An ontological and semantic foundation for safety science

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An ontological and semantic foundation for safety science

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ABSTRACT: This article proposes an ontological and semantic foundation for safety science, based on an etymological and etiological study of the concepts of risk and safety. The awareness regarding the concepts of safety and risk have both evolved in similar ways because of increasingly more demanding situations and events that impact society in an economic way, also linked to the value of human lives. From a purely negative view on risk and safety, this awareness has grown into a more systemic and even holistic perspective on these concepts. The proposed foundation is aligned with the semantics and concepts used in the ISO 31000 risk management standard. Based on this foundation, the article also advocates a theoretical model and a metaphor on how to look at safety and performance in any organization.

1 INTRODUCTION

When one talks about safety, risk or performance, everyone understands what is being talked about. There's no one who doesn't grasp what the words mean in one's own perception and how they can be understood. However, when opening a discussion on what these concepts really are, and how one should study or deal with them, it is most likely to end up in ontological and semantic debates due to different views, perceptions and understanding.

Science is served with clear concepts and well-defined parameters. Because, having these concepts and parameters allows for exact measurement of observations and in its turn, this opens the opportunity of accurate analysis, which then can be used to develop sound theories and practices. When studying in the field of safety science (a relatively young field of science), it is hard to find unambiguous definitions and parameters that clearly link safety, performance and risk.

When reviewing the safety science literature, the question "what is safety" is answered in many ways and it is very hard to find a clear definition of its opposite, which we could also name 'unsafety'. Likewise, there is also a lack of standardization when it comes to defining its opposite. Terms like accident, incident, mishap, disaster, catastrophe, etc. have different meanings depending on the persons or fields of knowledge using these commonly used words.

Because there is no commonly accepted way to define safety and its opposite, it becomes very difficult to measure and compare the level of safety of situations and organizations in an unambiguous or objective manner, certainly amongst different sectors or societies. Also, it is more difficult to think of proactive solutions that generate safety instead of developing reactive methods that prevent unsafety.

Although the field of safety science is relatively novel as a separate and independent domain of study, many theories, models and metaphors have already been proposed, attempting to describe what safety is and how it can be achieved. Often these theories are drawn from the investigation of – and lessons learned from– catastrophes and disasters. As such, these theories are often justified by explaining how these mishaps came about. Therefore, in general, efforts to improve safety of systems have mostly been driven by hindsight, both in research and in practice (Woods and Hollnagel, 2006).

2 EVOLVING PERCEPTIONS REGARDING SAFETY (SCIENCE) AND RISK (MANAGEMENT)

Safety and risk are two concepts that are tightly coupled and have known similar evolutions in their development and in how people understood these concepts. Also, the evolution on how people have dealt with risk and safety is very much comparable. Safety and risk are often perceived in a similar way and are regularly used as antonyms. Risky often means unsafe and safe often means without or protected from risk (as indicated in many dictionary definitions of safety). And, when looking at the past, one can see that ideas about safety and risk have evolved in a very analogous way and for comparable reasons.

2.1 *A historical perspective on risk management, the etymology of risk and its etiology*

2.1.1 *Ancient times*

For thousands of years, people considered all that happened being the will and acts of the gods (Bernstein, 1996). So, the general idea was that whatever one tried, things finally always happened to the will of the gods and there was nothing to do about it but to accept it.

However, this doesn't mean that concepts as risk and safety were strange to people. In their article "Risk analysis and risk management: an historical perspective", Covello and Mumpower (1985) describe how in the Tigris-Euphrates valley, about 3200 B.C. the Asipu already offered a kind of consultancy services related to risk and safety.

2.1.2 *The Renaissance and modern time period*

The serious study of risk started during the Renaissance and it took until the work of Pascal in the 17th Century to see a sudden progress in the understanding of risk and decision making based on numbers.

