TU Delft

Delft University of Technology

Emerging Risk Management Versus Traditional Risk: Differences and Challenges in the Context of Occupational Health and Safety

Brocal, Francisco; González-Gaya, G.; Sebastián, Miguel A.; Reniers, Genserik; Paltrinieri, Nicola

DOI
10.3850/978-981-11-2724-3_0777-cd

Publication date
2019

Document Version
Final published version

Published in
Proceedings of the 29th European Safety and Reliability Conference

Citation (APA)
Brocal, F., González-Gaya, G., Sebastián, M. A., Reniers, G., & Paltrinieri, N. (2019). Emerging Risk Management Versus Traditional Risk: Differences and Challenges in the Context of Occupational Health and Safety. In M. Beer, & E. Zio (Eds.), *Proceedings of the 29th European Safety and Reliability Conference* (pp. 3895-3902). Article 777 Research Publishing. https://doi.org/10.3850/978-981-11-2724-3_0777-cd

Important note
To cite this publication, please use the final published version (if applicable).
Please check the document version above.

Copyright
Other than for strictly personal use, it is not permitted to download, forward or distribute the text or part of it, without the consent of the author(s) and/or copyright holder(s), unless the work is under an open content license such as Creative Commons.

Takedown policy
Please contact us and provide details if you believe this document breaches copyrights.
We will remove access to the work immediately and investigate your claim.

This work is downloaded from Delft University of Technology.
For technical reasons the number of authors shown on this cover page is limited to a maximum of 10.

Emerging risk management versus traditional risk: differences and challenges in the context of occupational health and safety

F. Brocal

Department of Physics, Systems Engineering and Signal Theory, University of Alicante, Alicante, Spain. E-mail: francisco.brocal@ua.es

C. González-Gaya & M.A. Sebastián

Department of Manufacturing Engineering, National Distance Education University (UNED), Madrid, Spain. E-mail: cggaya@ind.uned.es; msebastian@ind.uned.es

G. Reniers

Faculty of Technology, Policy and Management, Safety and Security Science Group (S3G), TU Delft, Delft, The Netherlands.
Faculty of Applied Economics, Antwerp Research Group on Safety and Security (ARGoSS), University Antwerp, Antwerp, Belgium E-mail: G.L.L.M.E.Reniers@tudelft.nl

N. Paltrinieri

Department of Mechanical and Industrial engineering, Norwegian University of Science and Technology - NTNU, Trondheim, Norway. E-mail: nicola.paltrinieri@ntnu.no

As a result of the important and rapid technological advances in industrial processes, in recent years the scientific interest in the field of occupational health and safety (OH&S) is increasing. This scenario of continuous change generates both new opportunities and new challenges in the workplace. This circumstance allows eliminating or minimizing familiar or traditional risks, but it can also generate other risks called emerging risks.
Recently the ISO 45001:2018 standard has been published, which specifies the requirements for an OH&S management system. ISO 45001 standard includes some aspects related to the new hazards, for example during the hazard identification process and the change management process. However, the standard does not explicitly distinguish between the concepts of emerging risk and traditional risk.
In this way, the general objective of this paper is to identify the main differences between emerging risk management and traditional risk management in the context of the management system defined by ISO 45001. This standard has been analyzed together with other management systems and relevant scientific literature to achieve the stated objective. All this has been aligned with the results previously published by the authors of this work, within the framework of a research project on emerging risks.
As the main conclusion of this work, the monitoring and assessment process of the emerging risk uncertainty should be integrated into the iterative process Plan-Do-Check-Act (PDCA) used by organizations to achieve continual improvement.

Keywords: emerging risk, health, ISO 45001, management, occupational, safety, uncertainty

1. Introduction

As a result of the important and rapid technological advances in industrial processes, generates both new opportunities and new challenges in the workplace. This circumstance allows eliminating or minimizing familiar or traditional risks, but it can also generate other risks called emerging risks.
Recently the ISO 45001:2018 standard (ISO 2018b) has been published, which specifies the requirements for an occupational health and safety (OH&S) management system. However, the standard does not explicitly distinguish between the concepts of emerging risk and traditional risk. In this way, the general objective of this paper is to identify the main differences between emerging risk management and traditional risk management in the context of the management system defined by ISO 45001. This standard has been analyzed together with other management systems and relevant scientific literature to achieve the stated objective.

