Safety Science 101 (2018) 72–85

Contents lists available at ScienceDirect

Safety Science

journal homepage: www.elsevier.com/locate/safety

On the calculus of risk in construction projects: Contradictory theories and a rationalized approach

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A R T I C L E I N F O

Keywords:
Construction risk management
Risk scoring
Mathematical formulas
Multifaceted information

A B S T R A C T

Evaluating risks through numbers-although an inevitable stage of risk management-can be seriously problematic, especially when marginalized groups of risks turn out to be significant, for example, to the lives of people. While it questions the effectiveness of the traditional approach to risk scoring, the literature provides no alternative satisfying all the criteria stressed by the critics. In fact, different dimensions of uncertainty, along which a risk can be viewed, entail different quantifications. Most previous work, however, concentrates on supposedly all-purpose solutions that are often justified or promoted over others by reasons not necessarily applicable; little information is available on how to best select the needed scoring approach. This research investigates the issues involved in constructing a risk factor formula that is more consistent with the nature of the project and its goals. Major concerns addressed in the literature are organized, serving as a basis to evaluate and improve seven groups of alternative formulas in light of mathematical arguments without which fallacious conclusions-such as the myth that importance is implied by exponents greater than one-would be inferred. These groups are complemented by a multifaceted approach introduced for the first time in this paper, providing the observer with customized information about risks. A robust scoring system founded on these results will ensure that allocated risk factors are neither too high nor too low. Although expressed in the terminology of construction safety, the findings of this research can be extended to other industries that feature some element of uncertainty.

1. Introduction

It is the attitude of an organization toward uncertainty that determines how it will overcome potential failures. Improper treatment of uncertainty results in defective risk assessments and, thus, faulty decisions (Zio and Aven, 2013). Exemplary disasters that resulted from perceived but underrated risks can be found in the history of engineering, the analysis of which reveals a fundamental misunderstanding of different aspects of uncertainty.

Although it can be quite unrealistic in the absence of accurate information (Ale et al., 2015; Zio and Aven, 2013), a proper quantification of uncertainty is essential for the comprehension, description, and communication of the risks associated with a system under consideration, and how they change over time and after intervention (Apostolakis, 2004; Duijm, 2015; Mackenzie, 2014).

To many of those involved in risk management and research, the quantification process is driven by the relative seriousness of risks (Fine, 1971), expressed as an index or factor which has attracted attentions in recent years even more than what has been paid to the analyzed risks (Mackenzie, 2014), because it is the only way to identify priority risks (Groso et al., 2012).

Summarizing available information into a single number is indeed a difficult and sensitive issue (Mackenzie, 2014), which requires an analyst to carefully select and utilize constituent elements and algebraic operations (Azadeh-Fard et al., 2015; Ni et al., 2010). While nearly all the improvements or alternatives available to the traditional risk scoring formula have taken a ‘one size fits all’ approach, items such as the cause of uncertainty, properties of available information, and details required by the observer can determine which mathematical expression is best suited for a risk assessment tool (Groso et al., 2012; Zimmermann, 2000).

A widespread belief that risk is nothing more than the “expected loss” summarized by averaging the “probability” of events times their corresponding “impacts” can falsely relieve the effort required to

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http://dx.doi.org/10.1016/j.ssci.2017.08.014
Received 8 September 2016; Received in revised form 28 July 2017; Accepted 16 August 2017

manage unbearable risks which are, although low in the product of their probability and impact, high in other remarkable contents of uncertainty. Even though this traditional method of risk scoring looks simple and produces consistent results, a number of flaws identified in the literature suggest that its use should be revised (Bowles, 2003). The literature is, however, replete with both incautious uses and sharp criticisms of the product formula with no established criteria for determining when it is appropriate to be used. Shortcomings of the product formula are endlessly enumerated in the papers presenting new approaches which themselves suffer from the same problems.

The appropriateness of a risk scoring technique is usually examined from two perspectives: whether special contents of interest are addressed or not, and whether an acceptable distinction between important and unimportant risks is provided. The traditional two-dimensional risk calculation method is perhaps not capable of including parameters such as manageability, criticality, worsening factors, social amplification, voluntariness, dread, and familiarity (Ale et al., 2015; Derby and Keeney, 1981; Duijm, 2015; Groso et al., 2012; Kasperson et al., 1988; Zeng et al., 2007), and the traditional approach to combining the selected factors into a single factor, which uses the multiplication operator, is likely to produce unreliable results (Bowles, 2003; Duijm, 2015; Kaplan et al., 1981; Seyed-Hosseini et al., 2006; Williams, 1996).

