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Risk Management in Occupational Health and Safety Context: A Proposal for a Coherent Structure of Concepts and Terminology

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Abstract

Applying and developing specific methodologies, a system of definitions/concepts is characterized and elaborated which is intended to be coherent and sufficiently comprehensive to allow for a terminological treatment of the Management Process Risk and, consequently, contribute to a justified uniformity of the terminology applicable to Safety Engineering. This paper proposes a coherent and interrelational structure of concepts, definitions, and terms, focused on the risk concept. As a conclusion and synthesizing those definitions, it was possible to construct a proto glossary with biunivocal relations between them.

Keywords

Occupational Health and Safety, Risk Management, Terminology

1. Introduction

As stated in [1], occupational health and safety (OH&S) is a developing branch of knowledge. As this is a field composed by knowledge from different sciences, which uses specialist terms and expressions, its terminology is sometimes a source of ambiguity, often difficult to understand and interpret, or subject to general agreement when employed in OH&S debates. The terminology adopted may therefore be at the origin of controversy among experts from different areas and sciences, with different views and concepts, which may become a constraint to smooth discussion.

It is broadly accepted that all OH&S concepts are somehow risk-related, as risk is an integral part in occupational health and safety. Risk and safety are, in fact, conceptually and pragmatically linked. Usually, risk is defined as the likelihood that something unwanted can happen, while safety is the absence of unwanted health harmful events, that is, the absence of risk [2]. And although the risk concept has always been related with culture and language, even at a technical level the different languages deal with risk in an imprecise and dispersed way. The same concept appears with different definitions and associated with different terms; the same term is used to characterize different concepts; redundant terms are common.

Any science needs, to consolidate, a conceptual and terminological scheme that is comprehensive, uniform and, above all, coherent, which may ensure that all stakeholders understand what is meant; a terminological scheme that lays consistent and quality foundation.

It is, particularly, within the scope of Safety Engineering, where this need stands out, that the present systematization proposal is focused.

2. Methodology

The current paper aims to extend the research of an early paper [1]. Definitions were proposed, and terminology validation criteria were established. A set of bibliographic references was revised, which have now been revisited, adding the most recent literature.

This will be the basis for the development of the current work. Hence, risk will be approached as a core concept, conditioned by a logical tree of antecedent concepts and from which a set of consequent concepts is derived. The risk management process can be considered as an engaging concept such as safety, globally understood.

Figure 1 outlines the logical relationship of the various concepts to be defined. It is, of course, a restricted enveloping universe, which does not aim to encompass the entire terminological edifice related to the concept of risk.

Naturally, in this scheme, only the most significant levels are referred to in relation to the core concept.

Further investigation can lead to a more comprehensive document which can be assumed as a Glossary of terms, definitions, and concepts.

3. Results and Discussion

The definitions of terms associated with the concepts used are based on theoretical assumptions and must be interpreted in their mathematical, physical, chemical, psychological, medical or legal meaning where applicable. Without necessarily excluding them, an attempt is made to avoid the use of legal interpretations.

Taking into account the scheme represented in **Figure 1**, some definitions of terms associated with concepts are presented below, with the respective justification and exemplification whenever necessary.