Proceedings of the 29th European Safety and Reliability Conference.
Edited by Michael Beer and Enrico Zio
Copyright © 2019 European Safety and Reliability Association.
Published by Research Publishing, Singapore.
ISBN: 978-981-11-2724-3; doi:10.3850/978-981-11-2724-3_0777-cd

2. Analysis of the emerging risk concept

From a standardized point of view, the ISO 31000:2018 standard indicates that a risk is usually expressed in terms of risk sources, potential events, their consequences and their likelihood (ISO 2018a). In OH&S field, the ISO 45001 standard defines an OH&S risk as the combination of the likelihood of occurrence of a work-related hazardous event or exposure (s), and the severity of injury and ill health that can be caused by the event or exposure(s). These definitions are among the models on risk collected in Table 1, highlighting the adaptation of the model 2 to the definition of OH&S risk. However, from a general perspective, Aven (2012a) notes that the definition or model 3 is the most appropriate.

Table 1. Main definitions on risk used in the professional and scientific fields.

Definition		Description
(1)	R=E	Risk=Expected value (loss)
(2)	R=P&CO	Risk=Probability and scenarios/ Consequences/severity of consequences
(3)	R=CO&U	Risk=Consequences/damage/ severity of these + Uncertainty
(4)	R=U	Risk=Uncertainty
(5)	R=OU	Risk=Objective Uncertainty
(6)	R=CO	Risk=Event or consequence
(7)	R=ISO	Risk=Event or consequence

Source: adapted from Aven (2012a)

2.1 Characteristics of emerging risk

From a systemic perspective, the International Risk Governance Council (IRGC, 2010a, 2010b) suggests that a risk includes: (i) emerging conditions: the risk is emerging when it is new in a broad sense, as in the case of new technologies, new materials; e.g. carbon capture and storage (Wilday et al., 2011); and (ii) the risk is emerging when being familiar or traditional, it is presented under new or unfamiliar conditions; e.g. larger volumes of LNG handled (Paltrinieri et al. 2015). From an occupational perspective, the European Agency for Safety and Health at Work (EU-OSHA) defines a new and emerging risk (henceforth emerging risks) as any occupational risk that is both new and increasing (Flaspöler et al., 2005; Brun et al., 2007a, 2007b, 2009). Brocal et al (2017) have proposed a theoretical framework based in such definition. With this framework the emerging risk concept has been modeled. For it, a risk (R) is considered a structure consisting of five components: the source of risk (SR), causes (C), events (E), consequences (CO) and the likelihood (L); this set may be expressed as (8):

$$R = (SR, C, E, CO, L) \quad (8)$$

The emerging risk definition from EU-OSHA has been codified by Brocal et al. (2017) through the so-called conditions (Ci) that define an emerging risk (C1, C2, C3, C4, C5, C6). Thus, such authors consider that a risk is new (NR, new risk) when its components are associated with the conditions according to any of the following combinations (Table 2): C1 is linked to new SR and new C. The novel aspect can be both technological and organizational; C2 and C3 are linked to new SR, C, E, and CO. The novel aspect of C2 is related to changes in social perceptions; and the novel aspect of condition C3 to new scientific knowledge about risk.

Table 2. Combinations R (model 8)-Ci that can form a NR

New risk (NR)		New conditions		
		C1	C2	C3
Risk Components	SR	New technological or organizational variable	New social perception	New scientific knowledge
	C			
	E	---		
	CO	---		
	L	---	---	---

Source: adapted from Brocal et al. (2017)

And a risk is increasing (IR, Increasing risk) when its components are associated with the conditions according to any of the following combinations (Table 3): C4 is linked to the increase of SR; C5 to the increase of L (exposure level and/or the number of people exposed); and C6 to the increase of CO (seriousness of health effects and/or the number of people affected).

Table 3. Combinations R (model 8)-Ci that can form a IR

Increasing risk (IR)		Increasing conditions		
		C4	C5	C6
Risk Components	SR	Increase in the number of sources of risk	---	---
	C	---	---	---
	E	---	---	---
	CO	---	---	Increase health consequences
	L	---	Increase in the likelihood of exposure	---

Source: adapted from Brocal et al. (2017)

Brocal et al. (2017) consider the third type of emerging risk, which arises when a risk is both new and increasing (NIR), that is, when the risk components are associated with both new and increasing conditions (Tables 2 and 3).