In this time period science was on the rise and it was a period of expanding trade of new and scarce products, transported overseas. This created a new reality. Trade oversea to distant regions and countries was a high-risk endeavor. This economic factor made people become more aware of the concept of managing risk. Soon, the insurance industry emerged as an effort to manage risk in commerce. Wealth was no longer the privilege of the happy few, but could be earned by investing in trade and making the right decisions (Bernstein, 1996; Covello & Mumpower, 1985).

2.1.3 *20th century*

Although the etymological roots of the term risk, can be traced back as far as the late Middle Ages, the more modern concepts of risk appeared only gradually, with the transition from a traditional to a modern society. With larger and ever more complex technology systems emerging after the second World War (e.g. nuclear installations), the focus on probability and risk supported a scientific, mathematically-based approach toward risk and risk assessment (Zachmann, 2014).

Later in the twentieth century, with standards of living quickly rising after World War II, other objectives became also important and the concept of managing risk expanded from a mathematically-based approach to include also more qualitative methods. Hence, the origins of operational risk management, which can be traced back to the discipline of safety engineering (Raz & Hillson, 2005).

Continuing losses, injuries and casualties, triggered the US Armed Forces and NASA to develop risk management proposing a more comprehensive approach, called Operational Risk Management (ORM), adapting the world of risk management to the human factor involved in day to day operations. However, by the end of the century further development of the concept of operational risk management expanded the view on risk from a loss and probability perspective to a systemic view, shifting attention from probability to achieving goals.

In the same period of time, due to scandals such as the Barings Bank (1995), the dot.com bubble (1997–2001) and ENRON (2001), people became ever more concerned with the management of risk and the good ethical practices in managing organizations. During this last decade of the twentieth century, there has been a major surge of interest in improving the ability to deal with an uncertain future, and at that time, still with a focus on the negative impact at the organizational level. Operational risk scarcely existed as a category of practitioner thinking at the beginning of the 1990's, however, by the end of that decade, regulators, financial institutions and practitioners could talk of little else (Power, 2005). At that time, the first risk-related standards were published (Raz & Hillson, 2005).

2.1.4 *21st century*

The changes that emerged during the last quarter of the 20th century persisted and ongoing changing ideas concerning risk management generated an increasing understanding of the concept of risk, as modern risk management evolved substantially due to factors such as the rise of knowledge-intensive work, an expanding view on stakeholders, a growing importance of project management, the expanded use of technology, increased competitive pressure, increased complexity, globalization and continuing change (Raz & Hillson, 2005).

This growing concern and increasing awareness regarding risk management at the turn of this century led to the development of a whole range of additional risk management standards. These standards were issued by governments (Canada in 1997, United Kingdom 2000, Japan 2001 and Australia/New Zealand 2004), International institutions (IEEE-USA 2001, CEI/IEC-CH 2001) or professional organizations (IRM/ALARM/AIRMIC-UK 2002, APM-UK 2004, PMI-USA 2004). Each of these standards, coming from different perspectives, reflect an increasing understanding of risk and risk management, proposing different definitions of risk and comparable processes to manage risks. At that moment in time, a shift occurs from a purely negative view on risk, still expressed in the definitions of some of those (older) standards (CAN/CSA-Q850-97:1997 and IEEE 1540:2001) to more neutral or even very broad definitions of risk in the other, more modern, standards. Another remarkable aspect of the "newer" definitions is the fact that risk is more explicitly linked to objectives and that the effects of uncertainties on objectives (consequences) can be positive, negative or both (Raz & Hillson, 2005).

2.1.5 *Enterprise Risk Management (ERM)*

Also in the first decade of this century, and due to a number of scandals—similar to ENRON, there is an ever-increasing attention for corporate governance and the role of operational risk management in that regard. This resulted in the first internationally used comprehensive corporate standard on risk management, the COSO Enterprise Risk Management Integrated Framework (2004). (Mestchian et Al, 2005). Enterprise Risk Management (ERM), similar to ORM in the military and aviation sectors, is the more holistic approach that is needed to cope with the complex realities and awareness of risks for the corporate world in the 21st century.

