

INTEGRATED RISK MANAGEMENT IN INDUSTRIES FROM THE STANDPOINT OF SAFETY AND SECURITY

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Research article

Abstract: Manufacturing plants as well as robotic cells within their structures are complex systems, whose safety requires implementation of a wide ranging set of activities. These activities are mainly focused on risk minimization, with the aim of achieving acceptable levels of risk by means of appropriate measures. The human being, as a constituent of the man-machine-environment system, is in the centre of their attention. At the organizational level, risk management has to be integrated with strategic planning and managerial processes in the organization. This includes, inter alia, the need to effectively monitor and review the risk management processes. Comprehensive approach within the risk management process is based on interconnecting safety and security-related processes in the form of a generic approach.

Keywords: Risk, safety, security, management system, generic model.

Introduction

Effective prevention requires every citizen to be able to identify and assess risks himself/herself. This means that they should not be ordered to do so by the government or any other relevant institution. Effective prevention is defined as an obligation of experts to provide adequate explanations about the extent and consequences of risks, and especially to explain to citizens what mechanisms and factors lead to the fact that some risks are underestimated and some overestimated (Renn, 2014).

In an effort to ensure their sustainable development, organizations or companies have to constantly manage processes in accordance with the current quality requirements and thus maintain a competitive position among their rivals. Changing conditions in society, production systematization and automation, new materials and technologies which give rise to new and emerging risks also bring about new trends in the effective management of all company processes. The focus must always be on organization's prosperity, which involves manufacturing high-quality products and providing high-quality services while ensuring the safety of the working environment.

The safety of the manufacturing process involves not only the occupational safety and health of the organization's employees but also minimization of risks related to the use of the final product - the outcome of the manufacturing process. Safety has an important place in all areas of contemporary life in society. It includes not only the environment, materials and work environment but especially the human being within the man-machine-environment system. Safety has to be perceived as an integral part of all human activities. It is important that people are well prepared for the hazards or threats they will encounter at every stage of their lives. The basic principle in the management of human and technological risks is based on the fact that, in order to avoid malfunction or accident (injury), it is necessary to identify potential risks in a timely manner and activate the appropriate measures leading to the application of effective forms of prevention. In most cases, risks arise as a result of natural processes and human activities. In this context, it is necessary to realize that, on the one hand, human has the potential for causing random, untargeted adverse event but also for causing targeted, intentional harm to another person, technologies and environment. Risks are a natural part of (both active and passive) human life; therefore, their management aiming for

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their minimization (prevention) forms a part of the effective economic and social development of society. Manufacture of machinery, mechanical systems and other technological devices as well as their utilization takes place in a “cultural” environment, which has to take safety into consideration and implement all measures to minimize risks, and thus ensure the (technological) safety, i.e. all attributes forming the culture of safety. In order to ensure an integrated approach to risk management, one of the objectives is to develop comprehensive tools for defining and managing a combination of safety and security risks, such as risks with consequences affecting third parties or the environment (floods, storms and earthquakes). The problem is that, in some cases, it is impossible to precisely define the parameters of individual risks, and therefore, it is very difficult to estimate the resulting risk within the integrated approach. Examples may include the construction of residential areas near gas reservoirs or tanks for hazardous substances, situating petrol stations near chemical companies, and storing hazardous substances near airports and their runways. Even if the risk assessment of individual technical equipment shows that the risk level is acceptable, the synergic effect resulting from the combination of risks to the whole industrial system may far exceed the acceptable level of risk. In such case, it is necessary to develop new technological, political and communication tools that will ensure that all aspects of the interdependence between safety and security (if this dependence is known) are taken into account with regard to influences from all parties involved. These tools should also facilitate the development of risk minimization (reduction) procedures and implementation of all effective tools in the risk prevention.

Materials and methods

Company safety as a factor of its development

Enterprise/organization/company as well as robotic cells within a company are complex systems, whose safety and prosperity requires the implementation of a wide range of activities. It is therefore necessary to consider the possibilities of an effective integration of all safety components in the form of integrated safety. The human being has to be in the centre of attention in risk minimization procedures that ensure the safety of man-machine-environment systems (achieving an acceptable level of risk). Depending on the area, in which the impact

on human is assessed, the following types of safety and security are distinguished - Fig. 1 (Sinay, 2014a).



