to as personal or personnel safety) has the objective to prevent any injury or fatality of individual worker (Vallerotonda et al., 2018). Personal safety hazards affect individuals but have little to do with the plant processing activity (Hopkins, 2009). They result in incidents that are not in a large scale at once (Mataqi and Srikanth Adivi, 2013), and typically give rise to falls, trips, electrocutions, and vehicle accidents (Hopkins, 2009). ISO (2018b) defines an OSH risk as the “combination of the likelihood of occurrence of a work-related hazardous event(s) or exposure(s) and the severity of injury and ill health that can be caused by the event(s) or exposure(s)”. Aldrich et al. (2015) well summarise the characteristics of occupational safety hazards: limited in extent and harm, generally affecting a small number of people, cause and consequences are generally closely related in time and location, events are relatively common and within the general experience of the workforce, and typically a simple chain of events leading to harmful consequences.

On the other hand, process safety (sometimes, asset or technical integrity) can be described as a disciplined framework for managing the integrity of operating systems and processes handling hazardous substances (Khan et al., 2016). It focuses on major incident hazards associated with release of energy, chemicals, or other hazardous substances (Mataqi and Srikanth Adivi, 2013). A major accident is defined by European

Union (2012) as “an occurrence such as a major emission, fire, or explosion resulting from uncontrolled developments in the course of the operation of any establishment [...], and leading to serious danger to human health or the environment, immediate or delayed, inside or outside the establishment, and involving one or more dangerous substances”. Therefore, major accidents have consequences not restricted to the immediate occupational area (Jørgensen, 2016), and can result in multiple injuries and fatalities, in addition to economic, property, and environmental damage (Baker et al., 2007). Process safety hazards arise from the processing activity in which a plant may be engaged (Hopkins, 2009). According to Aldrich et al. (2015), process safety hazards are potential for causing widespread harm and large numbers of casualties, causes and consequences may be widely separated, there is often a considerable time difference between the cause and the consequence of an incident, events are infrequent and unlikely to be experienced during a typical working life, and chains of events are often complex.

Although personal safety and process safety are often distinguished, there is an acknowledged advantage in their integration (Leclercq et al., 2018). Indeed, process safety should be integrated with occupational safety: good process safety, integrated with effective personal safety management, ensures good safety performance of an organisation (Mataqi and Srikanth Adivi, 2013). Consequently, the aim of this paper is to provide an overview of the existing approaches that integrate personal and process safety risks, pointing out the main challenges to be addressed for developing a future enhanced framework.

2. Methods

To achieve this objective, a systematic literature review was conducted. A systematic review is an explicit and reproducible research methodology to answer a specific research question on a specific topic, and allows pinpointing all relevant studies that meet the inclusion criteria, critically appraising them, and summarising the state of the art on the topic of interest (Stefana et al., 2015). The research question formulated for the study is: “Which approaches are available in the literature to integrate occupational safety and health and process safety?”. The definition of this research question and the identification of keywords and their related synonyms permitted designing a search string by means of Boolean operators AND and OR. The search string was implemented in title, abstract, and keywords fields in the following electronic (bibliographic) databases of scientific publications: Scopus and Web of Science. To consider all potentially relevant papers, a starting date was not established, and documents were retrieved until 16 November 2019. Only English documents were examined. The search was limited to source titles that are pertinent to the research topic and scope: for instance, Safety Science and Journal of Occupational and Environmental Hygiene were included, whereas BMC Public Health and BMJ Open were excluded. Endnote® X9 was employed to manage references, remove duplicates, and create a unique reference database. To perform a sequential publication selection, the initial database in Endnote® X9 was converted into a Microsoft® Excel spreadsheet. The specification of several inclusion criteria allowed filtering relevant articles. If papers did not meet such inclusion criteria, they were not considered in results. The records were rated based on the relevance of their titles, abstracts, keywords, and full-texts. Studies were excluded if focused solely on a specific risk kind, on analysis of types, causes, and characteristics of accidents, on safety culture and climate, on features of work-related injuries, on emergency issues, on estimations of individual risk. Additionally, review papers and researches applying an existing framework were ignored. Studies proposing an original approach whose intent is not to combine personal and process safety, but implicitly consider both the domains and their risks were included in the results. The search string and the different selection process steps are reported in Figure 1.