However, the COSO ERM framework, developed as an auditing tool to check compliance, failed during the 2008 financial crisis, because organizations implementing ERM would still follow the reductionist approach these organizations were used to. So, the International Standardisation Organisation (ISO), set out to establish a working group to achieve consistency and reliability in risk management by creating a standard (ISO 31000) that would be applicable to all forms of risk and to all kinds of organizations, creating a foundation for risk management (Purdy, 2010).

Little real progress could be made with the ISO standard until all agreed on a definition of risk that arose from a clear and common understanding of what risk is and how it occurs. The working group arrived at: "*risk is the effect of uncertainty on objectives*". When risk is defined like this, it reveals more clearly that managing risk is, quite simply, a process of optimization that makes the achievement of objectives more likely, objectives being understood in the broadest sense of the word. Successfully detecting and understanding risk, including how it is caused and influenced, allows, if necessary, to change it so that it is more likely to achieve objectives and reach them faster, more efficiently, and with improved results. (Purdy, 2010)

The specific way in which risk is regarded by the ISO 31000 standard also broadens the understanding and attention of risk management towards performance, instead of solely focusing on compliance or the prevention of loss.

2.2 *Evolution of awareness in safety science*

Compared to the other sciences, surprisingly little attention has been given to the history of safety. (Guarnieri, 1992). As such, the following sections only try to give an indication of how and why the perspective of safety changed over time.

2.2.1 *The industrial revolution*

Safety science, similarly to risk management, originated because of a need to cope with uncertain profit, the failure of maintaining possession of valuable assets and the accidental injury or loss of workforce. In the same way expanding views impacted the etymology of the concepts of risk and risk management, ever-increasing awareness and knowledge regarding the concepts of safety and safety management has also impacted the etymology of safety and safety science.

The industrial revolution and the appearance of new technologies provoked reoccurring and severe accidents, damaging valuable assets, causing severe casualties and injuries to workers. In the beginning these accidents are just seen as set-backs, caused by workers behavior and part of the business. However, during the second industrial revolution, starting at the end of the 19th Century, the ongoing mechanization and new technological developments are used to develop new industries. Furthermore, production engineering substantially increased productivity with the advent of mass production. As a result, life was getting better, incomes were rising and mortality was declining. (Mokyr, 1998). These rapid economical, technological and social changes also triggered the dawn of safety as a science.

Accidents have always been a problem. Yet they did not appear as a major economic and health issue until the early 1800s when the declining death rate from infectious diseases shifted attention to other causes of mortality (Guarnieri, 1992). Accidents in a production line are costly, not only due to the casualties and lost workforce, but also the loss in production and production capacity are a burden to the profitability of the new factories. Furthermore, these accidents are responsible for a high mortality in the industrial world, leading to a bad reputation. Due to the rising prosperity, this is no longer acceptable. Accidents are no longer acts of God, but man made and can be prevented. (Swuste et al, 2010).

From the start, the awareness about risk and safety, risk management, safety management and safety science were triggered by the possibility of adverse effects, impacting on the profitability of endeavors and related to new emerging sectors. Both trying to accommodate for losses that impact that profitability. Risk, as such, became the domain of insurers and the start of a whole financial industry to compensate for financial losses. Likewise, safety science started with focusing on accidents, injuries and casualties and their prevention. In both cases, people drifted away from what they really needed, which is safeguarding and achieving objectives, getting what they want and being safe.

One of the first theories on safety is about accident proneness (Farmer, 1925). However, the accident proneness theory only looks at one possible cause of accidents and therefore cannot explain accidents in a general way.

Heinrich observed production facilities to discover trends and patterns in occupational accidents, resulting in Heinrich's pyramid or triangle (Heinrich, 1931). Heinrich also proposed his Domino theory on accident causation when studying the cost of accidents and the impact of safety on efficiency, opening up the perspective to the role of management in accident prevention (Heinrich, 1941). Heinrich's domino theory became a basis for many other studies on accident causation and the role of management in accident prevention, dominating the world of safety practitioners well beyond the Second World War (Hosseinian & Torghabeh, 2012).

