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RESEARCH ARTICLE

Accident, safety and risk management

Accidente, seguridad operacional y gestión del riesgo

Claudio Luis Salvetti

Electromechanical Engineer (UBA) specialising in radiological protection, nuclear safety and occupational health and safety. Universidad de Buenos Aires (UBA)

claudio.l.salvetti@gmail.com

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Abstract

Recommendations from systemic accident investigation and integrated risk management can contribute to more effective safety in organizations. This article discusses these ideas based on developments in each of these approaches.

Resumen

La emisión de recomendaciones surgidas de la investigación sistémica de accidentes y una gestión integrada del riesgo puede contribuir a una seguridad operacional más eficaz en las organizaciones. En este artículo se analizan estas ideas a partir de los desarrollos de los principales referentes en cada uno de estos enfoques.

Accidents and their Prevention

There is consensus in the field of safety that the beginning of accident analysis and investigation from a methodological perspective can be attributed to Herbert William Heinrich, who published his work "Industrial Accident Prevention" in 1931. The framework developed by the author has been revisited in numerous studies; it was a linear investigation model based on a study that indicated that most accidents occurred due to unsafe acts by individuals (Dekker, 2014).

This precedent initiated a path in which workers became the "center of the problem" in accident prevention, leading to the development of behavior-based safety programs. These programs focus on reinforcing "safe behaviors" of workers to prevent accidents. Prominent authors in this model include Scott Geller ("The Psychology of Safety Handbook," 2001), Terry McSween ("The Values-Based Safety Process: Improving Your Safety Culture with a Behavioral Approach," 1995), and José Meliá ("Seguridad basada en el comportamiento: Perspectivas de intervención en riesgos psicosociales", 2007).

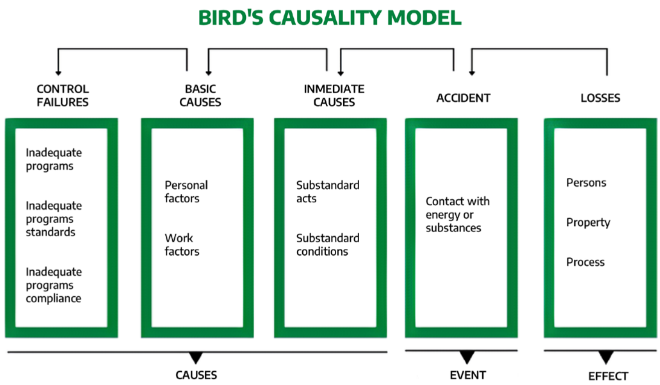
The behavior-based safety model still serves as a reference in many accident investigations in transportation and industries such as chemistry, mining, oil, and gas. However, advancements were made in prevention tools through the development of programs that focused on the role of supervisors. The most recognized of these was the program called "Safety Through Observational Practice" (STOP), created by Dupont and still applied in many industries.

Figure 1. STOP Program Fragment

Source: Dupont Security.

Other studies advanced in the direction set by Heinrich, among which the work of Frank Bird and Robert Loftus (1976), "Loss Control Management," stands out as a qualitative leap in accident investigation.

Figure 2. Causality Model



Source: Bird, Loftus (1976), Loss Control Management.

The main contribution of this model can be summarized in the idea that not only immediate causes (unsafe acts and substandard conditions) occurring at the accident scene should be determined, but also:

- Basic or underlying causes related to higher levels of the organization: contributing factors, which can be personal (e.g., inadequate capacity, lack of knowledge or skills) or work-related (e.g., insufficient supervision, inadequate engineering or maintenance, inadequate tools or equipment, inadequate procedures).
- Control failures in work programs and standards, which are related to management and various levels of supervision.

This model expands the scope to accidents that do not have consequences for people but cause material damage, affect processes, or impact the environment (losses). In subsequent studies, Bird developed a safety management system called "loss control".

From a more comprehensive perspective, with management retaining a central role in accident prevention, James Reason, renowned for his studies on human error, focuses on organizational aspects that influence safety management. He notes, "We cannot change human nature, but we can change the conditions under which people work in organizations" (Reason, 1990, cited in Covello, 2021).

This author emphasizes the problem of human fallibility in relation to "organizational accidents," which are characteristic of complex technological systems associated with the potential for serious consequences in communities and the environment (Reason, 1997).

Reason postulates the "Swiss Cheese Model," in which accidents occur due to the "alignment of defense layers." He proposes that all accidents occur within a combination of active failures and latent conditions.