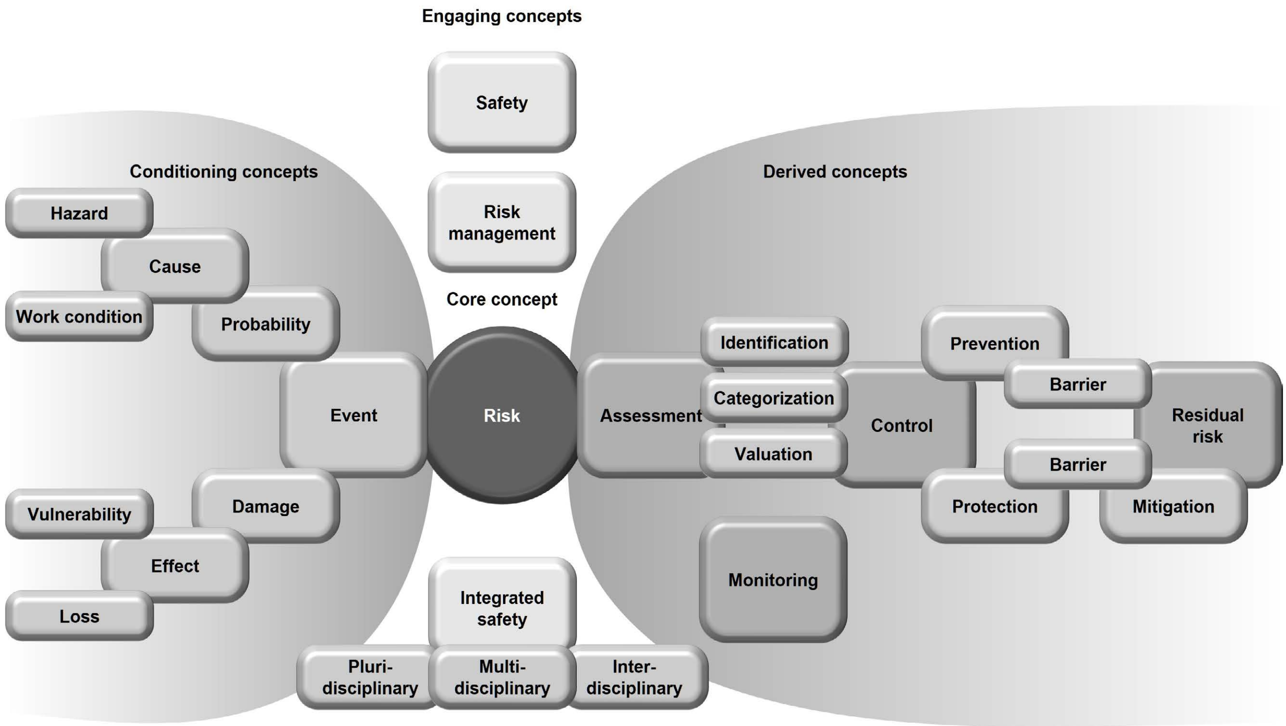

Figure 1. Terms related with the risk concept—conceptual scheme.

3.1. Risk (Core Concept)

Risk [3] can be defined conceptually, algorithmically or textually and corresponds to the logical equation: {Causes} ⇒ Event ⇒ {Effects}. Figure 2 represents the conceptual model of this definition.

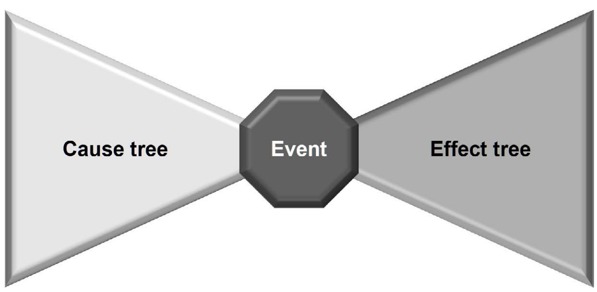

Figure 2. Conceptual definition of risk.

The valuation of risk, that is, an algorithmic definition of risk can be expressed as:

$R = p \cdot d$, where p is the valuation of the probability of occurrence of the event, associated with the cause tree and d the valuation of the damage eventually resulting from such an occurrence and contextualized in the respective effect tree.

These definitions can be translated, textually, by: Risk is the probability of occurrence of an event that could cause harm.

The probability results from a cause tree (convergent) and the damage is related to the effect tree (divergent).

3.2. Conditioning Concepts

Note that the risk definition presented introduces five new concepts, which are its immediate constraints:

3.2.1. Event (Conditioning Concept)

It can be defined as a situation that can occur with a certain probability—a risk situation—and that, if it occurs, may cause damage (proactive approach).

But it can also be understood as an incident—a hazardous occurrence—which resulted in damage (retroactive approach).

3.2.2. Probability (Conditioning Concept)

Ratio between the number of verified occurrences of an event and the number of possible occurrences of that event.

In the case under study, the probability results from the logical combination of the probabilities of occurrence of the causes, in case a risk situation is being dealt with. The probability of a hazardous occurrence is equal to one.

3.2.3. Damage (Conditioning Concept)

Quantification, normally on a discrete scale, of physical and psychological injuries, material losses, environmental, social, economic, or political consequences, of the eventual occurrence of an event.

To assess the damage, it is necessary to consider the direct damages—quantifiable—and the indirect damages—estimable—not necessarily translatable into monetary units.

Various risk assessment methods quantify damage based on only a few measurable aspects [4]. In view of the previously proposed concept of damage, such practice is acceptable, provided that the quantifiable factors considered effectively represent the damage resulting from the occurrence of the event.

