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The Review of the Definition of Risk

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Abstract

In accordance with the Serbian legislation, occupational safety is the provision of such working conditions that, to the possible extent, reduce injuries at work. It is further stated that occupational injuries can be caused by exposure of employees to hazards, and risk is defined as the probability of injury to an employee. In engineering practice, however, the risk is commonly expressed as product of probability of the occurrence of an adverse event and the weight of the consequences of that event. The definition expressed by the risk management standard introduces the concept of objective, which is a significantly different concept. Since a concept discussed necessarily needs to be defined, this paper attempts to give an overview of the key efforts to define risk, to show differences and conditions, in order to enhance the understanding and work on the subsequent analysis and risk management, as well as to improve occupational safety.

Keywords: risk, perception, construction works execution, occupational health and safety.

Introduction

In accordance with the Serbian legislation, occupational safety involves providing such working conditions that reduce injuries at work to the highest extent. It is further stated that occupational injuries can be caused by exposing the employees to hazards, and risk is defined as the probability of the occurrence of injury to an employee. In engineering practice, however, risk is commonly expressed as the product of the probability of the occurrence of an adverse event and the weight of the consequences of such an event. The definition expressed by the risk management standard introduces the concept of objective, which is a significantly different concept. Since a concept discussed necessarily needs to be defined, this paper attempts to give an overview of the key efforts to define risk, to show differences and conditions, to enhance the understanding and work on the subsequent analysis and risk management, as well as to improve occupational safety.

Risk is a word that has various meanings to various people (Adams, 2014). It is a word that causes the feeling of urgency because it addresses detrimental, sometimes catastrophic outcomes. This misunderstanding greatly results from the lack of agreement about the meaning of the word itself. People use the same word to address different terms. If you asked ten different persons what they imply by the word risk, you would probably get ten different answers (Johansen & Rausand, 2014). Not only do the concepts of laymen and professionals differ, but there are differences within those communities as well. To illustrate, we shall quote several sentences using the word *risk* from the press (in July 2015):

"… leads to the conclusion that tobacco, to a moderate extent, can increase the risk of psychosis…"

"… the instability in Greece poses risk to the Balkans…"

"… this results in caution due to the risk factors mentioned, in particular, because of increased deterioration at the periphery of the Eurozone…"

"… and it is about risk that affects the proper functioning of the financial system in general, and not only a specific financial institution…"

"… when you download a program from an internet site, you do that at your own risk…"

"… because of that, the risk of the outbreak of a new world war is so great…"

"… we also face a unique mixture of geopolitical risks…"

"… inflation risks grow…"

"… can cause serious risks to our economy…"

"… on the one hand, there is a risk of a lasting conflict and the division of its territory…"

"… and accepts the technical and commercial risk…"

Concept

Risk is an important concept in a number of scientific fields, yet there is no consensus on how it is to be defined and interpreted (Aven, 2011). Some of the definitions are based on probabilities, others on expected values, some on uncertainty and others on objectives. Some authors regard risk as subjective and epistemic, depending on the knowledge available, some regard it as aleatoric, due to the probabilistic character of certain parameters, while yet others give risk the ontological status independent from the person assessing it. The situation has simply not been resolved in an authoritative manner. On the one hand, this certainly hinders efficient risk management and the development of the field, while, on the other, it is possible that there are rather good reasons for such a situation. Inevitably, specific areas require different methods, procedures and models of risk, for example, medicine and engineering. But the question remains whether these areas should have such disparate views on the concept of risk and uncertainty, when the challenge they face is essentially the same – creating a concept that describes the activity of the system resulting in outcomes different from the expected, desired or planned, or different from its objectives.

Since the meaning of risk varies with different situations and the human perception of those, a clear definition of the word risk has to be made. How can we discuss something then we have not defined what it is about? We proceed to give an overview of key definitions in chronological order.