Active failures correspond to actions or omissions (lack of attention, demotivation, procedure violations) and are typically associated with front-line personnel (operational staff). Latent conditions can exist long before an accident occurs and are related to organizational factors, such as decision-making at managerial and supervisory levels, leadership, goal setting, communication, work organization, training, procedures, or design.

It should be noted that, although industries often focus on analyzing active failures in investigations, there is greater resistance to analyzing latent conditions. This difficulty stems from the following clarification in ICAO Doc. 9859 (2018):

> "It is important to highlight that latent conditions, when created, typically have good intentions. Decision-makers in the organization often must balance finite resources, conflicting priorities, and potentially conflictive costs. Decisions made routinely in large organizations could, under particular circumstances, inadvertently lead to harmful outcomes".

In line with this statement, we may also ask: should we also highlight the good intentions of operational levels where active failures occur?

Investigating accidents under this model would lead to considering not only the identification and critical analysis of active failures but also the conditions under which people work, created by the organization," as stated by Covello (2021). This underscores the importance of risk management throughout the organization, as we will discuss in more detail later.

We will now move on to safety management, in which accident investigation, albeit with a reactive approach, is an essential part. Following Leveson (2019), we affirm that "an accident in which people die is tragic, but not as tragic as not learning from it."

Safety Management

The loss control management or modern safety management model (Bird and Loftus, 1976) marked a significant advancement in accident handling and safety management. It focuses on management, a management activity, and introduces a shift in safety perspective:

- It shifts the focus from people's behaviors to control, giving prominence to management: "80% of safety problems are attributable to decisions or actions ofmanagement" (Bird and Loftus, 1976).

- It places particular emphasis on measuring performance as a key element of safety management.

- It links safety management with other organizational (business).

This model includes stages of identifying loss exposures, risk assessment, planning, system implementation, and monitoring (ISMEC). It consists of twenty elements, among which leadership, training, procedure and task analysis, communication, change management, system measurement, and accident investigation stand out.

"The latent conditions can exist long before the accident occurs and are related to organizational factors."

It also incorporates organizational management practices, under the premise that what cannot be measured cannot be controlled, managed, improved, and deteriorates.

In this direction, many organizations develop specific policies, programs, and procedures for accident prevention. Reasons for this change include:

- The increasing demand of labor legislation and regulatory authorities' oversight.

- The need to prevent accidents due to their impact on people and the organization.

- Awareness of the cost impact of accidents on the business.

The Company Dupont, a leader in the field, supplemented its STOP program with others focused on safety leadership and operational discipline. To do this, they applied management practices to safety management with a focus on operational processes (Thomen, 1991; Briceno Graterol, 2017). Among the principles of their safety policy, the following stand out:

- All injuries can be prevented.

- Safety is the responsibility of line management (from top management to various levels of leadership and supervision).

Special mention should be made of industries that manage complex technologies, such as nuclear and aerospace, in which safety management has been determined from the beginning by a rigorous regulatory framework based on national and international regulations, as well as standards and guidelines issued by specific international organizations (International Civil Aviation Organization [ICAO], International Atomic Energy Agency [IAEA]).

In the 1990s, safety management systems emerged. These began with the publication of British Standard 8800, followed by similar standards in different countries. In Argentina, IRAM 3800 (Occupational Health and Safety Management Systems) was published.

In 1999, the first international standard specifying the requirements for an occupational health and safety management system was issued: the Occupational Health and Safety Assessment Series (OHSAS), which was updated in 2007.

A management system consists of a set of interrelated elements within an organization to establish policies, objectives, and processes to achieve these objectives (ISO, 2018). System elements include organizational structure, roles and responsibilities, planning, operation, performance evaluation, and improvement. It can address a single discipline (e.g., safety) or multiple disciplines.

The scope of a management system can include the entire organization, specific sectors or functions, both within the organization itself and within a group of organizations.

Safety management systems (SMS) currently constitute a relevant reference framework not only for industries that manage complex technological systems, such as aerospace and nuclear (ICAO, Doc. 9859, 2018; IAEA, 2011; ARN, AR 10.6.1., 2020) but also for the maritime industry (ISM Code, 1998), the railway industry (MT SMS 1st Railway Safety Directive, 2018), as well as other industries and organizations in general (ILO, 2001; ISO 45001, 2018).