Fig. 1 Structure of comprehensive safety

At the organizational level, risk management has to be integrated with strategic planning and managerial processes in industrial organizations, which include the necessity to effectively monitor and review risk management processes, because risks and the parameters of the probability and consequence of a negative phenomenon (e.g. its impact over time) are in most cases of a dynamic nature.

Integrated Safety + Security

Characteristics of the safety platform

Numerous definitions of **safety** can be found in the specialist literature; however, for the purposes of risk management systems in the field of industrial technology, safety concerns mainly the health and safety of people at work - occupational safety and health (OSH), integrated with the safety of technical systems (STS). **Safety** focuses above all on the human factor, safety of machinery, systems and industrial technologies, including internal mechanisms in the company, i.e. with regard to individual jobs. Its objective is the creation of safe

working practices and safe workplaces. **Safety** assessment deals with the work environment as well as its impact on the performance of employees; it also includes the interaction between machinery, systems and the work environment (climate, noise, and lighting), and workplace behaviour of employees while performing their jobs within the framework of the “**man-machine-environment**” system (Sinay, 2014b). The concept of **safety** is based on the assumption that damage or loss is caused by unintentional human activity, and the prevention of damage of different nature requires the creation of technological measures as well as measures that prevent the consequences of such action from affecting people.

Characteristics of the security (protection) platform

Historically, **security** has its origin as a part of military operations. It is currently gaining a new dimension in the context of intense debates over the issues of global security, national security, territorial security, the security of ethnic groups and minorities, security of integrated residential units, etc. **Security** is primarily related to object or subject protection strategies and it therefore focuses on the protection of people. **Security** is in most cases related to such intentional human activities targeted against subjects or objects whose aim is to negatively influence or destroy them (terrorism) by exposing them (object, material and environment) to certain influences and thus cause extensive damage. Special area in the field of security is devoted to the events that are not directly caused by human activity, such as natural disasters of various kinds.

Common elements between safety and security

The fields of safety and security overlap in many respects, they influence each other, and it can be said that, when combined, they form a comprehensive system of protection of citizens' life, health and property (Fratszcher, 2013) (Winzer, 2010). The current understanding of the concept of safety in its broad sense is based on the principle of precaution. Therefore, the areas of occupational safety and health, safety of technical systems, as well as the area of public security often use similar diagnostic methods and means for early identification of the possibility of the occurrence of failures, accidents and injuries. The area of safety (OSH + STS) uses especially those means of technical diagnostics that serve for identification of the possibility of failure and subsequently prevent technological accidents

(e.g. nuclear reactor or its components; disabling a gas pipeline's pumping stations, or the pipeline itself), especially inside the system. The area of security utilizes mainly the methods and means that allow early identification of intentional action plans targeted against subjects/objects with the aim of destroying or damaging them. The aim must be to apply methods of protecting people, technology or environment against the actions targeted from external or, in some cases, even internal environment. The interaction of safety and security within a technological unit - a robotic cell - is shown in Fig. 2.

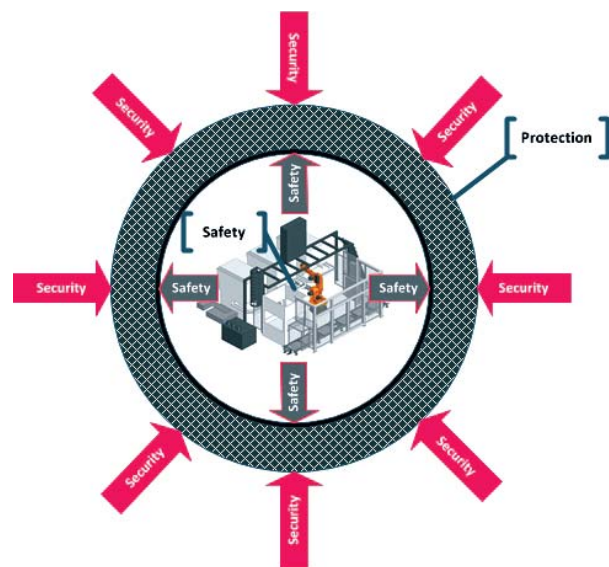


Fig. 2 Mutual relationship between safety and security

Examples from the field of safety

Practical examples in which there is a strong connection among occupational health and safety, safety of technical systems, and public safety, taking into account the causal dependency of the occurrence of a negative phenomenon, include the following (Sinay, 2014b):