1. Risk is the measure of probability and the weight of undesired consequences (Lawrence, 1976).
2. Risk equals the triplet (s_i, p_i, c_i), where s_i is the set of scenarios, p_i is the likelihood of that scenario, and $c_i$is the consequence of the scenario, i = 1, 2, ..., N (Kaplan & Garrick, 1981).
3. Risk equals the product of probability and severity (Wilson & Crouch 1982).
4. Risk is a combination of five primitives: outcome, likelihood, significance, causal scenario and population affected (Kumamoto & Henley, 1996).
5. Risk is a situation or event where something of human value (including humans themselves) has been put at stake and where the outcome is uncertain. (Rosa 1998).
6. Risk is the expression of influence and possibility of an accident in the sense of the severity of the potential accident and the probability of the event (MIL-STD-882D, 2000).
7. Risk is a combination of the probability and scope of the consequences (Risk Management Vocabulary ISO 2002).
8. Risk is an uncertain consequence of an event or activity related to something of human value (IRGC, 2005).
9. Risk equals expected damage (Campbell, 2005).
10. Risk is the likelihood of an injury, disease or damage to the health of employees due to hazards (Law on Safety and Health at Work, 2005).
11. Risk refers to uncertainty about and severity of the events and consequences (or outcomes) of an activity with respect to something that humans value (Aven & Renn, 2009).
12. Risk is the effect of uncertainty on objectives (Risk Management, ISO, 2009).

The definitions of risk stated are commonly used in practice. They can be categorized in several groups, in which risk is expressed:

1. By means of uncertainty and expected values
2. Through events/consequences and uncertainty
3. In relation to objectives

Various attempts have been made to establish a uniform viewpoint on risk, but none of them has been widely accepted in practice. This is due to various reasons.

- Firstly, scientific work on risk may not have fully developed for establishing such a general definition, i.e., there still remains research to be conducted.

- Secondly, the scientific literature focuses on the creation of new ideas, propositions and paradigms, as well as on the criticism of other contributions. Naturally, it is difficult to reach a broad consensus on scientific matters in general, and on the definition of risk in particular.
- Thirdly, organizations responsible for standardization are generally not capable of creating definitions broad and precise enough to be accepted by the scientific community.

The reasons for diverse perceptions, besides the diverse contexts and nature of problems to be solved, certainly lie in the diverse backgrounds of the theoreticians and practitioners as well (mathematicians or physicists, engineers, psycho-sociologists, etc.), as has already been stated in the previous chapter.

On Certain Definitions

Quantitative definition (Kaplan & Garrick, 1981)

In the level 1 definition, risk R is defined as a set of triplets

$$R = \{(s_i, p_i, x_i)\}, \qquad i=1,2,\ldots,N.$$

where s_i is the is a scenario identification or description; p_i is the probability of that scenario; and x_i is the consequence or evaluation measure of that scenario, i.e., the measure of damage.

Kaplan states that it is common to say that ‘risk is probability times consequence’. He considers this definition to be inconsistent and proposes instead, in keeping with the set of triplets idea, that ‘risk is probability and consequence’. In the case of a single scenario, the ‘probability times consequence’ viewpoint would equate a low-probability high-damage scenario with a high-probability low-damage scenario – which is clearly not the same thing. In the case of multiple scenarios, the ‘probability times consequence’ view would correspond to saying that the risk is the expected value of damage, i.e., the mean of the risk curve. If the scenarios are put in an increasing severity of damage order, then the risk curve can be made as in Figure 1.

Risk is not the mean value of the curve, but the curve itself. A single number is not a big enough concept to communicate the idea of risk. It takes the whole curve. The truth is, however, that a curve is not a big enough concept either. It takes a whole family of curves to communicate fully the idea of risk. This is the basis for the level 2 definition.

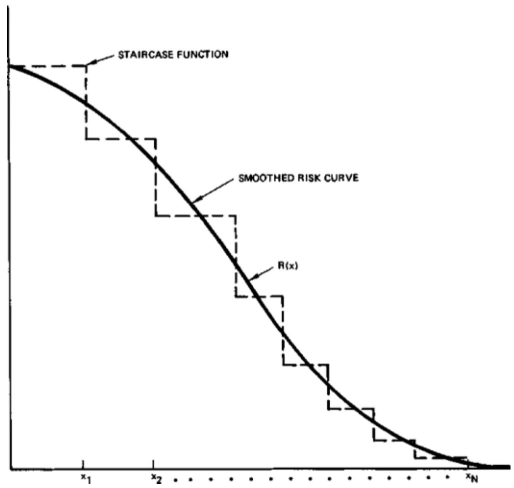

Figure 1. Risk curve (Adams, 2014)