The following main characteristics of safety management systems in general are highlighted:

- They are systems, meaning their elements interact and should not be analyzed in isolation.

- They are based on the Deming cycle (plan, do, check, and act for improvement) (ISO, 2018).

- They focus on implementing measures to ensure compliance with requirements, achieve objectives, and improve safety performance (performance, in terms of the ICAO Manual of Safety Management (Doc 9859, 2018)).

These systems consider leadership and the commitment of top management as success factors, as well as the commitment and participation of workers at all levels of the organization.

The planning stage of the management system involves establishing policy, identifying hazards, evaluating safety risks, and defining objectives.

Implementation also includes considerations regarding necessary resources, employee competencies, awareness of the importance of safety, necessary communications, and the definition of documented information required by the system. This stage also includes operational controls required to reduce operational risks to as low as reasonably practicable levels, along with emergency response planning.

"A management system consists of a set of interrelated elements within an organization to establish policies, objectives, and processes to achieve these objectives."

In the verification stage, activities are carried out to assess the effectiveness of operational risk controls, monitor safety performance indicators or safety performance, and achieve objectives, safety inspections, and safety management audits. In this phase, top management must also review the effectiveness and improvement of safety performance resulting from system implementation.

The act stage includes activities such as reporting safety deviations or findings, highlighted by Hopkins as a central tool for maintaining and improving performance, as well as any other improvement activities (Hopkins, 2021). Accident investigation is also included in this stage of the safety management system.

Nancy Leveson (2019), at the Massachusetts Institute of Technology (MIT), applied systems theory and developed two models that differentiate between the proactive moment and the reactive moment of safety management (the latter includes accident investigation). One of them, the Causal Analysis based on System Theory (CAST), is used for analyzing scenarios in which accidents occurred, while the other, the System Theoretic Process Analysis (STAMP), is a proactive model aimed at identifying potential scenarios that can lead to losses.

Risk Management

The significant development of complex technological systems during the second half of the last century was accompanied by growing interest from the community and social sciences in the study of risk associated with these systems. This led sociologist Ulrich Beck to characterize contemporary society as a "risk society" (1999). Authors began to ask questions such as: What is an acceptable risk, and who defines it? (Mary Douglas, 1986), How safe is safe enough? (B. Fischhoff, 1978).

This made it clear to the industry that it was no longer sufficient to manage the safety of technological systems solely from a technical perspective. In this regard, German sociologist Niklas Luhmann (1991) analyzed the concept of risk and highlighted that it was complementary to security: "greater security, less risk," a statement that aligns with the technical approach. Safety management has focused on preventing accidents and acting to reduce their number and severity, a perspective that falls under what Hollnagel (2014) calls Safety I.

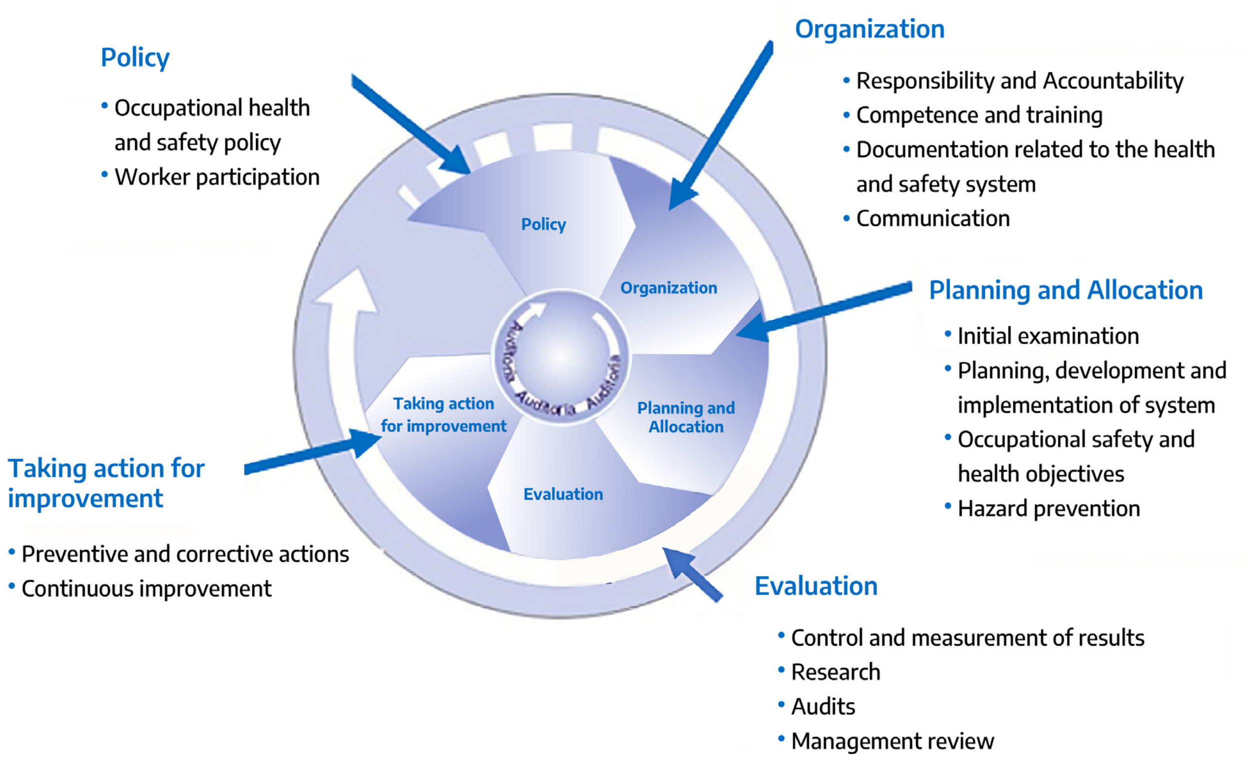
The focus on risk management, complementarily, revolves around questions such as: Have all hazards or sources of risk been identified? Are safety controls being applied? Are these controls adequate and effective? Are safety inspections and management audits effective in detecting deviations before accidents occur?