2.2 Uncertainty

From a standardized and general point of view, the ISO 31000:2018 standard defines risk as effect of uncertainty on objectives. This general definition is also included in the ISO 45001 standard, and it can be expressed according to model (5). SRA (2018) define uncertainty from a qualitative perspective as imperfect or incomplete information/knowledge about a hypothesis, a quantity, or the occurrence of an event.

In the context of environmental health, Javen et al. (2019) have studied the concept of "uncertain risk" and they consider that the uncertainty about the presence or existence of risk may be the result of six different epistemic uncertainties linked to dangerous agents. These six situations of uncertainty are related to the following exposure factors to the agent: (i) intrinsic hazardous properties; (ii) adverse effects; (iii) limit levels of exposure; (iv) relationship exists between an agent and certain effects; (v) the source of adverse effects; or (vi) actual exposure levels. Aven (2012b) has studied in depth how ''exposure'' and ''risk exposure'' are connected to the risk. In this context, Aven (2012b) proposed reformulate this risk definition to risk refers to the uncertainty about and severity of the consequences of the system being exposed to a risk source or/and hazard/threat.

In engineering risk management context, Meyer and Reniers (2016) considered three types of uncertainties: Type I, uncertainties where a lot of historical data is available; Type II, uncertainties where little or very little historical data is available; and Type III, uncertainties where no historical data is available.

In the emerging risk context, the uncertainty is the main characteristic of risk (IRGC, 2015a). Considering this factor, the emerging risk concept can be expressed according to model (4). However, the IRGC (2015a) notes that this uncertainty is related to the probabilities and / or consequences of the emerging risk. In this way, model (2) would also be applicable. However, Aven (2010) considers that the probability component of the risk concept should be replaced by uncertainty. From this perspective, Aven (2010) has studied the definitions (9-13) included in the Table 4, and he notes that these definitions consider uncertainty as a main component of a risk description, being the probability a just a tool used to express the uncertainties. Such definitions can be related to the risk components according to (8) and to the conditions that define an emerging risk (Ci). In this way, the definitions (9-10) are related to the conditions that determine an NR; the definition (11) with the condition that defines an IR; and the definitions (12-13) are related to the conditions that can define an NIR.

Table 4. Risk definitions that consider uncertainty as a main component of a risk description according Aven (2010) and their relation with the risk components (RC) and conditions (Ci) according to theoretical framework proposed by Brocal et al. (2017).

	Definition	RC	Ci
(9)	Risk refers to uncertainty of outcome, of actions and events	E	C2 C3
(10)	Risk is a situation or event where something of human value (including humans themselves) is at stake and where the outcome is uncertain	E	C2 C3
(11)	Risk is an uncertain consequence of an event or an activity with respect to something that humans value	CO	C6
(12)	Risk is equal to the two-dimensional combination of events/ consequences and associated uncertainties	E/ CO	C2 C3 C6
(13)	Risk is uncertainty about and severity of the consequences (or outcomes) of an activity with respect to something that humans value	CO	C2 C3 C6

Brocal et al. (2017) have associated their three emerging risk typologies (NR, NIR and IR) with risk evolutionary phases likely to be integrated into the technology lifecycle (TLC) in technology management. So, as shown in Figure 1, at the initial time of the embryonic phase of the new technology, the NR arises and finally, the IR is transformed into a TR, once the technology is between the maturity and aging phase.

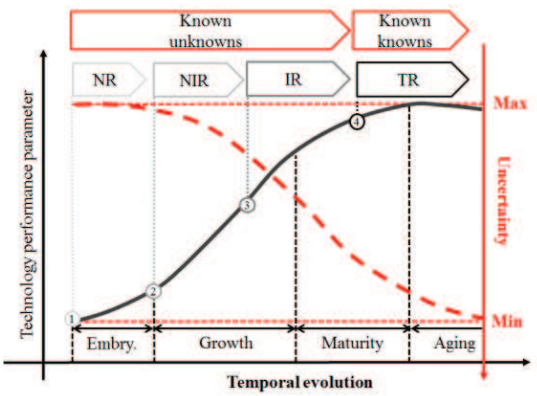

Figure 1. New Risk (NR); New and Increasing Risk (NIR); Increasing Risk (IR); Traditional Risk (TR)