In listing our set of triplets, it is obvious that the frequency of the occurrence of the scenario s_i has been disregarded. We would then express our knowledge about this frequency with a probability curve $p_i(\square_i)$, which is the probability density function for the frequency $\square_i$, of the i^{th}scenario. Thus we have a set of triplets in the form:

$$R = \{(s_i,p_i(\phi_i),x_i)\} \qquad (1)$$

which set of triplets, we could say, is the risk including uncertainty in frequency.

From set (1) we can construct the risk family in Figure 2, by cumulating frequencies from the bottom in a manner parallel to that used previously. Similarly, if there is uncertainty in the damage, we would also have the set of triplets:

$$R = \{(s_i,p_i(\phi_i),\ \xi_i(x_i)\} \quad (2),$$

or, more generally,

$$R = \{(s_i,p_i(\phi_i,x_i)\} \qquad (3)$$

using a joint distribution on $\phi_i,\square x_i$. In this case we can again construct the risk of family curves given in Figure 2.

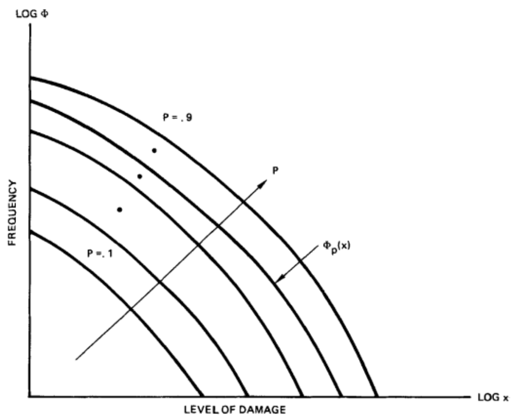

Figure 2. Risk curve in probability of frequency format (Adams, 2014)

The expanded level 2 definition of risk is presented in Figure 2, as well as the equations (1), (2) or (3). It expands the level 1 definition by including uncertainty. This is of particular importance in risk analyses, where scenarios are defined using fault trees and event trees, and where the fundamental input data on failure rates of components are uncertain.

Traditional engineering definition (Wilson & Crouch, 1982)

The traditional definition in the context of engineering is led by the authors Wilson and Crouch.

Risk = Certainty x Severity

In contrast to the definition (Aven, 2011), where it is stressed that risk is not the mean curve, but the curve(s) itself, (Wilson & Crouch, 1982) takes the mean curve in Figure 1 as risk. The authors admit that conditions are just perception. This definition is assessed as superior in the application of risk/benefit analyses. It gives a complex measure that is unambiguous, simple to use and capable of ranking alternatives. In the case of multiple events, measure is usually called expected loss or expected value. Since risk is defined as the product, it is assumed that probability and consequence can be formulated numerically. This is often not the case, for example, when the simplified risk assessment is used in combination with risk matrices.

When comparing levels of risk within this framework, catastrophic damage of low probability is measurable to smaller damage of high probability. However, fatal outcomes of a very low probability of occurrence cannot be envisaged by decision makers equally as small injuries of the high probability of occurrence, which is the result generated by the function of expected value. The two events illustrated are far from being proportional or equal (Sotic, Pavlovic & Ivetic, 2015). A hydrotechnical tunnel is not designed for a mean value of protocol, but for its maximal, extreme value; a bridge is not designed for a mean traffic load. Traditional expected value, which corresponds to risks of all ranges of damage weight, is only the central tendency of damage.

Haimes (Haimes, 2004) states that the relative importance of probability and consequences is distorted, thus masking the critical nature of extreme events such as a dam failure. (Aven & Renn, 2009) also criticizes definitions of this type arguing that events of low probability with potentially large consequences are equated with frequent events with lesser consequences. Since situations such as these require different strategies of management, definition (Wilson & Crouch, 1982) will probably hinder efficient risk management.