Safety management systems (SMS) were developed to address these questions and specialize in proactive risk management, particularly operational risks. However, within these same systems, questions like the following can also arise: Are there issues related to the context or stakeholders that can generate risks affecting safety management? Can safety be impacted by risks associated with other processes within the organization or the political-administrative-organizational system?

Safety management systems address the aspects mentioned in these questions and create conditions for integrated risk management with a systemic perspective.

Let's briefly examine one of the internationally recognized models for risk management: the one

Figure 5. Guidelines on Occupational Safety Management Systems



Source: OIT (2021).

developed in ISO 31000 (ISO, 2018). This model can be applied at any organizational level, from strategic to operational (where safety risks are included), and it can be applied in various industries, including industrial and financial sectors.

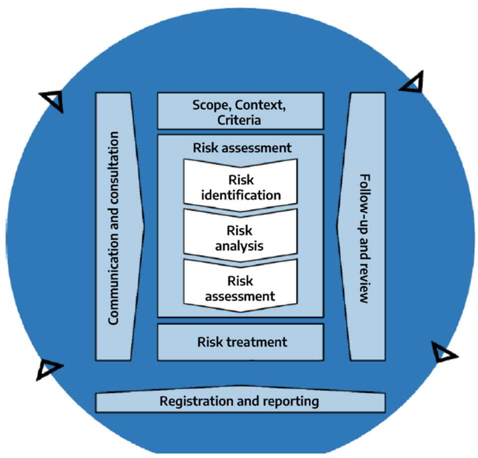
In ISO standards, risk is generally defined as "the effect of uncertainty on the achievement of objectives." These objectives include compliance with legal requirements and those of other interested parties, achieving goals, and improving safety performance.

This standard defines risk management as "the coordinated activities to direct and control an organization with regard to risks associated with its activities." Its purpose is to create and protect the organization's value. Managing risk, from this perspective, emphasizes achieving expected results; thus, it is a positive approach aligned with the principles of Safety II developed by Hollnagel (2014).

In the same vein, there are high-reliability organizations (HROs) models that operate safely in complex scenarios. They are characterized by promoting a culture of reporting failures and errors, delegation of decision-making at all levels, and a higher perception of the risk associated with disruptions in operation that could eventually lead to accidents (such as the U.S. air traffic control system) (Dekker, 2019). The organizational robustness model also fits in this context, defining a robust system as one that can adapt to disturbances through more or less complex regulation mechanisms (Boissieres, 2007).

ISO 31000 highlights that top management should exercise leadership and commitment in managing each of the organization's processes as a whole system. Process owners should also be responsible for managing risks related to their processes.

Figure 8. Risk Management Process



Source: ISO 31000 Std.:2018.