In this process of maturation and extinction of emerging risk, the variable uncertainty (in red) has been added to the present paper in relation to

Brocal el al. (2017), considering for it the dynamic framework of risk management developed by Villa et al. (2016) as well as an open qualitative approach based on the point of view of Aven (2010). In this regard, it can be considered that the emerging risk and uncertainty evolve inversely, that is, when the risk is in an embryonic phase the uncertainty is maximum (Type III), and when the emerging risk is extinguished, the uncertainty is minimal (Type I). This minimum value is a relative value with respect to the emerging risk since with respect to traditional risk said value should not necessarily be low or negligible.

If the event (E) is considered as a reference risk component in the process of evolution and extinction of emerging risk, can be observed two types of events among four types are defined by the QRA (Quantitative Risk Assessment) analysts: Unknown unknowns; Unknown knowns; Known knowns; and Known unknowns. These four types are based on the one hand on the fact that people have and one mind towards the possibility of the event, and on the other hand on the available knowledge or information on events from the past (Meyer and Reniers, 2016). Thus, under the premise that the identification of a NR requires an open mind in a context of high uncertainty, its evolutionary process (NR-NIR-IR) can be integrated into a "known unknowns context" (events that we do not know from the past and have open minds towards). Consequently, after the extinction of the emerging risk, that is, when it has been transformed into a TR, it is integrated into a "known-knowns context" (events that we know from the past and have open minds towards). From this perspective, uncertainty should tend to be negligible over time.

This relation among the emerging risk concept and the four events types has been analyzed by Flage and Aven (2015), in particular its relation to black swan type of events, and he shows that these can be considered meaningful and complementary concepts by relating emerging risk to known unknowns and black swans to unknown knowns, unknown unknowns and a subset of known knowns.

2. Risk management systems

In the risk management field linked to industrial safety, three groups of management systems can be differentiated. First, the systems that address risk from a general and / or systemic perspective can be pointed out. Second, the systems that deal with accident risk management. In this case, the risk of an occupational accident and a major accident can be differentiated. And thirdly, the systems that address the emerging risk. Next, the main aspects of these systems will be described.

2.1 *Risk management*

The ISO 31000:2018 standard defines risk management as coordinated activities to direct and control an organization with regard to risk. SRA (2018) considers risk management as activities to handle risks such as prevention, mitigation, adaptation or sharing. It often includes trade-offs between costs and benefits of risk reduction and choice of a level of tolerable risk.

Grøtan and Paltrinieri (2016) consider risk management frameworks unanimously address the following steps: pre-assessment, risk assessment, tolerability/acceptability judgment, and risk management. Such authors point the following frameworks: CSA Q850-97 standard (Risk management: guideline for decision makers); ISO 31000:2009 standard (Risk management: principles and guideline); NORSOK Z-013 standard (Risk and emergency preparedness assessment" by the Norwegian petroleum industry); and the "Risk governance framework" by the IRGC.

2.1.1 *OH&S management*

In OH&S field, the ISO 45001 standard defines management system as a set or interrelated or interacting elements of an organization to establish policies and objectives and processes to achieve those objectives; and OH&S management system is a management system or part of a management system used to achieve the OH&S policy. This OH&S management system approach is based on the concept of Plan-Do-Check-Act (PDCA).

Table 5. The evolution of the IMS with focus on Sustainability and OH&S throughout the years 1990–2018.

IMS	First version	Last version	Institution
HSG 65	1991	2018	HSE
ISO 14001	1992	2018	ISO
BS 8800	1996	2018	BSI
UNE 81900	1996	2001	AENOR
UNI 10616	1997	2011	UNI
OSHAS 18001	1999	2018	BS
AS/NZS 4801	2001	2018	AS/NZS
ILO-OSH	2001	2018	ILO
SS 56	2004	2018	SSC
ANSI/AIHA Z10	2005	2018	ANSI
ISO 45001	2018	2018	ISO

Source: adapted from Marhavilas et al. (2018)

Marhavilas et al. (2018) have identified and analyzed the main International Management Systems (IMS) with focus on Sustainability and OH&S. The evolution of such IMS throughout the years 1990–2018 they are included in the Table 5. In this Table 5 there are 11 IMS of which all have their focus on OH&S, except ISO 14001 standard with a focus on Sustainability.