The location and severity of injuries to people implies a certain number of days off, as well as possible (permanent) reductions in work capacity. Equipment that is partially or totally unusable implies the need for its repair and probable replacement with quantifiable costs associated with both repair/replacement work and eventual downtime in the production chain. Production stoppages imply a reduction in the ability to fulfil orders with negative consequences for the company's image, but which is normally very difficult to quantify financially, particularly since this damage can be spread over several years.

3.2.4. Cause (Conditioning Concept)

Antecedent of the event in a convergent logic tree [5]. A probability of occurrence of the event results from the set of causes, considering the logic gates and the levels of significance.

However, the concept of cause can also be derived from two other concepts that relate to each other as pairs, that is, each hazard/work condition pair results in a cause [4].

The same hazard, under different working conditions, leads to different causes. Similarly, when several hazards are present in the same working condition, the resulting causes for the occurrence of the event are different.

A task carried out in a place close to dangerous machines operating in the vicinity can result in an accident that can be classified as "stuck between objects" whose cause is objectively the operation of these machines in the vicinity. The same task carried out in the same place, but in addition to a noisy environment, will have two causes: the operation of machines in the vicinity and the noisy environment, since this also contributes to increasing the accident by reducing the perception of the presence of machines.

1) Hazard (second-level conditioning concept)

Intrinsic characteristic of a product, a substance, a machine, an equipment, a task, a person, which could be the cause of an injury or a dysfunction.

It is an absolute concept, that is, it is a characteristic or property of the element in question, which manifests itself independently of the circumstances, dimensions, location, constitution that it presents.

It is common to find, namely in the bibliography and legislation, two terms that can be understood—at least for the purposes of the proposed terminological structure—as synonyms of Hazard: Risk Factor and Agent. Being conceptually equivalent terms, they are used in specific contexts. The term Risk Factor is used to identify hazards related to psychosocial and organizational risks (e.g. monotonous/repetitive work and shift work) and the term Agent is used to identify biological agents (some viruses and bacteria) and chemicals (toxic chemicals). However, both definitions fit the presented—more generic—definition of Hazard.

2) Working condition (second-level conditioning concept)

How a hazard can become effective, including quantities, storage or use of products, facilities, processes, work environment (physical, chemical, or psychological), among others.

That is, a hazard, by itself, does not constitute a cause of an event. It needs to be associated with a certain working condition. It is from this pair that a situation results, which can contribute, as a cause, to the occurrence of the event.

Methane (CH_4) is dangerous because it is flammable. But an ampoule with one centilitre of methane will not be a significant cause of a harmful event. Here, quantity—working condition—is decisive.

3.2.5. Effect (Conditioning Concept)

Consequent of the event in a divergent logic tree [5]. The set of logically related effects permits to assess the damage possibly resulting from the occurrence of the event.

An effect results from a susceptibility to damage [4] to which two complementary situations contribute:

1) Loss (second-level conditioning concept)

Loss of work capacity, material loss, consequences for the environment or for the community.

2) Vulnerability (second-level conditioning concept)

Inverse of the ability of a system to resist internal or external aggression.

This set of concepts restricts the definition of risk. The concepts that define the way in which that risk can be dealt with, with the fundamental objective of controlling it, can be derived rooted in that definition.

3.3. Derived Concepts

3.3.1. Assessment (Derived Concept)

To control a risk, first and foremost it is necessary to assess it. This means that risk assessment can be defined as the methodology that enables to know, as profoundly as possible, the risks present in a production process.

This in-depth knowledge requires a methodological treatment based on three sequential steps [6]: Identification, Categorization and Valuation.

1) Identification (second-level derived concept)

Detection of risks present in the production process in a systematic and descriptive way based on a model (operational, algorithmic, or conceptual) that is representative of that process. This is a necessary but not sufficient step.

2) Categorization (second-level derived concept)

Awareness of risks, typifying and characterizing them, which implies the elaboration and interpretation of trees of potential causes and trees of possible effects. This is a necessary and sufficient step, considering the essential objective of the assessment, that is, to gather data and knowledge that allow an effective risk control.

3) Valuation (second-level derived concept)

Measuring risks with their hierarchy and scaling into defined risk levels according to reliable criteria [7]. It is a complementary step, an added value to the results of the previous step, hence increasing the conditions under which the control can be carried out and, therefore, its efficiency.

3.3.2. Control (Derived Concept)

It is the main step of the risk management process (see 2.4.1). Once the risks are known, it is possible to control them, that is, to elaborate, design and implement barriers leading to their minimization.