2.2.2 *After World War II*

Heinrich's research and work inspired other researchers, also to incorporate the role of management in their models. For instance, Petersen (1971) developed a model based on "unsafe acts" and "unsafe conditions" and Weaver (1971) and Bird (1974) updated the domino model with more emphasis on the role of management. (Hosseinian & Torghabeh, 2012; Swuste et al, 2014).

At the beginning of the second half of the twentieth century, Gibson (1961) and Haddon (1970) focused on the causation of injuries, discovering a formula for injury prevention. This shift in focus, also caused safety science to look at engineering to reduce injuries, leading to safety belts, bumpers and many other devices capable of absorbing or deflecting energy (Guarnieri, 1992). In this period of time, also the introduction of the "hazard" – "barrier" – "target" model and tools, such as Failure Mode and Effect Analysis (FMEA), Hazard and Operability Analysis (HAZOP), the Energy Analysis approach and so on, are to be noted. (Swuste et al, 2014)

Similar to the evolutions in risk management, safety science further evolved as a result of a series of accidents which had a huge impact on society. Flixborough (1 June 1974), Seveso (10 July 1976) and Three Miles Island (28 March 1979) are part of the history of safety science, provoking a broader perspective on safety and increased safety regulations. This enlarged awareness about safety, also reflects in the increasing political attention for safety related issues and the rise in associated regulations, clearly demonstrated by the advent of a number of safety related scientific journals in the last quarter of the twentieth century (Hale, 2014). Investigating these accidents, expands the awareness of safety practitioners from the role of management, to interactions in the entire socio-technical system.

2.2.3 *More major accidents and disasters*

The socio-technical concept arose in 1949 (Trist, 1981). However, at that time in the fifties, the societal climate was negative towards socio-technical innovation. This would only change thirty years later (Walton, 1979). Again, alike the development of risk management and operational risk, safety science took up this wider organizational perspective on safety issues as from in the early eighties. At the same time, advances in technology also make safety engineering an indispensable part of safety science, with the development of safety equipment, for instance safety belts, air bags etcetera.

Another result of analyzing, amongst others, the Three Miles Island accident, is Charles Perrow's book, Normal Accidents (1984), in which the `normal accident theory' (NAT) is proposed. It has been particularly influential among researchers concerned to understand the organizational origins of disasters and the strategies which might be used to make organizations safer (Hopkins 1999).

Safety science further developed in the past thirty year as a result of another series of significant disasters, such as Bohpal (2–3 December 1984), Challenger (January 28, 1986), Tsjernobyl (26 April 1986), and The Herald of Free Enterprise (6 March 1987). Each of these accidents show the complexity of socio-technical systems. As a result, scholars try to model systems in order to predict their behavior. Building on the work of Rasmussen (1983), Reason (1990) proposes the Generic Error Modeling System (GEMS), later to become known as the Swiss Cheese model (of defenses) (Reason, 1997, 2016).

By the end of that disastrous decade, people also look at human factors and behavior, by introducing the notion of safety culture. It is loosely used to describe the corporate atmosphere or culture in which safety is understood to be, and is accepted as, top priority (Cullen, 1990). A more specific approach is the concept of Just Culture (Dekker, 2008, 2017). Furthermore, the concepts of 'High Reliability Organizations (HRO)' (LaPorte & Consolini, 1991; La Porte, 1996; Weick & Sutcliffe, 2001) and 'Resilience Engineering' (Woods & Hollnagel, 2006; Hollnagel, 2013) were introduced, looking at the whole organization.