A. Airports

Airport safety encompasses a vast system of measures contributing to the minimization or elimination of risks arising from a number of errors that can occur in the performance of jobs. In this particular field, there are risks that pose a continuous threat, such as a pilot's wrong decision when controlling the aircraft, erroneous activity of aircraft safeguarding equipment or ground staff. Effective prevention from potential errors requires introducing effective measures based on redundant

systems within the aircraft control system. As part of the redundant system, a backup system has to be used not only for devices but also for pilots and workers responsible for the safe operation of the aircraft. Each public airport has to develop an airport safety program ensuring the safety of customers and employees and responding to all air traffic needs. The airport security program must comply with the regulations of the national aviation security program and the requirements on its development and implementation specified by the civil aviation authority. Airport security program is approved by the aviation authority. The airport operator is directly responsible for the implementation and execution of all security measures for a public airport. The airport security program assigns a person responsible for overall coordination and implementation of the necessary security measures.

B. Chemical Industry

In this sector, it is particularly important to know what kind of chemical substance is being used in the industry - when handling or transporting the chemical, or when being in direct contact with it. Based on this information, it is possible to propose measures that can minimize the possibility of an adverse event. Even a minor inattention on the level of safety can cause considerable damage to human health - not only to the health of the employees who are in close contact with the substance, but it can also affect third parties who are not even aware of the possibility of leakage of hazardous substances in their vicinity.

Examples from the field of security

The field of security concerns employees but also other constituents - the wider public, citizens in the vicinity, and the environment. It primarily deals with the consequences of failures in the field of safety (OSH and STS), whose threats have changed from the category of safety to security, i.e. posing a threat to the wider public, not only employees. Examples include the transport of dangerous chemicals, airport operations, handling of nuclear material and the use of information and communication technologies.

A. Airports

Airport security includes aviation security, but also the security of wider surroundings of the airport against potential risks. The risks are primarily related to intentional negative human activities against the airport or technology. Therefore, in order to protect people from being hijacked, there is a need

for personal checks, but also checks of the contents of luggage.

B. Chemical Industry

In the chemical industry, it is important to distinguish the kinds of dangerous substances employed, in order to use appropriate prevention methods to protect citizens. When working with hazardous substances, it is also important to know the geographical conditions of the plant, the topography of the earth's surface so that it is possible to define the potential spread of the substance and the extent to which it may threaten citizens, their property or environment. In this area, it is necessary to have sensors that diagnose the possible leakage of hazardous substances and thus create opportunities for a timely response, in order to take effective protective measures.

Interdependence of safety and security platforms as parts of integrated safety

The systemic approach to the issue of safety and security is based on the idea that activities aiming to ensure the safety of an object can be considered as an open dynamic system with a set of internal and external relations. This results from the following:

- the object is considered as a system or process comprised of a wide range of subsystems and relationships among them, which require separate examination,
- the object is defined as a system constantly interacting with its environment, which is also a system in its own right,
- each object and its surroundings develop and operate over time, although the time interval and the course of the changes may vary - from seconds to decades or even centuries,
- the object and its surroundings are both the source and the target of threats and risks; the object can be affected by the hazards and risks from its surroundings, however, it can simultaneously pose a threat to its surroundings.

When applying the integrated systemic approach in risks assessment of an object, the resulting risk is not a simple sum of the risks related to the objects' components; the level of the resulting risk is determined by the highest level of risk of a component of the object (part of the system). Ensuring comprehensive safety of any entity (region, industrial technology, machine system, machine or robotic cell) requires developing a protection system around it.

In terms of understanding the concept of safety and security, individual entities have to satisfy two conditions:

1. they must be safe - (only acceptable risks may occur) - they may not cause adverse events, impair employees' or customers' safety (they have to manufacture safe and high-quality products - EU Directives) and their surroundings (net production) - internal safety system.
2. they must be secure - the existence of the subject protection system - they must resist external influences which could initiate an adverse event and threaten not only the organization itself but also its surroundings.

Fig. 3 documents the general perception of complete interactions between the areas of safety and security in objects performing various activities that affect the elements of the man-machine-environment (M-M-E) system. These objects can be manufacturing or non-manufacturing organizations, energy carriers, fuel storages, but also mines or petrol stations.