Note that it refers to minimization and not elimination. In fact, the null probability (impossible event) or the null damage (innocuous event) that, in $R = p \cdot d$, would result in a null risk, are not considered in the risk study, that is: $R \in]0; 1[$ with $p \in]0; 1[$ and $d \in]0; 1[$.

Risk control can focus on the cause tree and/or the effect tree [5], minimizing the probability of an event (prevention) to occur and/or minimizing the damage that may result from that occurrence (protection). From this observation, new derived concepts result.

1) Prevention (second-level derived concept)

Action with the objective of minimizing the probability of occurrence of a risk situation. It is a proactive concept because it is applied to a possible situation.

The use of explosion-proof equipment in ATEX atmospheres reduces the like-

lihood of ignition sources to occur and, consequently, of explosion.

Specific training on electrical hazards for workers performing tasks in the vicinity of electrical installations reduces the likelihood of contact with electrical current.

2) Protection (second-level derived concept)

Action with the objective of minimizing the damage that may result from the occurrence of a risk situation. This is, also, a proactive concept as it applies to something which may occur.

Task rotation minimizes the severity of musculoskeletal injuries caused by certain repetitive and/or straining movements.

A fire extinguisher, adequate in terms of capacity and extinguishing agent, minimizes the damage that can be caused by a fire.

3) Mitigation (second-level derived concept)

Action with the objective of reducing the damage effectively caused by the occurrence of the event. In this case, there is a retroactive concept as it is used when an occurrence has been detected.

Organizing work times to limit presence in environments with high noise levels reduces hearing loss from noise exposure.

4) Barrier (second level derived concept)

Device, procedure, or action which results in the minimization of the probability (prevention barrier) or of the expected damage (protection barrier).

A guardrail minimizes the likelihood of falls from a height (prevention barrier) and a safety net or a harness attached to a lifeline (protective barrier) minimizes injury resulting from a fall from a height.

But, as mentioned earlier, risk cannot be eliminated, only minimized. Barriers never have a reliability of one [8]. This means that there will always be risk situations that could be the origin of damaging events. This conclusion results in the concept of remaining risk.

3.3.3. Residual Risk (Derived Concept)

Uncontrollable or uncontrolled risk that implies a non-zero probability of a harmful occurrence.

Unknown risks, namely in scientific terms, are considered uncontrollable. Once science identifies and characterizes the risk, it becomes controllable.

A typical example is the case of asbestos, which was broadly used before its carcinogenic properties were known.

Controllable but uncontrolled risk is understood to be the risk that results from the difference between minimization and elimination, that is, the risk that depends on the technical, human and economic capacity for the efficient application of control barriers. It is this last concept that allows identifying remaining risks and assuming them (see **Figure 3**).

There might be technological solutions capable of controlling certain risks. However, an assessment of the cost/benefit ratio may make its application currently unfeasible.

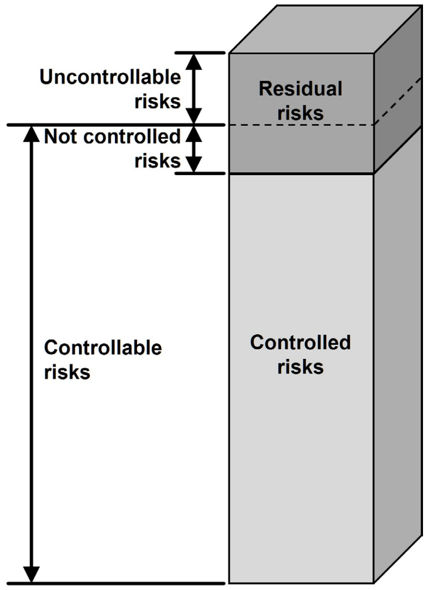

Figure 3. Controlled risks and residual risks.

3.3.4. Monitoring (Derived Concept)

Any management process, namely the risk management process (see 3.4.1), must include a step that allows auditing results and incorporating new technical-scientific advances and relevant organizational changes.

Monitoring can therefore be defined as the recurrent step of the risk management process which, analysing the results of the control phase, identifies, on the one hand, inefficiencies in the safety barriers and, on the other hand, dynamic changes in the production process, such as new equipment, changes to the staff, training actions, use of new products, new market requirements, new legal directives, new environmental constraints, among others.