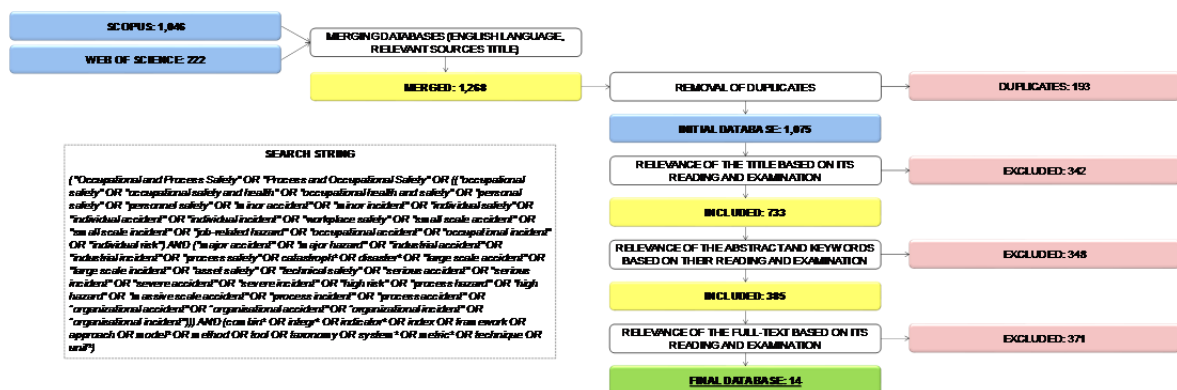


Figure 1: Search string and steps of the systematic review

3. Results

The results of the screening process are shown in Figure 1. In the analysed literature, 14 articles propose approaches able to combine occupational safety and process safety. For each approach, Table 1 reports a brief description, while Table 2 a possible type classification and the focus. The consideration of the focus allows differentiating if the approach is developed for properly addressing both occupational and process safety or, alternatively, if the article aim is not to provide an integration between the safety domains and/or the overall focus is mainly on a prospective. The approaches are largely heterogeneous and adopt different perspectives (e.g., Jørgensen (2016) shifts his attention from risks to safety barriers). The level of detail changes considerably among the approaches: e.g., Gnoni and Bragatto (2013) quantify a risk level, Leclercq et al. (2018) offer a harmonised hazard characterisation for every accident, and Lee et al. (2011) discuss about a development plan for an integrated Health, Safety and Environmental (HSE) management system. Some studies are not generic and are right fit for specific industries (e.g., Yu et al. (2017) describe an approach for the drilling and servicing operations). Not all the studies refer to the terms occupational and process safety, dealing with the concepts of minor and major accidents (e.g., Amir-Heidari et al. (2016)). The results highlight how the line separating occupational and process safety is not clear and well mapped out.

Table 1: Brief description of approaches

Reference	Brief description
Ale et al. (2014)	Dynamic risk management support tool based on Bayesian Belief Nets. Risk contributing factors (combined in a top node): a runaway reaction in a thermal cracker, overflow in a storage tank, pipe rupture in a jetty-arm, and occupational risks.
Amir-Heidari et al. (2016)	Comprehensive risk assessment for identifying significant risks, by means of past research and accident statistics, checklist, expert opinion, estimation of the contribution of each factor, semi-quantitative structured methodology, risk matrix, and controls.
Casson Moreno et al. (2016)	Checklist for performing a first step in bioprocesses hazard identification, based on engineering process, operating procedures, and plant layout.
Collins (2010)	Systematic framework to integrate Job Safety Analysis into Process Hazard Analysis techniques, considering potential modes of operation, process-related initiating events or upsets, and contact possibilities.
Gnoni and Bragatto (2013)	Risk index for representing the criticality level characterising each job profile during a shift at Seveso plants, which depends on the percentage of the working time spent by each worker in any unit, hazards, and accidental scenarios.
Jørgensen (2016)	INFO cards for covering all hazard sources and connected information: generic (needed in all kinds of risk situations), cross-cutting, and specific (for specific risks) safety barriers.
Leclercq et al. (2018)	Damage production model from the loss of control of energy characterising the hazard for any accident, based on different targets exposed to hazard, personal (human movements) energy, and energies specific to process operation / external to human.
Lee et al. (2011)	Integrated HSE management system, with foundational and framework standards, key performance indicators for safety, and for operation integrity and process safety.
Leino (2002)	Quality, Occupational Safety, and Health Management System, composed by risk assessment and safety instructions, responsibilities of personnel involved in the management of major hazards, procedures for systematic assessing of major hazards.
Marhvilas et al. (2019)	E-HAZOP framework that integrates Hazard and Operability study with Decision-Matrix Risk Assessment technique and Analytical Hierarchy Process to identify critical points and potential hazards and prioritise risks in industry.
Papadakis and Chalkidou (2008)	Individual occupational risk index based on the quantitative risk assessment principles for MAH control as a probability function of the active hazard frequency, probability of employee presence at a workplace, consequence zones, and employee vulnerability.
Pitblado and Tahilramani (2010)	Web-based solution for integrated risk management (facility and process risks), containing procedures, performance, bow tie reports, hazard and effects risk registers.
Wang et al. (2012)	Risk-Based Maintenance strategy, composed by system scope identification (subsystems and facilities), risk assessment (failure probability estimation and consequence analysis) and evaluation (definition of a risk index based on weight factors), and maintenance planning.
Yu et al. (2017)	Integrated Safety Management System by means of causal factors of incidents (e.g., personal protective equipment, equipment selection, inspection and maintenance, hazard assessment, work practice, training, and emergency response planning).

