Reliability Engineering and System Safety 140 (2015) 116–121

Contents lists available at ScienceDirect

Reliability Engineering and System Safety

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

# On the allegations that small risks are treated out of proportion to their importance

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ARTICLE INFO

*Article history:*
Received 14 March 2014
Received in revised form
31 March 2015
Accepted 2 April 2015
Available online 10 April 2015

*Keywords:*
Risk
Over-estimation
Uncertainties
Misconception
Terrorism risk

ABSTRACT

Many authors argue that we suffer from a lack of ability to treat small risks; we either ignore them completely or give them too much emphasis. An example often referred to is terrorism risk, the reference being the number of fatalities observed due to terror compared to for example deaths in traffic accidents. The thesis is that the risk is over-estimated. However, these assertions, that the risks are over-estimated and we give them too much emphasis – they are treated out of proportion to their importance – cannot be justified in any scientifically meaningful way when there are large uncertainties about the consequences of the activity considered. Over-estimation is a value judgment, as is the phrase "far too much emphasis". In the paper the author argues that the statements represent some serious misconceptions about risk. The purpose of the present paper is to point to these misconceptions and provide some guidance on how they can be rectified.



## 1. Introduction

The point of departure for this paper is the book, *Thinking Fast and Slow*, of Daniel Kahneman [15], for sure one of the most influential researchers on risk and decision analysis in the last 30–40 years. The response to this book has been overwhelming, with words like 'brilliance' and 'masterpiece' frequently used to describe it.

The book is based on a dichotomy between two modes of thought: *System 1* which operates automatically and quickly, instinctive and emotional, and *System 2* which is slower, more logical, and deliberative. The book identifies cognitive biases associated with each type of thinking, using several decades of academic research on the issue, to large extent linked to Kahneman's own research.

The book also relates to risk. Kahneman asserts that we have a basic lack of ability to treat small risks: we either ignore them completely or give them too much weight. The main thesis put forward is that we over-estimate small risks [15, p. 324].

Kahneman is not alone in thinking along these lines. The literature is filled with contributions where the same type of reasoning prevails. Authors lampoon the way society deals with security issues – the terrorist risks are over-estimated; very small risks are treated out of proportion to their importance.

The purpose of the present paper is to point to these views and to argue that they represent some serious misconceptions and consequently need to be refuted. They are serious, as they could have a great effect on the way we manage risk, whether it relates to security, technology and engineering, environmental impacts and natural disasters, health, or financial risk management. All areas are concerned with managing small risks.

The remainder of the paper is organized as follows. Firstly, in Section 2, more details about the above theses are provided and it is pointed to the problems of their use in light of common ways of looking at risk and probability. It is not possible to provide a meaningful discussion of this issue without being precise on what these terms – risk and probability, and over-estimation – mean. Then, in Section 3, some perspectives on how we should in fact think regarding small risks and large uncertainties are presented and discussed. The key is to acknowledge that when it comes to risk, uncertainty is a main factor and there is no way of measuring, at the point of decision, what is over-estimation of risk. Finally, Section 4 provides some conclusions.

## 2. The misconceptions

Kahneman [15] provides many examples to illustrate his message. One is related to suicide bombings in buses in Israel in the period 2001–2004:

> I visited Israel several times during a period in which suicide bombing in buses were relatively common - though of course quite rare in absolute terms. There were 23 bombings between December 2004, which had caused a total of 236 fatalities. The number of daily bus raiders in Israel was approximately 1.3 million

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http://dx.doi.org/10.1016/j.ress.2015.04.001

at that time. For any travelers, the risks were tiny, but that was not how the public felt about it. People avoided buses as much as they could, and many travelers spent their time on the bus anxiously scanning their neighbors for packages or bulky clothes that might hide a bomb.

I did not have much occasion to travel on buses, as I was driving a rented car, but I was chagrined to discover that my behavior was also affected. I found that I did not like to stop next to a bus at a red light and I drove away more quickly than usual when the light changed. I was ashamed of myself, because of course I knew better. I knew that the risk was truly negligible, and that any effect at all on my actions would assign an inordinately high "decision weight" to a minuscule probability. In fact, I was more likely to be injured in a driving accident than by stopping near a bus. But my avoidance of buses was not motivated by a rational concern for survival. What drove me was the experience of the moment: being next to a bus made me think of bombs, and these thoughts were unpleasant. I was avoiding buses because I wanted to think of something else [15, pp. 322–323].