Among the results shown in Table 5, it can be seen that the most recent standard is ISO 45001. The publication of ISO 45001 supposes the annulment of OHSAS 18001, for which companies certified according to this standard have three years to make the migration (Contreras, 2018). There are many differences between ISO 45001 and OHSAS 18001, but the main novelty is that ISO 45001 focuses on the interaction between an organization and its business environment, while the OHSAS 18001 standard puts the emphasis on OH&S management and other internal aspects (Glaesel and Corrie, 2018).

The implementation of ISO 45001 provides numerous benefits, among which are to achieve greater optimization on OH&S management as well as improve the image of the company to demonstrate to its stakeholders, their responsibility and commitment to on OH&S (Campos et al., 2018).

2.1.2 *Safety management*

Li and Guldenmund (2018) consider that a safety management system (SMS) is either a system that is used to manage and control safety or it is a management system specifically aimed at safety. Such authors have studied multiple definitions of a safety management system (SMS), and they considered that its definition is always concerned with three core issues, i.e. safety, management and system, whose intersection configures an SMS being its main purpose to control risks and, by doing this, to prevent accidents.

Table 6 shows the standards and regulations for general SMS studied by Li and Guldenmund (2018). These authors have considered SMS on 4 different focuses: Mayor Accidents, OH&S, Environment, and Quality. Brocal et al. (2018a) note that occupational safety and major accidents are two branches of the safety are interconnected. This interconnected has been studied by Brocal et al. (2018b), considering for this the links and transition spaces configured by three SMS: Directive 89/391/EEC (Framework Directive on OH&S), Directive 2012/18/EU (Seveso III on major accidents) and ISO 45001 standard.

Table 6. Standards y regulations for general SMS

IMS	Publication year	Focus	Institution
ISO 9001	1987	Quality	ISO
ISO 14001	1992	Envir.	ISO
ISO 31000	2009	General	ISO
ISO 45001	2018	OH&S	ISO
SEVESO DIRECTIVE	1982	Mayor accident	EU
SEVESO II	1996	Mayor accident	EU
SEVESO III	2012	Mayor accident	EU
DIRECTIVE 89/391/ECC	1996	OH&S	EU EU
BS 5750	1979	Quality	BS
BS 7750	1954	Envir.	BS
BS 8800	1996	OH&S	BS
OSHAS 18001	1999	OH&S	BS
PART 1910 (Standards–29CFR)	2001	OH&S	OSHA (USA)

Source: adapted from Li and Guldenmund (2018)

2.2 *Emerging risk management*

IRGC (2011, 2015a) addresses management emerging risks linked to technology and industrial processes. The IRGC (2015b) has reviewed emerging risk governance frameworks, and it has selected five: ENISA (European Union Agency for Network and Information Security); EFSA (European Food Safety Authority); SONAR system (the Swiss Reinsurance Company); Dutch framework (emerging risks related to the use of chemicals); and CEN (European Committee for Standardization) workshop agreement (CWA) 16649:2013 (emerging risks related to technology).

CWA 16649:2013 proposes the Emerging Risk Management Framework (ERMF). The whole process is based on the concept that emerging risks go through a maturation process (IRGC, 2015b). This ERMF is based on the risk management frameworks defined by IRGC (2005) and ISO 31000: 2009. Currently, International Organization for Standardization (ISO) is developing the ISO 31050 standard - Guidance for managing emerging risks to enhance resilience (ISO, 2018c). This new standard has taken CWA 16649 as one of its references (ISO, 2018c). In Spain, within the structure of the Spanish Association for Standardization (UNE), there is the technical standardization committee CTN 81 on OH&S, in which the working group GT3 on emerging risks is integrated (UNE, 2019).

2.3 *Monitoring management process*

The monitoring process is one of the main links between structures of risk management systems configured by Directive Seveso III, Framework Directive and ISO 45001 (Brocal et al., 2018b), i.e. between safety management (major accidents) and OH&S management (occupational accidents). In fact, according to ISO 45001, in order to achieve the intended outcomes of the OH&S management system, the processes should be monitored, measured and analyzed. This standard defines monitoring as determining the status of a system, a process or an activity. This monitoring should take place in all stages of the management process (Figure 2).