Table 2: Type of approaches and focus of the relevant publications selected

Reference	Type of approaches	Focus on personal and process safety	Other aim and/or focus
Ale et al. (2014)	Adjustment of an existing method		×
Amir-Heidari et al. (2016)	Combination of existing methods		×
Casson Moreno et al. (2016)	New method or tool	×	
Collins (2010)	Combination of existing methods		×
Gnoni and Bragatto (2013)	New method or tool	×	
Jørgensen (2016)	New method or tool	×	
Leclercq et al. (2018)	New method or tool	×	
Lee et al. (2011)	Integrated management system / risk management	×	
Leino (2002)	Integrated management system / risk management	×	
Marhavalas et al. (2019)	Combination of existing methods		×
Papadakis and Chalkidou (2008)	New method or tool		×
Pitblado and Tahilramani (2010)	Integrated management system / risk management	×	
Wang et al. (2012)	New method or tool		×
Yu et al. (2017)	Integrated management system / risk management	×	

4. Discussion

The critical analysis of the retrieved approaches allows identifying both strengths on which to leverage and weaknesses to be addressed for the development of a future enhanced approach. This approach should be represented by a structured framework with the purpose to integrate occupational and process safety, considering hazards, hazardous conditions, and risks arising from traditional and non-traditional operation modes (e.g., production activities, inspection and maintenance tasks, planned shutdowns, non-routine maintenance tasks, temporary activities, emergency operations). The framework is intended to be used by a wide range of organisations and industries, and should permit including new information and evidence when available to dynamically assess both occupational safety and process safety. It comprises both qualitative and quantitative risk assessments.

A preliminary enhanced framework is depicted in Figure 2. This framework is based on the definitions of risk, hazard, exposure, consequence (ISO, 2009), risk elements, hazardous event and situation (ISO, 2010), and the widespread process of risk management by ISO (2018a). The basic element of the risk management process is a specific department of the site under investigation.

The focus is on the three elements constituting any risk assessment: people, process, and plant. A deep analysis of each of these elements helps to screen hazards, hazardous events, exposures, and their combinations in order to recognise risks and consequences. Although process safety also regards consequences to population and environment, an enhanced framework should concentrate on employees and facility personnel as asset category, and on all possible consequence categories (e.g., loss of life and health, personal injury, reduction in life expectancy). With particular regard to hazardous events, their identification should investigate different types of undesired and unexpected set of circumstances both inside and outside the department (e.g., loss of containment, loss of control, human errors, component failures, anomalies, and malfunctions). Potential hazardous event classes can be: (1) external circumstances that could produce adverse impacts on the department under study, (2) undesired events at the boundary of the department, (3) technical circumstances related to the process and plant (by means of analyses of equipment, system components, substances), (4) unwanted events related to human errors and/or failures, and (5) negative interferences among process, plant, and/or people. To perform such complete risk identification, the enhanced framework could be based on the influence diagram tool. Indeed, the influence diagram could clearly outline the several nodes related to causes, intermediate events, and consequences, showing the various interconnections and causal relationships, and capturing different possible concatenations and dependencies of events involved in the contemporary consideration of occupational and process safety.