One view on this example by Kahneman is as follows – to be further substantiated and discussed in the coming Section 3:

However, the individual risk is not determined by hindsight, observing historical fatality rates. At a specific point in time, an objective risk metric for this person does not exist. The statement by Kahneman that the individual risk is minimal lacks a rationale, as risk relates to the future and the future is not known. Thus the associated behavior cannot be said to be irrational (in a wide sense of the word), as there is no way to determine the truth about risk at the decision point. We can make the same considerations concerning probability. Kahneman seems to link probability to historical observations, not to the future and to judgments about the future. He refers frequently to the "exact probability level" – for example he writes on page 323: "… The emotion is not only disproportionate to the probability, it is also insensitive to the exact level of probability." However, there exists no objective probability that can be used as a basis for a proper decision weight. His thinking fails to take into account the uncertainty dimension. He refers to risk and probability as being objective quantities for which rational comparisons can be made. Such concepts do not exist in the example addressed here or in most other real-life situations. Note that the critique here relates to what Kahneman writes about risk and probability in this particular case, not his work in general.

Kahneman goes on with another example, linked to Lotto. He points to a similarity: buying a lotto ticket gives an immediate reward of pleasant fantasies, as avoiding the bus immediately is rewarded by relief of fear. According to Kahneman, the actual probability is inconsequential for both cases; it is only the possibility that matters [15, p. 323]. However, the two situations are not comparable; in the latter case there exists an objective probability that we can relate to, but not in the former case. It is this lack of objective reference values that makes risk so difficult to measure and handle. Kahneman and his school of thought have for decades conducted research that shows that people (and in particular laypersons), are poor assessors of probability if the reference is an objective, true probability, and that probability assignments are influenced by a number of factors [24]. It has been shown that people use rather primitive cognitive techniques when assessing probabilities; these are *heuristics*, which are easy and intuitive ways for specifying probabilities in uncertain situations. The result of using such heuristics is often that the assessor unconsciously tends to put too much weight on insignificant factors. The most common heuristics are the availability heuristic, the anchoring and adjusting heuristics, and the representativeness heuristic.

If it is not possible to relate the probability assignment to a true value, how can we then speak about biases and poor assessments? For an individual taking the bus in the above example, the research framework of Kahneman and others may be questioned as the event is a unique event for this person. Of course, he or she may benefit from the general insights provided by the research of biases and heuristics, for example the availability heuristic, which means that the assessor tends to base his probability assignment on the ease with which similar events can be retrieved from memory; events where the assessor can easily retrieve similar events from memory are likely to be given higher probabilities of occurrence than events that are less vivid and/or completely unknown to the expert. There exists, however, no reference for making a judgment that this heuristic leads to a bias. Care has to be shown when applying the results from the research framework of Kahneman and others into unique events. It can lead to what the author of the present paper considers to be unjustified conclusions, as in the above example where the "true" probability of being killed in a bus bombing was said to be negligible. The discussion in the coming section will give further arguments for this view.

The above discussion has the recent book by Kahneman as a point of departure, but the literature and media are filled with examples where this type of ideas prevails. As an example from the public discourse, let us go back to a newspaper article in Norway from 2009 [20], which refers to a book by the philosopher Joakim Hammerlin [13]. The topic is again terrorism risk, but now we have a focus on the authority perspective.

The message from these authors is that the terrorist risk is fictional. It is argued that there is a greater risk of drowning than being hit by terror. They point to research showing that there is no scientific basis for claiming that the security controls at airports make it safer to fly, and that the statistical probability of dying in a terrorist attack in the West is 0.0000063; after 11 September 2001 more people have drowned in the bathroom in the U.S. than are killed in terrorist attacks. Terror is not something to fear, says Hammerlin, as the risk is microscopic. The population is frightened by a fictitious danger and risk. Is it any wonder that the authors are upset and lampoon the authorities?

Again the reference seems to be some underlying true risk which is provided by the observed historical numbers. The authors take a blinkered view of what has happened. But there is a big leap from history to the future. And it is the future that we are concerned about. What will happen tomorrow, what form will an attack take, and what will be the consequences? We do not know. There is uncertainty associated with these events and their consequences.