Figure 2. Management risk. General process (adapted from ISO 31000:2018)

Paltrinieri and Khan (2016) notes that most methods for quantitative risk assessment mainly provide static evaluations. This problem can be extended to emerging risks occurring as a result of a change in technology, product, operating conditions, as well as in organization of activities in conventional industrial plants (Stanojevic et al., 2013). It is important to include the time dimension in any risk assessment of emerging risks (Wilday et al. 2011).

Beyond the OH&S risks, the most standards and regulations suggest updates of risk assessment (i.e. risk identification, risk analysis and risk evaluation). However, there is not a consolidated approach for such periodic monitoring, both in OH&S risk and in Seveso sites. The CWA 16649 document solves the monitoring problem partially through the concept ‘‘risk maturation,’’ since this concept still requires further development, especially in terms of indicators that allow performing a monitoring of the conditions that determine new and increasing risk qualities (Brocal et al., 2017). Anyway, in the last decade, increasing attention has been dedicated to evaluation and monitoring of early deviations through appropriate indicators, as a way to assess and control risk (Paltrinieri and Reniers, 2017). For this reason, Paltrinieri et al. (2014) have proposed a dynamic approach to risk management based in the Dynamic Procedure for Atypical Scenarios Identification (DyPASI) and the Dynamic Risk Assessment (DRA) methods. This dynamic approach is able to take into account new risk notions and early warnings and to systematically update the related emerging risk issues.

In Seveso sites, one of the most complete monitoring approaches is suggested in the United Kingdom, where the competent authorities require systematic collection of past events and safety performance indicator (Paltrinieri and Reniers, 2017). In a health and environmental context, Stanojevic et al. (2013) have proposed an approach that provides a possibility of online monitoring and assessment of risks based of monitoring of key performance indicators (KPI’s) (e.g. categories of occupational diseases, normalized number of fires and explosions, etc.). In OH&S sites, the theoretical framework developed by Brocal et al (2017) allows its monitoring the emerging risk through the TLC, especially in industrial processes. With this theoretical framework, Brocal et al. (2018c) have designed a qualitative technique called TICHNER, which is compatible with standards ISO 31000:2018 (ISO, 2018a) and ISO/IEC 31010:2009 (ISO, 2009) and permits to identify and characterize occupational emerging risks.

3. Discussion and conclusions

Three groups on risk management systems linked to safety have been studied in this paper: (i) risk management; (ii) accident risk management: (a) OH&S management; (b) Safety management; (iii) Emerging risk management. These groups are very interrelated (in some cases there are overlaps) and currently they are subject to a strong development in the field of standardization.

Brocal et al. (2018b) have identified and analyzed the links and transitional spaces between the risk management of occupational accidents and major accidents. However, said authors have not distinguished between traditional risk management and emerging risk management. Similarly, no distinction has been made between static and dynamic approaches.

These limitations point to new challenges whose main characteristics are described below.

The emerging risk definitions published by EU-OSHA and CEN trough of the CWA 16649 are very similar. The definition adopted by the EU-OSHA has been integrated into the CWA 16649 document with certain modifications (Brocal et al., 2017). The main modification is that in the CWA 166749 does not include the term "workers / occupational" due to the "global" treatment of risk.

There are some significant differences in the use of emerging risk concept in technical and scientific literature. These differences, according to Brocal (2016) and Cantonnet et al. (2019) point a clear problem of consensus on terminology and knowledge around the emerging risk. Knowledge gaps for emerging risks, in general, include: uncertainties in risk assessment; lack of experience, including lack of standards and the need to educate a new workforce; and the best way to achieve risk communication with politicians, the public and other stakeholders (Wilday et al. 2011). From a standardized point of view, the CWA 16649 document may prove to be the first step. The next steps could be trough ISO with the current development of the ISO 31050 standard - Guidance for managing emerging risks to enhance resilience (ISO, 2019) and trough the Spanish Association for Standardization (UNE), with the technical standardization committee CTN 81 on OH&S, in which the working group GT3 on emerging risks is integrated (UNE, 2019). However, from organizations like SRA (Society for Risk Analysis) and SIF (Manufacturing Engineering Society) complementary efforts are needed to strengthen the foundation of the emerging risk.