Figure 7: Relationship between Risk and Safety

Source: Own elaboration.

The main stages of the risk management process stipulated in this standard, similar to those established in management systems, include risk identification, analysis and assessment, and subsequent treatment to meet acceptability criteria. These criteria should be established based on the best available information, industry or sector standards, legislation, policies, and current regulations. Organizations should define the scope to which the risk management process applies, document it, and carry out monitoring activities for each of the mentioned stages.

Additionally, this model includes activities such as context analysis and consultation and participation of stakeholders (including suppliers, regulatory bodies, workers, and the public) in the operational risk management process. Let's see how some of the previously presented management systems address these issues.

ISO 45001, which includes requirements for occupational safety and health management systems applicable to organizations in various industries, states that issues related to the context (such as potential changes in legislation, macroeconomic, political, environmental, technological, or social factors) and the needs and expectations of interested parties should be determined. Then, based on this analysis, risks associated with these issues that could impact safety management system planning and implementation should be addressed.

Furthermore, according to the regulations issued by the Argentine Nuclear Regulatory Authority (ARN), the management system "must integrate specific safety elements (radiological and nuclear) with environmental, economic, social, organizational, and human factors" (2020).

Among the requirements of the management systems published by the IAEA (2011), it is established that the management should "take into account the expectations of interested parties in the activities and interactions of the management system processes to increase the satisfaction of interested parties while ensuring that safety is not compromised." The same organization also recommends good practices related to involving stakeholders in risk management (IAEA, 2006).

In the aviation sector, the SMS developed in ICAO Doc. 9859 (2018) indicates that recognizing the aviation system and its context, considering all organizations and processes involved, contributes to better risk management and, consequently, improved safety performance of the "total system."
Furthermore, in the same manual, what is known as Integrated Risk Management (IRM) is developed, emphasizing the overall reduction of risks within the organization. The document specifies the following:

> The aviation system as a whole comprises different systems and processes, such as financial, environmental, safety, and aviation security. While each system has developed risk management frameworks and practices aimed at addressing their own characteristics, consequences can occur between systems, given that effective risk management action in one sector may have negative consequences on another operational aviation sector (e.g., restrictions on carrying personal electronic devices in the cabin may shift the security risk from the cabin to the cargo hold, increasing safety risks).
>
> Successful risk management in aviation should aim for the overall reduction of risks in the system, including all involved systems or functional areas, a process that requires a system-wide assessment at the highest level (State, regional organizations, service providers)
>
> Integrated risk management aims to coordinate management processes from a systemic perspective with the goal of reducing hazards through their assessment in each sector, using a holistic approach to achieve the highest level of system performance at a socially acceptable level (ICAO, Manual of Safety Management, 2018, section 1.4.3).

Finally, it is important to emphasize that risk management has an anticipatory nature. Were the risks associated with the dysfunctional characteristics of

"Risk management should not neglect the political, power-related, and general interests involved in high-impact decision-making within organizations and their context."

the Chernobyl plant's structure and leadership system not known before the catastrophic accident in 1986? Were the managers of the Challenger project at NASA not warned in the same year about the possibility of component failures before launch? Were Boeing's leadership not informed about the risks of lowering safety standards to meet business objectives, which created the conditions for the 737 Max accidents?

The hazards related to these accidents were known, and these examples underscore that risk management should not neglect the political, power-related, and general interests involved in high-impact decision-making within organizations and their context, as highlighted by Covello in the context of accident investigations (2021), which poses "a political, ethical, and intellectual challenge."

CONCLUSIONS

This article highlights the relevance of integrated risk management with a systemic perspective to achieve more effective safety management.

In this regard, we would like to summarize the following aspects:

- Due to its preventive nature, risk management should guide safety management.
- Integrated risk management, considering the interaction between risk management functions in various areas and processes of the organization (finance, procurement, human resources) and the global system it belongs to (transportation system or others), leads to more effective operational risk management.
- Analyzing the context, as well as communicating and consulting with stakeholders (suppliers, workers, customers, etc.) in the operational risk management process, can promote better safety performance.
- The determination of recommendations arising from the systemic accident investigation, with a focus on the analysis of the degree of integration of risk management of all processes in the organization, can contribute to the prevention of new accidents.
- While security risk management focuses on operational processes, it is essential that it is integrated into the management of risks associated with all functional areas and processes from a systemic perspective and under the leadership of senior management, given the interaction that can exist between them.

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