Numbers expressing the risk can be given, but they will always be dependent on the available knowledge and the assumptions made. The historical data referred to by Hammerlin say something about the risk, but the most important aspect of risk is not addressed, namely uncertainty; we do not know what is next. We hope that the security measures implemented can prevent a terrorist attack, but they are also motivated by a need to reduce uncertainty and make people feel more secure. However, if the underlying perspective is that the risk is objectively described by a risk number, such arguments will be of little interest.

This discussion may at a first glance seem to be closely linked to the distinction between Kahneman's two Systems, 1 and 2, mentioned in Section 1. However, the main point made in the present paper is not to give increased weight to the System 1 when assessing risk – the importance of highlighting the uncertainties can be solely based on the System 2 thinking. The logical and deliberative features characterizing System 2 can be the basis also for the uncertainty assessment highlighted here although there are more methodological challenges when we have to see beyond the traditional historical data case, as will be clear from the following discussion.

## 3. The rectification

The purpose of this section is to meet the challenges – what the author of the present paper will refer to as misconceptions – described in the previous section by providing a proper conceptual framework for understanding the situations discussed in Section 2. Firstly, some general features of the concepts of probability and risk are addressed. Then we specifically look into the two cases considered in the previous section. Finally, a general discussion is provided.

### 3.1. The concepts of probability and risk

The meaning of a probability in a risk context has been thoroughly discussed in the literature (e.g. [1,25,21,22,19,4]) There is no disagreement among experts on how to interpret classical and frequentist probabilities. If we have situations, as in gambling, where there are a finite number of outcomes and these are equally likely, the (classical) probability for a specific outcome is $1/n$, where $n$ is the number of possible outcomes. If we have a situation which can be repeated infinitely, under similar conditions, the limiting fraction of "successes" gives the frequentist probability. This latter probability is often associated with the propensity interpretation of a probability. It holds that probability should be thought of as a physical characteristic, a predisposition of a repeatable experimental set-up which produces outcomes with limiting relative frequency. When the set-up is defined, all these probabilities can be viewed as objective – they exist independently of specific knowledge held by individuals.

Many people tacitly presume the existence of a type of objective probability, such as a propensity interpreted probability. The scientific nomenclature and reasoning are based on such a concept and it leads to judgments about the probability being over-estimated or under-estimated, in the sense that the estimate of these probabilities is higher or lower than the true underlying probabilities. As these true underlying probabilities are unknown, we should add a statement about being confident that the estimates are higher or lower than these values. Over-estimation (under-estimation) can also be interpreted without referring to a true value: we speak of over-estimation (under-estimation) if the estimation produces higher (lower) values than can be justified by some defined standards. We refer to these two interpretations of over(under)-estimation as type I and type II, respectively.

However, the applicability of this type of objective probabilities is limited. When can such a set-up be established? For gambling situations and experimental situations, yes, but not for many cases where risk is an issue. Think about the two situations considered in the previous section – frequentist type of probabilities do not exist in these cases, they cannot be meaningfully defined. The situations are unique. Among all common categories of probability, the only type that the author of this paper can see justified in these cases is subjective (judgmental, knowledge-based) probabilities, a type of probability which expresses the assessor's degree of belief that the relevant event will occur. This probability is, as its name indicates, subjective. There is no reference value that can be used to say that a subjective probability is over-estimated or under-estimated at the time of assignment when speaking about interpretation I of this term. With hindsight we can check how the assessor performs compared to observations and we can discuss his or her ability to make accurate predictions, for example by comparing his/her hit rate with his/her assigned probability. However, for unique events, as we addressed in the previous section, this is of course not possible. No one can claim that a person's subjective probability is wrong. If a person states that his/her subjective probability for a specific event to occur is 10%, it means that he/she finds the uncertainty and his/her degree of belief to be the same as drawing a specific ball out of an urn comprising 10 balls under the standard experimental set-up [18,16,23]. When Kahneman and his colleagues speak about subjective probabilities, they refer to betting and a decision making context, in line with de Finetti and others, who interpret a subjective probability of 10% to be the maximum price one is willing to pay to play a gamble which gives one unit of money if the event considered occurs and zero otherwise. More precisely, if you assign the subjective probability $P(A)=0.1$ you are expressing that you are indifferent between receiving (paying) €10 or taking a gamble in which you receive (pay) €100 if $A$ occurs and €0 if $A$ does not occur [4].