This paper attempts to explain why and on what grounds the traditional method is continuously undermined, and how it can be improved or replaced. A large number of articles, including both original research and reviews, along with their references and the articles referring to them have been studied to illuminate the fundamental concerns of the critics. Not all criticisms are found to be based on accurate and relevant assumptions, nor do they apply to all types of risk scoring formulas. Major concerns addressed in the literature are first discussed, and summarized in six points detailed in Section 2. Amendments are also made, as appropriate. New approaches to risk scoring are then sought in the literature and assessed with respect to these points. These are introduced in Section 3 referring only to the oldest or most famous works that have implemented the suggested approach. A few approaches that have been found defeating their purpose are further scrutinized in the light of mathematical theories and examples. In Section 4, a completely new approach to risk scoring is presented. Comparing the attributes of different approaches introduced, a discussion is provided in Section 5 to clarify where to use each approach, and is further supplemented by a few case examples in Section 6. The results are then concluded in Section 7.

2. Concerns addressed in the literature

Rather than giving an overview of different approaches to risk scoring, this section first presents the major concerns addressed in the literature with the traditional risk scoring method, such that a subsequent overview of alternative approaches can adopt these concerns as a basis for assessment.

2.1. Dissimilarity

A most important and widely recognized drawback of risk scoring systems is the possibility of assigning similar Risk Factors (RFs) to naturally different risks. In this regard, critiques frequently found in the literature are categorized as the following (Ale et al., 2015; Bowles, 2003; Derby and Keeney, 1981; Duijm, 2015; Kaplan et al., 1981; Williams, 1996):

1. It is difficult to decide how to treat a risk based on a single RF, given that it provides no information about possible contributing factors. For example, if it results from the product of four and five, an RF of 20 only needs to be regularly monitored, but when the factors are ten and two, the higher factor should be reduced to a safer level while the lower one probably requires no action. When there are three factors multiplied together, the number 36, for example, is obtained from five different combinations: {(4,3,3),(6,3,2),(6,6,1),(9,2,2),(9,4,1)}, none of which is to be treated like the others.
2. Combining multiple factors into one takes no notice of their inequalities, i.e., the RF does not indicate whether either the Probability (P) or the Impact (I) is greater. Therefore, calculated RFs for a risk with high P and small I might be quite similar to one with low P and large I. To give an example, a potential threat to the lives of 100 people with a chance of one in a thousand and an unsafe act with a ten percent chance of claiming one life, although quite different in nature and features, will be assigned identical RFs. Yet the former calls for extensive design considerations and contingencies, while the latter can be eliminated by better education and more stringent regulations.
3. One can view the only purpose of risk scoring as to compare the risks, not to provide solutions. However, it is ambiguous even for someone who wants to compare the risks to see how some chains of inequalities ($RF_1 < RF_2 < RF_3$) show conflicting results. The product of 10×2, which implies an extreme case of both parameters, for example, is bounded between two moderate combinations 4×4 and 5×5.
4. A mysterious class of events often referred to as catastrophes result in such a heavy damage that they are usually expected to be flagged as important, almost regardless of how infrequent or irregular they are. Nevertheless, even maximal values of I will be overlooked when multiplied by a low P, therefore, many guidelines make specific reference to what they call 'risk aversion' or more specifically 'major risk aversion', suggesting that all the risks that are large enough in I should be manually assigned a high RF before they are multiplied by P. However, having ignored the fundamental element of uncertainty, P, this modification can also highlight some nearly impossible phenomena that happen rarely, if ever, only because they might be disastrous. Too much concentration on these unlikely but catastrophic risks at the expense of devising costly contingency plans will probably exhaust the resources required for other operations.

These problems, although often attributed to the product formula ($RF = factor1 \times factor2$), arise whenever a formula is symmetric on the variables, i.e. when it uses only 'commutative' operators, such as the product and average formula (Sections 3.1 and 3.2), or when non-commutative operators are used but interchanging the parameters does not change the results, as it is in the union-like formula (Section 3.3). While improvements such as those introduced in Sections 3.7 and 4 make the formula non-symmetric, taking the logarithm of a product (Section 3.6) is not beneficial in this regard.

2.2. Understandability

Systems are considered internally complicated if they are difficult to construct, and externally so, if they are difficult to understand (Ramasesh and Browning, 2014). While it is convenient to use an easy to calculate risk index such as those introduced in Sections 3.1–3.5, which may only require a desktop calculator, computer-assisted calculations (Sections 3.7 and 4) can be well worth employing to provide managers with less complicated and more readily understandable information.

Less information is not necessarily less complicated. Although results obtained from a single-output formula are better comparable (Ale et al., 2015), valuable information may be ignored when combining all the available data into a single number (Duijm, 2015; Kaplan et al., 1981; Williams, 1996). A single number gives no idea as to how the results can be improved, what a certain reduction in RF means, and whether a risk with an RF of 200, for example, is twice as risky as one with an RF of 100 (Bowles, 2003; Gilchrist, 1996; Mackenzie, 2014).