The effectiveness of noise control measures implemented by occupational safety can be monitored in audiometric exams evaluated by occupational medicine.

The effectiveness of the ventilation installed and the maintenance of its proper functioning, in a given workplace where certain toxic agents may be present can be monitored in blood or urine tests where the specific biological markers of these toxic agents are measured.

3.4. Engaging Concepts

In the methodological scheme proposed by [1] engaging concepts are those that encompass both restricting and derived concepts and, naturally, the core concept.

Such concepts are either paradigms that include the various interrelated concepts and link them in a coherent methodological structure, or paradigms that correspond to a perception that is more global, systemic and comprehensive.

3.4.1. Risk Management (Engaging Concept)

The concepts of risk assessment, risk control and remaining risk are sequential steps of a management process, in this case, risk management. To these three steps the recurrent phase of monitoring the process must the added.

Therefore, the risk management process can be defined as a sequential and recurring process, whose main objective is to minimize the known risk, always considering the existence of residual risks and the dynamic characteristic of the risk concept itself (Figure 4).

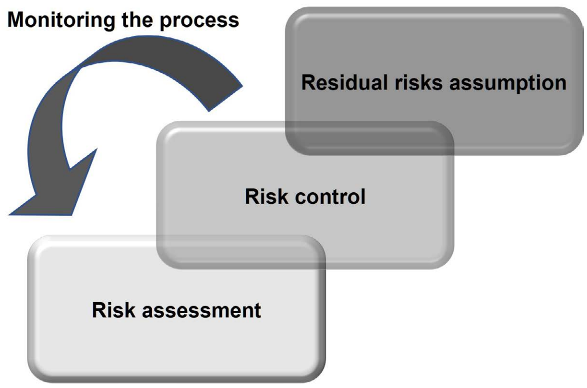

Figure 4. Risk management process.

Analysing this definition, one may conclude that risk control is the main, necessary and sufficient step of the process. The assessment step can be understood as a necessary but not sufficient step, while the assumption of the residual risks is a necessary and complementary step. Naturally, the recurrent step of this process—monitoring—represents the dynamic behaviour of the concepts.

Note that the different steps are not unquestionable compartments (one begins where the other ends), but rather presenting intersections—interface zones—for the passage from one step to the other (see Figure 5).

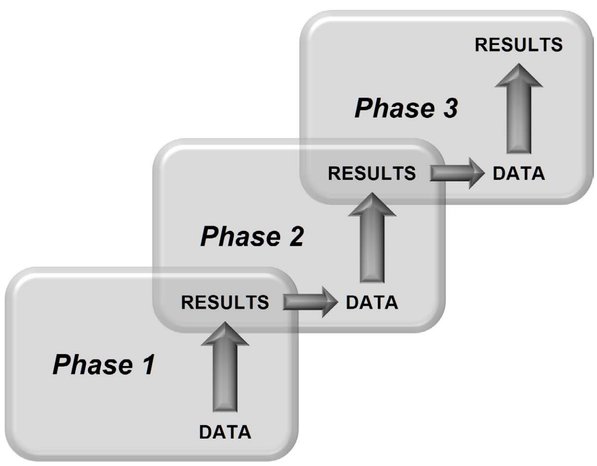

Figure 5. Sequential phases with interfaces.

3.4.2. Safety (Engaging Concept)

The term safety has several meanings, depending on the language level where it applies. However, in a technical-scientific context, it is imperative to clarify this meaning and use the term in a one-to-one exclusive way related to the respective concept.

It is, therefore, the concept of safety understood in a technical sense that it is important to define here. Hence, safety will be the risk inverse, as stated as: S = 1/R.

This algorithm enables to associate the concept of security with that of risk, thus making explicit terms also used as safety management or integrated risk.

3.4.3. Integrated Security (Engaging Concept)

The introduction of new concepts in this scheme, such as multidisciplinarity, pluridisciplinarity or interdisciplinarity, associated with systemic approaches to risk leads to the concept that can be defined as the global, systemic, and dynamic treatment of risk management, considering all types of risk and all methodologies capable of controlling them [3] [7] [9].

1) Multidisciplinary (engaging concept)

Approach from different angles—and, naturally, framed in different technical-scientific areas—which result in specific views that are intended to be complementary.

For example, occupational safety, occupational hygiene, ergonomics, occupational medicine and psychosociology of work.

2) Pluridisciplinarity (engaging concept)

Use of specific knowledge of a given subject or science for a common purpose.