The above points made for the urn type of interpretation are also applicable for the betting interpretation: a subjective probability is the only one that is meaningful in unique cases such as those studied in this paper; it cannot be subject to over or under-estimation at the point of assignment, when speaking about interpretation I of this term.

Now let us consider interpretation II of the term over(under)-estimation: the estimation produces higher (lower) values than can be justified by some defined standards. The issue is linked to the fundamental understanding of a subjective probability, and its link to so-called evidence-based and logic probabilities as will be discussed in the following.

Many authors have argued against the use of the term "subjective" in relation to the subjective Bayesian meaning of probability, for example Kaplan [16,17]. The problem raised is that the probability is linked to terms like "beliefs" and "confidence" which are subjective. But, according to Kaplan and others (for example [12]), a true Bayesian uses probability in sense of degree of credibility or confidence dictated by the evidence, through Bayes' theorem – there is no personality in it, no "opinion". Kaplan [17] refers to Jaynes [14]:

> Probability theory is an extension of logic, which describes the inductive reasoning of an idealized being who represents degrees of plausibility by real numbers. The numerical value of any probability $(A/B)$ will in general depend not only on $A$ and $B$, but also on the entire background of other propositions that this being is taking into account. A probability assignment is "subjective" in the sense that it describes a state of knowledge rather than any property of the "real" world; but is completely "objective" in the sense that it is independent of the personality of the user; two beings faced with the same total background of knowledge must assign the same probabilities. -E.T. Jaynes

Following this type of reasoning, it is more natural to refer to the probability as an "evidence-based" probability than subjective probability [17]. The argumentation leads us to logical probabilities as was first proposed by Keynes (1921): there is a number in the interval [0,1], denoted $P(H|E)$, which measures the objective degree of logical support that the evidence $E$ gives to the hypothesis $H$ [11]. However, the rational of these types of probabilities can be questioned, and several scholars have argued that interpretations of this type cannot be justified [9,8,4]. Using such probabilities it is not clear how we should interpret a number (say) 0.2 compared to 0.3.

Hence we are back to the subjective probability interpretations given above using for example an urn as a reference for comparing the uncertainty, degree of belief or confidence. The assigned probability expresses the assigner's uncertainty (degree of belief, confidence) given his/her background knowledge, and we have to acknowledge that if two persons have the same background knowledge they would not necessarily have the same probability [19, p. 44]. Lindley writes:

> Some people have put forward the argument that the only reason two persons differ in their beliefs about an event is that they have different knowledge bases, and that if these bases were shared, the two people would have the same beliefs, and

> therefore the same probability. This would remove the personal element from probability and it would logically follow that with knowledge base $K$ for an uncertain event $E$, all would have the same uncertainty, and therefore the same probability $P(E|K)$, called a logical probability. We do not share this view, partly because it is very difficult to say what is meant by two knowledge bases being the same. In particular it has proved impossible to say what is meant by being ignorant of an event, or having an empty knowledge base, and although special cases can be covered, the general concept of ignorance has not yielded to analysis [19, p. 44].

Acknowledging the subjective elements of this type of probabilities, it is essential to distinguish what is the evidence – the knowledge basis – and what is the assignment based on it. The probabilistic analysis then becomes more a tool for argument, rather than an objective representation of the truth [25].

We may be uncertain about an event occurring or not, or a quantity (for example the number of fatalities next year due to terrorist attacks), and to measure or express the uncertainty, we use the tool (subjective) probability. It is important to make a distinction between this uncertainty, and the measurement of it, as there are different ways of representing or expressing this uncertainty (although probability is the most common, see below).

We see that the concept of over(under)-estimation by making judgments of the estimation producing higher (lower) values than can be justified by some defined standards, is also problematic. What are these standards? In general and in particular in cases as discussed here characterized with large uncertainties, it seems impossible to obtain in some objective way what should be the standard used for such comparisons. In theory one could think of a reference probability obtained by removing all biases as described by the various heuristic (availability, anchoring etc.), but also these heuristics are founded on some references or standards for what is adequate reasoning. The fundamental problem of having an objective standard is thus not solved. We could of course also think about over(under)-estimation in relation to a subjective standard – for example the assigner's "best judgments", but that would not provide a basis for arguments about the true or real probability and risk, as have been the point of departure for the analysis in this paper.