The works by Brocal et al. (2017, 2018c) propose approaches and models to reduce the uncertainty associated with the identification and characterization of emerging risks. However, the efforts on emerging risk uncertainty must be deeper and address all phases of the risk assessment process. In this way, the approach of the analysis between the emerging risk concept and the four events types developed through Figure 1 is another step forward. Nevertheless, this approach is different from the approach developed by Flage and Aven (2015). In this regard, the main differences are related to the definitions of the emerging risk and the type of event considered, that is, occupational events or black swan events. However, with the present work, has not been deepened in the comparative analysis of such approaches. This analysis can be the main objective of future research work.

According to ISO 45001, the organization shall establish a process(es) for (among many other processes): (i) monitoring, measurement, analysis and performance evaluation; (ii) implementation and control of planned temporary and permanent changes that impact OH&S performance; (iii) reporting, investigating and taking action, to determine and manage incidents and nonconformities.

The monitoring activity addresses the systematic and rational control on the uncertainty affecting the risk analysis (Paltrinieri et al, 2014). The change, incidents and nonconformities management is directly related to the conditions that define an emerging risk (Ci) and consequently with the assessment process of those risks. In this way, the monitoring and assessment process of the emerging risk uncertainty should be integrated into the iterative process PDCA used by organizations to achieve continual improvement. This integration can be considered the most important challenge for the future development of OH&S management.

Acknowledgement

This work was funded by the Ministry of Economy and Competitiveness of Spain: Analysis and Assessment of technological requirements for the design of a New Emerging Risks standardized management SYStem (A2NERSYS); reference DPI2016-79824-R.

References

Aven, T. (2010). On how to define, understand and describe risk. *Reliab Eng Syst Safe. 95*, 623–631

Aven, T. (2012a). The risk concept—historical and recent development trends. *Reliab Eng Syst Safe. 99*, 33-44

Aven, T. (2012b). On the link between risk and exposure. *Reliab Eng Syst Safe 106*, 191-199.

Brocal, F., 2016. Uncertainties and challenges when facing new and emerging occupational risks. Archivos de Prevención de Riesgos Laborales 19 (1), 6–9.

Brocal, F., Sebastián, M.A., González, C. (2017). Theoretical framework for the new and emerging occupational risk modeling and its monitoring through technology lifecycle of industrial processes. *Saf. Sci. 99*, 178–186.

Brocal, F. González, C., Sebastián, M.A., Reniers, G., Paltrinieri, N. (2018a). Standardized risk assessment techniques: A review in the framework of occupational safety in *Haugen et al. (Eds). Safety and Reliability – Safe Societies in a Changing World.* pp 2889-2895. CRC Press.

Brocal, F., González, C., Reniers, G., Cozzani, V., Sebastián, M.A. (2018b). Risk Management of Hazardous Materials in Manufacturing Processes:

Links and Transitional Spaces between Occupational Accidents and Major Accidents. *Materials 11*, 1915, 1-23.

Brocal, F., González, C., Sebastián, M.A. (2018c). Technique to identify and characterize new and emerging risks: a new tool for application in manufacturing processes. *Saf. Sci. 109*, 144–156.

Campos, F., López, M.A., Martínez, M., Ossorio, J.R., Pérez, J.F., Rodríguez, M.D. et al. (2018). Guía para la implementación de la norma ISO 45001 "Sistemas de gestión de la seguridad y salud en el trabajo". Madrid: FREMAP, Mutua Colaboradora con la Seguridad Social Nº 61.

Contreras, S. (2018). Cómo implantar ISO 45001. *Revista de la Asociación Española de la Normalización*, 10 p.

European Committee for Standardization (CEN). (2013). Managing Emerging Technology-related Risks, 16649: 2013. CWA, Geneva.

Flage, R., Aven, T. (2015). Emerging risk – Conceptual definition and a relation to black swan type of events. *Reliab Eng Syst Safe. 144*, 61–67

Glaesel, K., Corrie, Ch. (2018). Todo lo que hay que saber sobre la ISO 45001. *ISO Focus,* 3 p.

