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Making the links among environmental protection, process safety, and industry 4.0

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ABSTRACT

Industry 4.0 is an emerging concept in production systems and is described as a concept that encompasses technologies such as the Internet of Things, big data, cyber-physical systems, and smart objects. Industry 4.0 will present new challenges and opportunities for process safety and environmental protection (PSEP) researchers and managers. There is a gap in the literature in identifying the main concepts related to industry 4.0 and PSEP, as well as the potential integration between these subjects. In line with this gap, this paper focuses on identifying and systemizing information regarding the integration of PSEP and industry 4.0 concepts and technologies. While identifying relationships, we also address non-existent intersections between keyword co-occurrence networks in PSEP and industry 4.0. The main outputs of this research are: (a) identification and discussion of potential connections between PSEP with industry 4.0 concepts; and (b) an in-depth discussion of potential benefits in integrating industry 4.0 concepts and technologies into PSEP fields. It can be concluded that there is much more collaborative research between environmental protection and industry 4.0 than between process safety and industry 4.0. Also, environmental protection research is characterized by a wide variety of research themes and multidisciplinary endeavours, in contrast with industry 4.0.

1. Introduction

The themes of process safety and environmental protection (PSEP) have implications for various areas of production systems (Gysin, 1976). Process safety is the common global language used to communicate the strategies of hazard identification and analysis, risk assessment and evaluation, safety measures, and safe critical decision making (Khan et al., 2015). Another driver to address hazardous installations and major accidents has been the regulations introduced by governments for environmental protection (Hutton, 2017).

Companies' decisions directed towards sustainable production systems will require a consistent and continuous procedure, especially in the PSEP fields. Industry 4.0 has been considered one of the major trends in production systems, with clear implications for sustainability in organizations (Jabbour et al., 2018a). Industry 4.0 is an emerging trend in production systems and is described as a concept that encompasses technologies such as the Internet of Things (IoT) (Lee and Lee, 2015), big data (Lee et al., 2014; Hauhang et al., 2015), cyber-physical systems (CPS) (Lee et al., 2015), smart manufacturing (Kang et al., 2012), and smart objects (Fortino et al., 2013; Gobbo Junior et al. 2017).

Thus, this paper argues that integration among concepts and technologies of industry 4.0 and PSEP would unlock the potential for sustainable production systems. An additional benefit to do research in these subjects would come from the already existing interaction between emerging topics in industry 4.0 and PSEP functions. A resulting cross-fertilization of ideas may facilitate the identification of novel approaches to risk reduction and environmental protection (Hutton, 2017). Therefore, the research in the PSEP arena will need to be integrated in the emerging cutting-edge discussion of industry 4.0.

Despite the fact that process safety and environmental protection researchers have been pioneers in the study of the impact of automation on safety, industry 4.0 will present new challenges and opportunities for process safety and environmental protection researchers. Angell and Klassen (1999) proposed an integration of environmental issues into research in productive systems. Early research integrating industry 4.0 and sustainable production concepts includes the works of Jabbour et al. (2018a, 2018b) and Jabbour et al. (2017).

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Although there are very few studies on the frontier of the relationship between these subjects and systematic reviews on the isolated themes, no studies have attempted to integrate, through a systematic analysis, concepts in PSEP and industry 4.0. Another gap in the literature is the lack of research with a systematic approach in effectively identifying the main concepts related to industry 4.0 and PSEP, as well as the existing intersections among these subjects.

In line with this gap, this paper focuses on identifying and systemizing information regarding the integration of PSEP and industry 4.0 concepts. While pointing out early intersection points between these subjects, we will also address possible directions for future integrative research into these fields, following Jabbour (2013). Consequently the primary question guiding this research is: what are the possible gaps and intersections points between PSEP and industry 4.0 concepts?

Taking this into account, the outline of this paper is to identify emerging research fronts in PSEP and industry 4.0. A secondary aim is to identify possible gaps and intersections as well as new directions in integrating the research themes in PSEP and industry 4.0. This identification of possible gaps and intersections will be elaborated by means of one very specific but influential type of evidence: topological measures in co-occurrences of keywords.

The paper's sections are organised as follows: the main theoretical background on PSEP and industry 4.0 is described in Section 2; approaches for visualization of bibliometric networks and extensions are described in Section 3; the research method is presented in Section 3; the results are discussed in Section 4; and in Section 5 some conclusions are presented about this work.