Recent years have seen a whole range of models that try to model the taxonomy and structure of accidents. Some examples are the Systems-Theoretic Accident Modell and Process (STAMP) (Leveson, 2011) and the Functional Resonance Analysis Method (FRAM) (Hollnagel, 2012). Most remarkable is that FRAM is focused on safety instead of unsafety, going beyond the failure concept and the concepts of barriers and controls, aiming at the day to day performance. (Hollnagel, 2012). The idea is to achieve safety proactively. An idea further developed with the advent of the concepts of Safety-I and Safety-II (Hollnagel, 2014a). In his article, 'Is safety a subject for science', Hollnagel (2014b) indicates the difficulty to change the mindset in the safety science community from what is going wrong to what is going right.

In the new millennium, alike risk management expanded into a systemic/holistic view with the advent of Enterprise risk management, today these approaches come together in concepts such as Resilience Engineering, HRO and Safety-I & Safety-II. Ever more these modern concepts in safety are focusing on what people want and how to achieve it, instead of trying to protect against failure. Likewise, increasingly, scientists are looking for significant leading indicators in order to be more proactive in preventing accidents by achieving what is the aim. Concepts therefore also evolved from a purely negative view on risk and safety towards a more encompassing view, also considering the positive sides of risk and safety. Now the focus is gradually more on safety instead of solely concentrating on unsafety.

3 INCREASING AWARENESS SEEN FROM A SYSTEMIC PERSPECTIVE – THE SYSTEMS THINKING ICEBERG

The above review of risk and risk management, safety models, metaphors and theories is far from complete. A more complete overview is to be found in reading the related references. We only wanted to show the changing etymology of the concepts of risk and safety, and its etiology, over a period of time.

A model that can help in getting a comprehensive view on the evolution of risk and safety is the systems thinking iceberg model (Bryan et al, 2006). The systemic iceberg model, is a way to look at reality from a systems perspective. The visible part of the iceberg, (above the waterline) represents *the events* that result from the system(s) involved. When events are observed over time, patterns and trends can be discovered. It is at this easy to perceive level of awareness of systems that safety science has originated. Still today, safety practitioners are driven by the facts that are directly visible, gathered in statistical data, trying to find and understand trends or delineate recognizable patterns related to the observed events. As such, they try to discover causal relationships and produce better predictions to prevent these negative events from happening.

The common approach to safety is to look at the events such as loss of life, injury, harm, damage, or any other event generating negative effects, trying to understand, predict and prevent accidents. As an example, the accident proneness theory can be seen as a result of that process.

Increasing awareness on accidents allows to become aware of the system of causes and effects that produces the unwanted events and that repeat themselves. It is what every accident investigation tries to achieve, i.e. the understanding how elements act together, in order to find ways to prevent them from happening again. When the system is understood, it is possible to proactively alter the system and prevent the same unwanted events happening. Through history, scholars have been searching for ways to explain why unwanted events happen and how disasters can be predicted, trying to discover the system(s) that is (are) behind their occurrence. One of the first to develop a theory on accident causation is Heinrich and his domino theory, naming the elements of the system that are involved in the creation of accidents and using the metaphor of domino blocks to represent the subsystems and their interaction. Also, NAT and the Brownian movements model (Rasmussen, 1995, 1997) can be seen as such.

To be able to predict or to obtain more understanding and control on the systems involved in accidents, scientists also try to determine the structure of the systems involved, getting a clearer view on the dynamics that are at the genesis of accidents. Recent years have seen a whole range of models that try to model and structure the systems that generate unwanted events. STAMP and FRAM can be seen as examples and there is also the Swiss Cheese model (Reason, 1997, 2016) and the models that build on the same human factor approach.

Finally, scientists and practitioners aim at developing understanding on how mental models generate the system(s) and how they can be controlled and managed. An example of a mental model generating safety is for instance the concept of Just Culture (Dekker, 2008, 2017).

4 A MODERN PERSPECTIVE ON RISK AND SAFETY

Safety is often defined as a dynamic non-event and mostly explained by the events that violated that state of dynamic non-events (Weick, 2011). The problem with this approach is that it only covers the domain of unsafety and leaves any interpretation of safety open. When safety thinking is linked with dynamic non-events it solely focusses on preventing bad things from happening. But is this the right approach in pursuing safety?