Each of the depicted objects is a subsystem of the M-M-E system and has its own specific relationships, both internal and external ones. Figure 3b represents the emergence of an adverse event in the organization - leakage of hazardous substances into the environment - which has a negative impact on people and environment. Fig. 3c shows a specific situation of an intentional third person's interference with the organization's activities (its specificity is highlighted with red colour), which may be a source of a threat. In this case, there is again a threat to humans and the environment, not only within the organization but also externally.

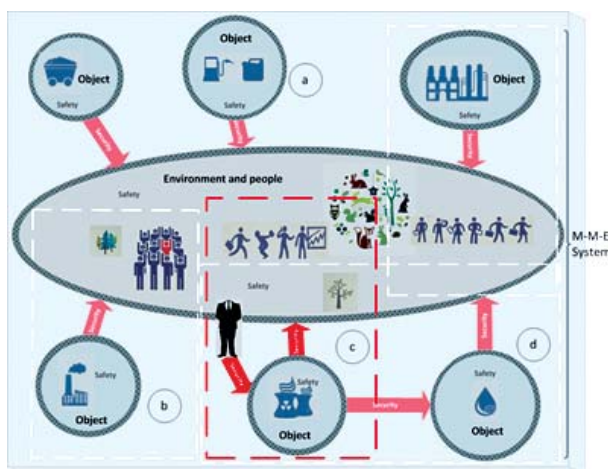


Fig. 3 Complex interaction of safety and security in the man-machine-environment system

Model scenario in Fig. 3d shows the threat to another "third party" organization or object (depending on the nature and scope of dangerous events) and taking into account the domino effect which results in a number of casualties, material and environmental damage.

Comprehensive safety is to be understood as the integration of activities in the field of safety and security - safety within the system and security (protection) from external interferences. Both areas must be analysed and subsequently managed so that they are interconnected.

Results

Generic model of comprehensive safety management

When taking a generic approach into consideration, it is possible to design the structure of an integrated safety management model - Fig. 4, which is characterized by the following procedures:

1. Requirements, trends, constraints:

- determination of legislative and normative requirements and conditions of sustainable development in various stages of the life cycle of a machine, system or technology,
- related to maintaining the trends in corporate and process management; tools for increasing competitiveness (ISO 31000 - Risk Management, ISO 50000 - Energy Management System, ISO 26000 - Social Responsibility, ISO 27000 - Information Security Management System),
- arising from the existence (occurrence) of new and emerging risks, resulting from the development of social processes and technological innovation (trends in new technologies and materials).

2. System process map with relevant inputs, outputs and requirements placed on the process, defining activities and objects (defining key performance indicators of processes as security parameters) - analysis of the functional structures of the company in accordance with the procedural approach.

3. Identification and description of relevant parameters for individual processes with a view of risk assessment.

4. Proposing the generic safety and security model structure for all areas of the organization (adaptation of the process output in the area of safety and security, using functional safety methodology, e.g. according to IEC 61508).

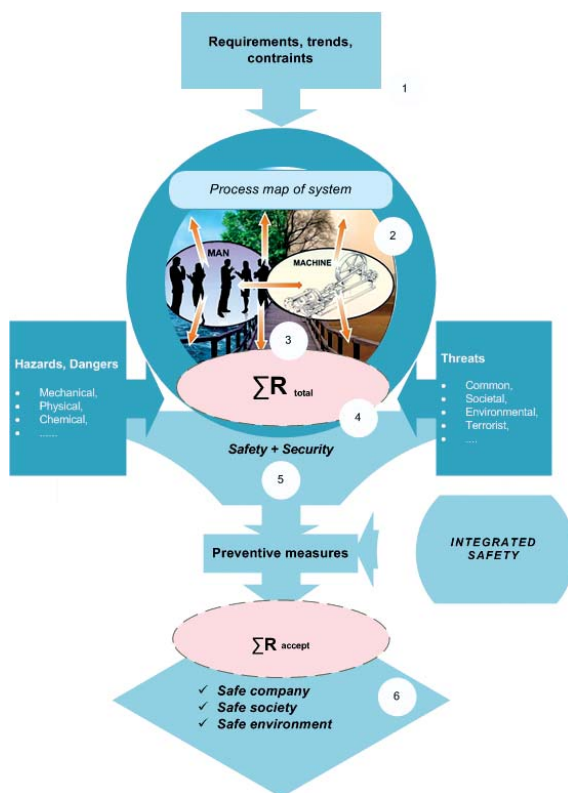


Fig. 4 Integrated security management model taking the generic approach into account (Sinay, 2014a)

5. Defining measures for the area of safety and security (TOP measures - concerning technology, organization and personnel).