Knowledge of acoustics is used for the treatment of surfaces to avoid reflections of sound waves and for the creation of barriers to prevent its propagation (*collective protection*), *but also in the design of ear protectors* (*individual protection*).

3) Interdisciplinarity (engaging concept)

Search for synergies between the different approaches, with the aim of finding global and integrated solutions.

Controlling the risks associated with noise can be carried out in an integrated manner: among other actions, designing inherently noisy workplaces with the implementation of effective acoustic insulation solutions, organizing work to minimize the dwell times, guaranteeing adequate maintenance of the noisiest machines, providing specific training on the risks associated with noise and ensuring audiometric surveillance in health exams.

3.5. Basic Glossary

Recapitulating the above considerations, the [concept ⇆ definition] relationship can be summarized, as shown in **Table 1**, in the form of a glossary, obviously reduced.

Table 1. Glossary.

Concept		Definition
Core	Risk	Probability of occurrence of an event that could cause damage
	Event	Situation…
Conditioning	Risk situation	…that can occur with a certain probability and which, if it does occur, may cause damage
	Hazardous occurrence	…occurred, resulting in damage

Continued

	Probability	Relationship between the number of real occurrences of an event and the number of possible occurrences of that event
	Damage	Quantification, usually on a discrete scale, of physical and psychological injuries, material losses, environmental, social, economic or political consequences, of the eventual occurrence of an event
	Cause	Antecedent in a convergent logical tree. Probability of occurrence of the event results from the set of causes, taking into account the logic gates and the levels of significance
	Hazard	Intrinsic characteristic of a product, a substance, a machine, an equipment, a task, a person, likely to be the cause of an injury or a malfunction
	Working condition	How a hazard can become effective, including quantities, storage or use of products, facilities, processes, work environment (physical, chemical or psychological), among others
	Effect	Consequent of the event in a divergent logical tree. The set of logically related effects allows to assess the damage eventually resulting from the occurrence of the event
	Loss	Loss of work capacity, material loss, consequences for the environment or for the community
	Vulnerability	Measure of the ability of a system to resist internal or external aggression
Derived	Assessment	Methodology that allows to know, in the most profound way possible, the risks present in a production process
	Identification	Detection of risks present in the production process in a systematic and descriptive way based on a model (operational, algorithmic or conceptual) representative of that process
	Categorization	Awareness of risks, typifying and characterizing them, which implies the elaboration and interpretation of trees of potential causes and trees of possible effects
	Valuation	Measuring risks with their hierarchy and scaling into defined risk levels according to reliable criteria
	Control	Elaboration, design and implementation of barriers leading to risk minimization
	Prevention	Action with the objective of minimizing the probability of occurrence of a risk situation
	Protection	Action with the objective of minimizing the damage that may result from the occurrence of a risk situation
	Mitigation	Action with the objective of reducing the damage effectively caused by the occurrence of the event
	Barrier	Device, procedure or action resulting in the minimization of the probability (prevention barrier) or of the expected damage (protection barrier)
	Assumption of the…	Financing or transferring liability for compensation for damages resulting from a…
	…residual risk	…uncontrollable or uncontrolled risk that implies a non-zero probability of a hazardous occurrence
	Monitoring	Recurring step of the risk management process, which, analysing the results of the control step, identifies, on the one hand, inefficiencies in barriers and, on the other hand, dynamic changes in the production process
Engaging	Risk management	Sequential and recurring process, whose main objective is to minimize the known risk, always considering the existence of residual risks and the dynamic characteristic of the risk concept
	Safety	The inverse of the Risk: $S = 1/R$
	Integrated safety	Global, systemic, and dynamic treatment of risk management, taking into account all types of risk and all methodologies capable of controlling them
	Multidisciplinarity	Approach according to different technical-scientific areas with specific yet complementary results
	Pluridisciplinarity	Use of specific knowledge and methodologies of a given science with a common objective
	Interdisciplinarity	Enhancement of synergies between the different approaches

4. Conclusions

Considering the objectives of the current study, the proposal of a coherent terminological structure that fits the concepts present in the context of the concept of risk, in a scientific and technical perspective, is introduced, justified, and exemplified. Such an approach is based on the interdependence of relationships, on their systemic character and on the antecedent/consequent paradigm, characteristic of logic trees.

This systematization allowed the elaboration of a proto glossary, in which the concepts and their respective definitions are characterized by a one-to-one exclusive relationship, thus promoting their coherence and applicability.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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