The expected value formulation is useful only in the simplest cases. It presupposes that the probability of loss is perfectly known and that the consequence can be estimated. The problem of this simple formulation is partly parallel to Heisenberg's principle (Heisenberg, 1927), i.e., the simplest artificially made cases excluded, it is impossible to know the exact probability and the exact consequence in the real world. For envisaging risks of extreme events in solving multiple problems of probabilistic nature, which cannot be encompassed by the traditional definition, methods have been developed such as partitioned multiobjective risk analysis (Sotic, Pavlovic & Ivetic, 2015), which determine conditionally expected risk values.

Papers must NOT exceed 20 pages, single-spaced with 6 points after the paragraph including tables, figures, references, abstract and keywords list.

The definition of the International Standardization Organization

(Kaplan & Garrick, 1981)

All activity of certain organizations involves risk. Organizations manage risk by identifying, analyzing and then assessing whether risk treatment options should be applied so as to satisfy their criteria of risk. During this process, they communicate with and consult the interested parties, monitor and analyze risk and measures applied in order to ensure that further treatment is not needed (Risk Management ISO, 2009). The Standard attempts at clarifying some of these questions by addressing the following five remarks:

1. An effect is a deviation from the expected – positive and/or negative.
2. Objectives can have different aspects (such as financial, health and safety, and environmental goals) and can apply at different levels (such as strategic, organization-wide, project, product and process).
3. Risk is often characterized by reference to potential events and consequences, or a combination of these.
4. Risk is often expressed in terms of a combination of the consequences of an event (including changes in circumstances) and the associated likelihood of occurrence.
5. Uncertainty is the state, even partial, of deficiency of information related to, understanding or knowledge of an event, its consequence, or likelihood.

Not so markedly, as it is not within the scope of risk definition or terms, and reminiscent of the traditional forms of definition, the standards express that the ’level’ of risk is a combination of consequences and their probabilities, not defining the concept of risk ’prediction’.

Aven (Aven, 2011) expressed criticism, acknowledging that risk is related to uncertainty, but wondering whether it really is a consequence of uncertainty. Or is it rather a consequence of an existing hazard, or a cause or the exposure to the hazard? Risk is related to objectives, but if there are no objectives defined, are there no risks either? This definition can undoubtedly lead to various interpretations. Such a definition is not precise enough, which should be its main purpose, and therefore its purpose can be regarded as questionable. Adams (Adams, 2014) notices that the remarks are numerous because the definition is not precise enough. In remark 2, it is explained that risk is a consequence of organizational setting and accomplishing objectives against the background of uncertainty. This definition is further used to describe risk management as a process of optimization, which makes the accomplishment of objectives more likely. Various authors also criticize the definition of risk on the ground that it is not clear, nor mathematically based and has little to say about probability, data and models.

Concluding Remarks

Although the concept of risk has been developed for thousands of years, the overview of different sources reveals that there has been no approximation towards the interdisciplinary definition of risk (Kaplan & Garrick, 1981), (Aven & Renn, 2009). There is still an ongoing debate as to how risk should be defined, and about the soundness of different definitions (Aven & Renn, 2009), (Johansen & Rausand, 2014). Risk relates to future events and their consequences (Aven & Renn, 2009). Risk is, therefore, a social concept influenced by various prejudices. The concept of ’risk’ was invented by humans, so there is no such thing as ’real risk’ or ’objective risk’ (Rausand, 2011), (Sotic, Mitrovic, Rajic, 2014). In the context of ambiguity, risk has today become a slogan (Johansen & Rausand, 2014). It is a topic of discussion and analysis, anxiety and speculation (Rausand, 2011). Despite the fact that the definitions are never entirely true or false, they provide us with useful tools for abstraction and clarification of points of interest (Rosa, 1998).

One of the most significant remarks is that risk is a derived category and cannot be addressed directly, without previous investigation into the objectives, contexts, hazards, vulnerability, resilience and interested parties. Although the discussion on different definitions can be at a fairly philosophical level, it is important to be aware of potential contradictory interpretations of concepts in conducting risk analysis, assessment, and management. One of the possible strategies while dealing with risk may be, surprisingly, to distance from risk as a concept, to change the paradigm and consider safety problems from a different point of view.

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