Now a few words about the risk concept. Given the above considerations about probability, we are led to the conclusion that if the risk and probability concepts are to be used for situations such as those studied in Section 2, i.e. unique events, probability must be understood as a subjective probability. However, a risk concept based on such probabilities would only to some extent be able to reflect the phenomena and aspects that we would like this concept to reflect. Think of two situations: one where the assessor assigns a probability of an event to be 0.1 and the knowledge base is very strong, and one where the assessor assigns the same number but the knowledge base is weak. Should not the level of risk then be different?

Adopting the urn type of interpretation of a subjective probability, the answer is obviously 'yes', as the probability represents a pure uncertainty assessment completely isolated from the related decision problems: in the airport case, whether or not to implement some specific security measures for passengers to board the planes. If some analysts assign a probability of an attack occurring to be 0.1, it is essential for the decision maker to know whether the background knowledge supporting this number is strong or weak.

For this reason many researchers and risk analysts prefer to use other approaches for representing the epistemic uncertainties, including those based on interval probability, possibility theory and evidence theory, as well as qualitative methods reflecting the strength of the background knowledge $K$ [10]. For the sake of simplicity these alternative approaches are referred to as non-probabilistic methods. Hence, to allow for these non-probabilistic methods, we have to leave the probability-based risk concepts. The natural extension is to consider perspectives on risk that are based on uncertainty in place of probability, as both the probabilistic and the non-probabilistic methods are ways of representing the uncertainties.

The perspective on risk seeing it as a combination of events/scenarios, consequences and likelihood/probability (for example [18]), limits itself to one representation of uncertainty – namely probability, but risk can be viewed to exist as explained above without linking it to one specific measurement tool. (Kaplan and Garrick [18] could also be interpreted along these lines when referring to risk as "damage+uncertainties".) When describing and measuring the risk we have to choose a suitable tool, being it probability or an alternative as mentioned above.

The above reasoning, leading to a risk concept based on uncertainty in place of probability, would also apply if the betting type of interpretation is used. However, the situation is somewhat more complex, given that if the event (the attack for example) occurs, you will get €10. But as noted by Lindley [19], see also Cooke [7], receiving the payment would be trivial if the accident were to occur (the assessor might not be alive to receive it). The problem is that there is a link between the probability assignment and value judgments concerning the price of the gamble, the money. How important is the €10 to you? This value judgment has nothing to do with the uncertainties per se, or your degree of belief in the event A occurring. We see that the interpretation is based on a mixture of uncertainty assessments and value judgments. This is why the author of the present paper cannot recommend the use of this interpretation of a subjective probability [4].

The above argumentation leads to a general risk framework based on the following ideas [3]: We study an activity in the future, for example taking buses in Israel in a specific period of time, (undesirable) events A may occur, giving some consequences $C$. At this point in time we do not know whether A will occur or not, and what $C$ will be; these quantities are unknown – uncertain ($U$). This is risk – for short we write Risk=$(A,C,U)$, or just $(C,U)$, where $C$ covers all consequences of the activity, including the events. This defines the concept of risk, and to describe risk we need to specify the consequences ($C'$) and use a measure (in a wide sense) of the uncertainties ($Q$), resulting in a risk description ($C'$, $Q$, $K$), where $K$ is the background knowledge that $C'$ and $Q$ are based on. If we specifically focus on the events $A$, the risk description becomes $(A',C',Q,K)$, where $A'$ are the events specified in the risk assessment. Note that $C$ is the actual consequences and $C'$ are the consequences specified in the assessment. The most common measure of uncertainty is probability $P$, so that $Q=P$, but alternatives exist as mentioned above. To be more concrete, let us consider the two cases introduced in Section 2.

### 3.2. Bus bombing example

Let us return to the suicide bombings in buses in Israel in the period 2001–2004. A person, say John, is considering taking the bus. He faces risk. The bus could be subject to a suicide bombing ($A$) having serious consequences ($C$) – most likely death. At the decision point, John does not know if the event $A$ will occur for this particular bus trip, but he is quite sure about the consequences given a bomb. Before he makes a decision about taking the bus or not, he considers risk; he makes a crude risk assessment, focusing on $A'$: the occurrence of a suicide bombing event on this particular trip, and $C'$: level of injuries and/or loss of life. John thinks the bombing will be fatal so the key issue is the probability of the bombing event occurring and the strength of knowledge. For a moment we just assume that other aspects, like fear, can be ignored. John tries to make a fair and balanced risk assessment.