Grøtan, T.O., Paltrinieri, N. (2016). Chapter 20 - Dynamic Risk Management in the Perspective of a Resilient System, In N. Paltrinieri, F. Khan (Eds.), *Dynamic Risk Analysis in the Chemical and Petroleum Industry*, Butterworth-Heinemann, pp 245-257

International Organization for Standardization (ISO). 2009. Risk management — Risk assessment techniques. ISO/IEC 31010:2009. Geneva.

International Organization for Standardization (ISO). (2018a). Risk management –Guidelines. ISO 31000:2018. Geneva.

International Organization for Standardization (ISO). (2018b). Occupational health and safety management systems-Requirements with guidance for use. ISO 45001:2018. Geneva.

International Organization for Standardization (ISO). (2018c). ISO 31050 Guidance for Managing Emerging Risks to Enhance Resilience: Thriving in a World Growing in Uncertainty ISO 31050-Leaflet_v09aj14082018. Retrieved January 28, 2019, from: https://www.eu-vri.eu/filehandler.ashx?file=16526

International Organization for Standardization (ISO). (2019). Guidance for managing emerging risks to enhance resilience. ISO/NP 31050, Geneva. Retrieved January 28, 2019, from: https://www.iso.org/standard/54224.html

International Risk Governance Council (IRGC), (2005). White Paper on Risk Governance. Towards an Integrative Approach. IRGC, Geneva.

International Risk Governance Council (IRGC). (2010a). The Emergence of Risks: Contributing Factors. IRGC. Geneva.

International Risk Governance Council (IRGC). (2010b). Emerging risks Sources, drivers and governance issues. IRGC. Geneva.

International Risk Governance Council (IRGC). (2011). Improving the Management of Emerging Risks. IRGC. Geneva.

International Risk Governance Council (IRGC). (2015a). Guidelines for Emerging Risk Governance. International Risk Governance Council (IRGC), Lausanne.

International Risk Governance Council (IRGC). (2015b). Guidelines for Emerging Risk Governance. Appendix. Lausanne: International Risk Governance Council (IRGC).

Li, Y.,Guldenmund, F.W. (2018). Safety management systems: A broad overview of the literature. *Saf. Sci. 103*, 94–123

Manufacturing Engineering Society (SIF), Working Group Risk Engineering Manufacturing (REM). Retrieved January 28, 2019, from: http://www.sif-mes.org/en/

Marhavilas,P., Koulouriotis, D., Nikolaou, I., Tsotoulidou, S. (2018). International Occupational Health and Safety Management-Systems Standards as a Frame for the Sustainability: Mapping the Territory. *Sustainability 10*, 1-26.

Meyer, T. Reniers, G. (2016). *Engineering risk management*. 2nd Edition. De Gruyter. ISBN 978-3-11-041804-0.

Paltrinieri, N., Khan, F., Amyotte, P., Cozzani, V. (2014). Dynamic approach to risk management: Application to the Hoeganaes metal dust accidents. *Process Saf Environ. 92*, 669–679

Paltrinieri N, Tugnoli A, Cozzani V (2015). Hazard identification for innovative LNG regasification technologies. *Reliab Eng Syst Safe. 137(6)*: 18-28.

Paltrinieri, N., Khan. F. (2016). *Dynamic Risk Analysis in the Chemical and Petroleum*. Butterworth-Heinemann.

Paltrinieri, N, Reniers, G. (2017). Dynamic risk analysis for Seveso sites. *J Loss Prevent Proc. 49*, 111-119.

Society for Risk Analysis (SRA). (2018). Society for Risk Analysis Glossary.

Spanish Association for Standardization (UNE). Retrieved January 28, 2019, from: https://www.une.org/encuentra-tu-norma/comites-tecnicos-de-normalizacion/comite?c=CTN%2081

Villa, V., Paltrinieri, N., Khan, F., Cozzani, V. (2016). Towards dynamic risk analysis: A review of the risk assessment approach and its limitations in the chemical process industry. *Saf. Sci. 89*, 77–93

Wilday, J., Paltrinieri, N., Farret, R., Hebrard, J., Breedveld, L. (2011), Addressing emerging risks using carbon capture and storage as an example, *Process Saf Environ. 89* 463–471.