Is turning away from unsafety the same as aiming for safety? When one considers a situation of 100% safety, is this a situation where nothing is happening? This seems an impossible assumption. There will always be something happening, events and consequences (positive effects on objectives) one wants and events and consequences (negative effects on objectives) one doesn't want, both are important from a modern safety perspective. So, what is distinctive for safety to emerge, exist and persist? A modern perspective on safety, in the same way as a modern perspective on risk and risk management, looks at the whole picture. It starts with what people want to achieve, what needs to be safe and first make sure this will be achieved. It is making certain that the return on investment is attained when pursuing an opportunity. Hollnagel (2014) talks of Safety I and Safety II, where safety I is the traditional approach of avoiding losses while safety II is making sure the objectives are accomplished. In our view, this is how safety and safety science should evolve. It is about both the absence of unsafety and the presence of achieved and safeguarded objectives.

Nancy Leveson says that Safety is an emergent property of systems, not a component property (Leveson, 2011). It means Safety is something that needs to be achieved by the system, repeatedly. Obviously, a component can also be considered as a system on its own. Every system is made up of sub-systems which have other objectives than the overarching system. The safety of these sub-systems is important to the safety of the overarching system and each of them is subjected to a set of risk sources that can affect those more specific objectives.

4.1 *Total respect management*

The modern perspective on safety, and the mental model to achieve safety in a proactive way we propose, is called Total Respect Management (TR³M). Respect, in the way it is used for this model, is an expression originally derived from the Latin word respectus. Respectus comes from the verb respicere, meaning 'to look again,' 'to look back at,' 'to regard' or 'to consider someone or something.' In other words, the original meaning of the word 'respect' holds the connotation of giving someone or something dedicated attention to have a better view on the matter or give it consideration, particularly to come to a better understanding (Blokland & Reniers, 2017). As much as possible the systems, sub-systems (including the human factor) and their objectives need to be known and understood.

The reason for this 'respect' for systems and their sub-systems is the conviction that there is no common structure to all 'accidents'. This is also a way how we intend to look at the Swiss cheese metaphor. In this metaphor, the whole cheese is a reflection and representation of a socio-technical system and its performance. The cheese itself can be understood as excellent performance, where objectives have been achieved and are safeguarded (Safety-II). On the other hand, the holes in the cheese are the sub-systems of which the objectives are not achieved or safeguarded. As such, these are the different factors contributing to accidents (Safety-I). The model's hypothesis is that one can never know for 100% sure which sub-systems will fail at a given time or why and how they will become connected at a given time to produce a major accident and therefore it is important to give attention to all failed objectives and aim at reducing the number and magnitude of these failed objectives by increasing the level of performance.

Each hole in the cheese is considered being a "failed" objective and therefore unsafe. The Swiss cheese is dynamic. The holes constantly change positions and dimensions in an unpredictable way and could be seen as shifting around, coming and going, shrinking and expanding in response to operator actions and local demands (Reason, 1997).

Although the idea of layers of protection is useful to a certain extent, it only covers for Safety-I. Therefore, the TR³M model also focusses on performance as an element of safety. The aim of performance is to achieve objectives and maintain objectives safeguarded. As such performance stands for the whole cheese, or the whole concerned socio-technical system and the aim of TR³M is excellent performance (excellence) in that regard.

The way TR³M approaches the Swiss cheese metaphor is by stating that each of these latent conditions (failed objectives) can be seen as accidents on their own. It is just the level of importance and number of objectives involved that differentiates 'accidents' worth investigating from 'less important' holes. However, for TR³M each one of the holes is meaningful and needs one's respect. Hence the name 'Total Respect Management'. The holes/accidents result from (sub)systems, created by non-aligned or defective mental models existing in, or surrounding, the system (Blokland & Reniers, 2017).