2. Theoretical background

2.1. Process safety: concepts and principles

Safety is a relative concept that must be understood in the presence of some hazard or risk. The concept of risk is related to both hazards created by humans and those created by nature; consequently, safety constitutes an ability to reduce or eliminate the likelihood of hazardous events occurring (Antonsen, 2009). The main focus of risk analysis is to support decision making by assessing and quantifying the risks associated with the operation and design of a technical system (Aven, 2016). Risk assessment and risk management provide important contributions in supporting the decision-making process. Therefore, risk assessment and management are a set of principles and methods developed to conceptualize, assess, and manage risk and recognized threats (also called hazards) (Aven, 2016).

A growing interest in the process safety field is the concept of safety culture. The existing research in the field supposes a connection between safety culture and safety. The conceptualization of safety culture is by no means conclusive. Aligned with this view, organizational culture may help to create safety by being a medium to disseminate safety-critical knowledge (Antonsen, 2009). Therefore, the inherent safe concept could be obtained in a process or product design that avoids hazards instead of controlling them. This stage would be achieved through four main methods: minimizing (reducing the amount of hazardous material), substituting (replacing one material with another of less hazard), moderating (using less hazardous process conditions), and simplifying (design process to be less complicated and therefore less prone do failure) (Heikkilä, 1999).

Process safety is identified as an integral part of process development and manufacturing rather than an "add-on" to the process (Gibson, 1999). Process safety differs from occupational safety as it solely focuses on preventing and mitigating major process accidents such as fires, explosions, and toxic releases. Process safety assessment/management includes several essential steps. Though every step is equally important, hazard identification, risk assessment, and management can be considered as the key steps of process safety management (Bahr, 1997). The primary objective of process safety is to prevent the unwanted release of highly hazardous chemicals/biological agents into locations, which could expose humans to serious hazards. Process safety management is an approach to evaluate processes that have the potential to cause catastrophic incidents such as fires, explosions, or toxic releases (OSHA, 2000).

Extensive industrial automation and computer control create many new issues in process safety, which have been extensively discussed in the literature (Hendershot, 2006). This is mainly due to human factors. Examples of different applications of automation to avoid human errors can be found in Hendershot (2006), Cameron et al. (2017), and Taylor (2017), not only to avoid safety hazards but also to automate Hazop's analysis or prevent maintenance.

2.2. Environmental protection: concepts and principles

Environmental protection is the practice of protecting the natural environment of the individual, organizational, and governmental levels, for the benefit of both the environment and humans (Kraft, 2017). Traditionally, environmental protection has been considered a public interest and external to the private sphere (Mazurkiewicz, 2004). The idea behind this concept is that the biophysical environment has been degraded and governments have begun to place restraints on activities that cause environmental degradation (White, 2017). Since its popularization, the concept of environmental protection has become closely associated with the concept of sustainable development. However, gradually the focus is shifting from sustainable development to the multiplicity of sustainability and analyses of the paths in which they are shaped (Haughton and Counsell, 2004).

Discussion concerning environmental protection often focuses on the role of government, legislation, and law enforcement. However, in its broadest sense, environmental protection may be seen to be the responsibility of all stakeholders, including industry, environmental, and community groups (Kraft, 2017). Gradually, environmental decision-making processes are evolving to reflect this broad base of stakeholders and are becoming more collaborative in many countries. The stringency of environmental regulations affects eco-innovation as firms respond to stricter environmental regulations with higher levels of eco-innovations (Kesidou and Demirel, 2012).

Peachey (2008) says that environmental protection management involves a complete assessment of the full impacts of power source choices and a conscious decision about what environmental impacts and mitigation measures are going to be made. The terms environmental quality, air quality, soil quality, and water quality invariably connote the status or condition of each condition that relates to requirements of wildlife or to human requirements and/or preferences (Johnson et al., 1997).

These are related to the role of government in environment protection. Urban air pollution poses a significant threat to human health, property, and the environment throughout both the developed and developing parts of the world. The issue of urban air quality is receiving increasing attention as a growing share of the world's population is now living in urban centres and demanding a cleaner urban environment (Gurjar et al., 2008). One impact of air emissions is that they also contain significantly high levels of sulphur components—heavy metals and fly ash being generally of greater regional concern because of direct health and environmental impacts (Peachey, 2008). All of them need to be monitored to ensure that they are in control under the specifications of govern-