Human as an object of safety and security analyses

The human factor plays a crucial role in the man-machine-environment system, whether in terms of safety management or security management.

Security can use the concept of a “**dangerous person**”. Such person’s aim is to create and initiate a causal dependence of a negative phenomenon so that this causes the highest possible damage. The threatened object is the M-M-E system with an emphasis on the **human factor**; individuals as well as groups of people of various sizes are affected.

In relation to the overlapping safety and security management activities, it is important that the designs of procedures for interrupting the causal dependency focus on the integral assessment of the influences of the human factor in relation to the final objective, which is the protection of all components of the man-machine-environment system (Sinay, 2014b).

Let us consider firefighters’ job as an example. Firefighters are involved in security-related activities aimed at minimizing the consequences of fire on people and property, by means of protective measures. In carrying out these activities, however, their own safety must be ensured - by a safety system protecting the subject (firefighter) inwards. Neglect of firefighters’ safety and health measures may endanger the implementation of security-related operations - protection of other people’s health and/or property. In this context, it is necessary to pay attention to the increased mental load on firefighters when performing security-related activities, caused by the nature of the activities, i.e. protection of human lives and property. The load may reduce the firefighters’ susceptibility to compliance with all safety requirements for carrying out their work, i.e. the perception of health protection and safety.

In order to increase the effectiveness of the conducted activities and minimize risks, these basic approaches may be applied:

- Intensive and effective training for implementers of security-related activities, so that they obtain automated habits in their implementation,
- The development of hardware and software tools independent of the impact of the human factor that will be helpful in minimizing human errors during the performance of particular jobs.

The development of effective ways of minimizing damage in the areas of safety and security has a common basis. In both cases, it involves the search for opportunities and development of methods of interrupting the causal dependency of negative phenomena in their early stages.

Interface between safety and security in the field of mechanical engineering

Safety and security interface is currently applied in mechanical engineering (e.g. automated robotic cells). It is particularly related the protection of an object (robotic cell) from external influences (security) and safety within the robotic cell. The aspects of safety and security can be considered and implemented relatively easily in case of individual machines that do not function as components of a production line. However, it is considerably more difficult in case of production line machinery or components of a complex machine system.

An example illustrating the interface between safety and security is the controlling software. A question arises in this respect - is there anything like safe software? It is difficult to define the concept of “safe” software. Depending on the domain, use

and fulfilment of security functions, a certain operational software security is assigned (e.g. using the corresponding safety standards, such as IEC 61508) in the form of safety integrity level. The incurred residual risk has to be at an acceptable level (for people). In the case of security, Evaluation Assurance Level is most commonly used; it takes into account the activities that may threaten the system (security against external interference). The creation of safe and secure software requires taking appropriate steps in the early stages of the production process. The achievable properties of machines, their reliability and availability are interdependent. For example, an aircraft is safest while on the ground, said Dr. Thomas Liedke, Business Unit Manager at Stuttgarter ICS AG, who is responsible, among other things, for the development and organization of the R&D. In contrast to hardware errors, software errors do not normally occur at random; they generally cannot be estimated by methods of mathematical statistics. Erroneous software cannot be as simply replaced as a faulty piece of hardware (Bauer, 2014). With the increasing integration of machines into systems, and application of complex production or handling lines, there appear two areas of safety; the area of automation is overlapping with the field of information technology.

Conclusion

The solutions selected to address the interface of safety and security have to be beneficial to all participants of the production process, and safety has to be their priority. Engineers and management

systems experts (systems integrators) must take all aspects of safety into consideration as early as at the machine design stage (EU Directive 42/2006/EC). Risk minimization has to be the priority for users of machine systems, and their actions must comply with this objective (391/89/EEC). The current goals in the field of safety include the protection of production-related data, product protection, know-how protection, access protection, integrity protection and the protection of machines by means of effective maintenance. Besides technological possibilities of risk minimization solutions, e.g. by means of adopting unified legislation or updating standards based on the results of applied research, other risk minimization solutions have appeared, which take into account also the economic aspects and psychological impacts, as well as training and education. One of the prerequisites for effective integration of risk minimization requirements within the integrated safety and security is the extent and form of communication between the two areas, i.e. between safety (safety of machinery, robotic cells as well as complete lines) and security (protection of these subjects from external influences).

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