In the risk analysis and evaluation steps, a valuable technique could be a tailored Failure Modes and Effects and Criticality Analysis (FMECA). This allows providing a risk ranking and thus facilitating the assignment of priorities in terms of preventive and/or protective measures in the risk treatment phase. As an alternative to a global risk ranking, two separate rankings (one for the severity and one for the likelihood) appear more informative for visualising the most severe and/or the most frequent consequences and for keeping distinct

these two scales (that could be completely different in terms of occupational safety and process safety). Particular attention should be dedicated to the probability estimation: the likelihood of occurrence of a harm depends on the probability of each causal factor and event. Therefore, exposure frequency and duration, and conditional probabilities should be taken into account. Note that the exposure duration is based on the expected duration of the activities performed by the worker and the consequence persistence.

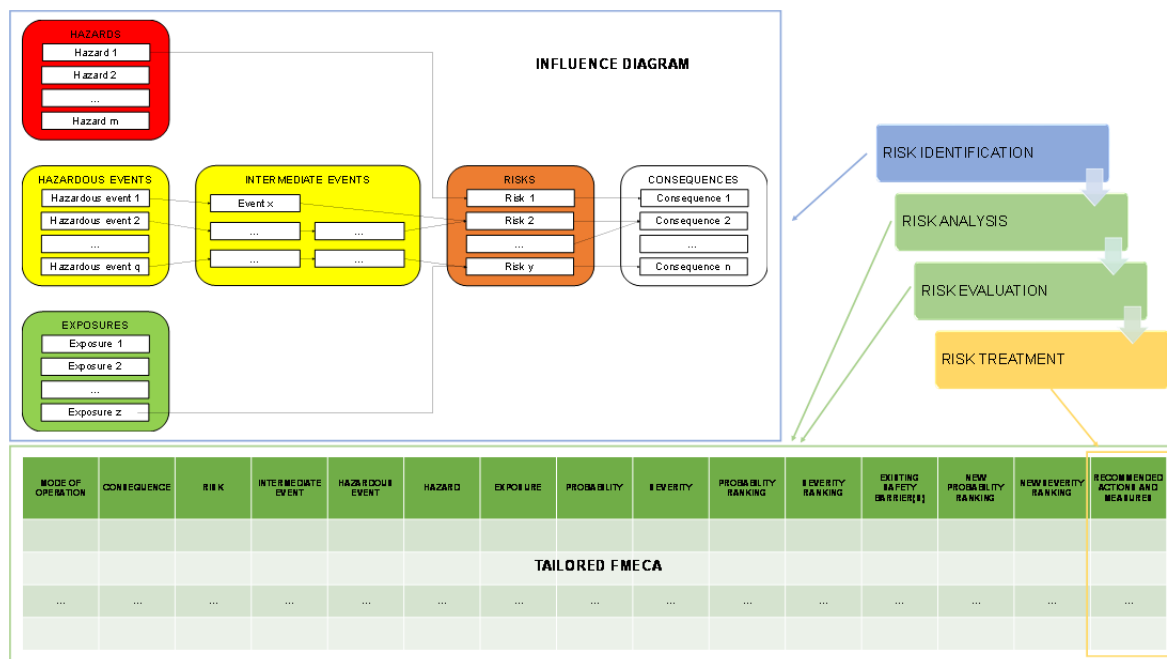


Figure 2: Enhanced framework for integrating occupational and process safety

5. Conclusions

A systematic literature review about the existing approaches integrating occupational safety and health and process safety is proposed. In the analysed databases of scientific publications, 14 studies are selected, each of them provides a completely different approach. The proposal of a new method or tool, a combination of existing techniques, the description of an integrated management system or risk management, and adjustments of an existing method are the approach types pointed out by the analysis. In a minority of approaches (6 out of 14), the associated article aim is not to suggest an integration between the two safety domains and/or the overall publication focus is mainly on a prospective. The main features, strengths, and weaknesses of the entire set of the results allow drawing attention to several challenges to be addressed for developing a future enhanced framework. Such a framework is intended to qualitatively and quantitatively assess and rank risks for employees related to both personal and process safety during traditional and non-traditional operation modes in any activity sector. Through a deep investigation of people, processes, and plants present in a company department, the enhanced approach permits screening hazards, hazardous events, exposures, and their combinations in order to recognise risks and consequences. In the risk assessment process, the influence diagram tool and a tailored FMECA represent useful techniques for properly identifying and analysing such risks and consequences.

Future work should explore other literature sources for capturing further relevant studies about approaches that merge the assessments of personal and process safety risks. Finally, more research is needed to refine the enhanced framework and to apply it in real companies, also belonging to various industries.

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