Risk and the level of risk, in this sense, is nothing more than the possible effects on one's objectives due to the decisions taken and performance reached at a given time, representing a possible future reality. This reality will also determine the level of safety. The better this future reality can be imagined, the more it can be shaped to the desires and needs of the beholders by taking the right decisions at the appropriate time, generating safety proactively.

4.2 *A semantic connection between risk and safety and performance*

Regarding risk, ISO 31000 provides a whole set of definitions, also to be found in the ISO Guide 73. However, for Safety, in its broadest sense, there is no such internationally agreed standard and neither a modern and commonly used definition. A random selection of some definitions (Wikipedia, Merriam Webster, Dictionary.com) gives a traditional view on safety. Safety is a state, a condition, a control, a device, a quality or anything else that keeps us safe. Sure, we all know what safety means, it is being protected from harm, from bad things happening, but what does it really mean to be safe? So, how can safety and security be defined, taking into account the most recent ideas on safety and risk, inspired by the ISO 31000standard and its definition of risk? When are systems or people completely safe? Isn't it when one has attained all of ones objectives, when everything performs well and nothing affects ones objectives in a negative way?

Defining risk being the effect of uncertainty on objectives, means that three aspects define risk, namely; 'Objectives'; 'Effects on objectives' and 'Uncertainty related to the effects and the objectives'.

The proposed semantic foundation can be seen as follows: risk is an uncertain effect on objectives, while the actual performance is the result of that uncertain effect. Performance is Safety I + Safety II. It is why both concepts have evolved over time in similar ways and at a comparable timing.

Risk management, in a way, started closely related with gambling activities. Because professional poker players know that they don't win by chance or as a result of acts from the gods, but through carefully gathering information and analyzing/considering options based on that knowledge. It allows them to increase the probability that they make the right decision to support their aim of winning the game by taking more risk when it is appropriate to do so and limit the risks they take when it is the wiser decision, each time counting on the fact that the risks run are low for the decisions they take. However, they will only be safe when the game is over, all effects of uncertainty have their outcome and the profit has been paid. As such, safety and risk are the same, where risk, and how it is managed, determines the future of one's safety. Therefore, the same semantical foundation can and should be used.

4.3 *What is the usefulness of defining SAFETY in this way?*

This perspective on risk and safety, allows to develop a commonly used terminology for safety science and risk management. It will also allow to build systems that can measure safety instantly and in a much broader range than it is actual the case. Or better said, to measure 'unsafety'. Because measuring safety would require knowing all objectives present in a system and its sub-systems. This is impossible, because most of the time people are not aware of all of their objectives and also organizations are unable to know all the objectives of all their stakeholders. On the other hand, it is much easier to discover unsafety. Because when an objective has failed, it is likely to be seen or trigger a reaction. Human nature is designed to recognize unsafety, because it is necessary for survival. To measure unsafety, it is sufficient to measure all the holes to get an idea of the level of safety in the cheese.

4.4 *Safety first or first in safety*

The adagio "safety first", certainly from a traditional perspective, is fiction. When safety is the prevention of bad things happening, this credo is a real show stopper, as the safest thing to do for avoiding losses is to do nothing and prevent any activity. However, when you look at this motto from a fresh and modern perspective, it becomes a helpful mental model in achieving safety proactively. Safety first then means to achieve and protect objectives as a priority, aiming on excellent performance (safety II) and calling to action instead of inaction. When this is the governing paradigm, it will also become possible to be the first in safety, aiming at excellence. Because also safety performance will be an objective to be achieved and safeguarded.

5 CONCLUSION

In this article, we have expounded the evolutions of the concepts of risk and safety, how the awareness grew due to repetitive adverse effects on objectives and looking for ways to understand and cope with what had happened. We also indicated how the meaning of the concepts changed as a result of this increased awareness. To finally propose a new paradigm regarding safety and performance, linking risk and safety rather as synonyms, instead of treating them as antonyms.

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