Let us assume that John is well informed about the bombings that have occurred up to this point. However, this information does not of

course give him reliable estimates of the frequency of bombing events for the future including his bus trip. What is coming next is subject to uncertainty. The attackers could change policy, and the form and intensity of attacks could increase (decrease) at any time. He does not know. John's subjective probability $P$ could be relatively low, but he has to acknowledge that it is heavily dependent on the assumptions made concerning the attackers. Alternatively, he could think through imprecision intervals, as he is not willing to make a specific probability assignment. Also, to be meaningful, such an interval needs to be based on some assumptions, but less than for the specific probability assignment. In both cases, the risk assessment covers judgments about the combination $(P,K)$, and it is for sure not a straightforward conclusion that the risk is negligible, as Kahneman argued. Rather, the author of the present paper believes that most people would find the risk $(P,K)$, based on common-sense thinking, to be rather high, having in mind that the bombing would most likely be fatal. Talking about over-estimation of risk is problematic, as there is no obvious standard to use as a reference.

Hence, John is likely to avoid taking the bus at this stage. In face of the risk – characterized by large uncertainties – one tries to avoid it, one is cautious (i.e. applies the cautionary principle [6]). This assessment is based on the assumption that John is able to perform a professional risk assessment, where fear and other types of feelings are not incorporated in the judgments. He is aware of the different types of heuristics, in particular the availability heuristic in this case, so his probability or interval probability (interpreted with reference to the urn standard) expresses his degree of belief given his knowledge. Clearly this knowledge is and should be strongly affected by the events that have happened recently, but it does not necessarily lead to these events being emphasized "too much". They could be given "too much" focus if the assessor is a layman, who is influenced by the extremity of the situation and the consequences, with all the terrible details, but then the professional risk assessment has become a risk perception, where the risk judgment is affected by personal feelings like fear. A layman's risk perception captures his/her $(P,K)$ but also feelings about the situation, the events and consequences, and we know that these feelings could be very decisive for the overall judgment about the risk and the related risk management. In this case, the feeling attributes would for most people lead to an even further cautionary attitude and avoidance of the buses. It is an extreme cautious policy which needs to be balanced, of course, with the need for the person to take the bus. The probabilities that Kahneman refers to in his argumentation, that should make them behave just as if nothing has happened, are based on the historical data and are informing John, but do not capture the uncertainty aspect of the risk and is therefore of limited value for guiding John in his decision making.

### 3.3. Airport terrorist attack example

The airport example is different than the bus bombing examples, as we take the perspective of the authorities: What measure should we implement to handle the risk related to potential attackers? The situation can then be characterized as follows:

An attack A can occur, somewhere, at any time in the coming years. The consequences C could have different degrees of severity depending on the type of attack and how it is met, how barriers work etc. We do not know if such attacks will occur and what the consequences will be. A risk assessment would need to address the type of attacks that could occur, their consequences, and the uncertainties. Probabilities and interval probabilities can be assigned, but, as in the previous example, they would not be so critical for the decisions that need to be made. The key aspect is the uncertainties, not the probabilities. The authorities know that an attack can occur, it has happened before and it could happen in the future. The probability cannot be ignored. The historical number of attacks and lost lives due to such events do not provide much information about what could happen in the future. The risk description, capturing a non-negligible probability of an attack, extreme consequence potentials, and the knowledge about potential attackers and their motivation and capacities, would obviously lead the authorities to conclude that the risk is so high that strong measures need to be taken to manage the risk. For the air industry, which is so important for our society, high safety/security standards and people's trust are essential. We can all be annoyed by the detailed controls at our airports, but the policies implemented after the September 11 events, are difficult to argue against. People are still traveling by plane and we have had no "successful attack" since September 11. In that respect, the cautious policy has worked. The costs have been extremely high but there has been broad political agreement all over the world that the cautionary measures have been required to regain trust and avoid new disasters like those of September 11.

### 3.4. Discussion

Kahneman was chagrined that he did not like to stop next to a bus at a red light, as he knew that the risk was negligible. It is the view of the present author that he should not be chagrined. His reaction when being close to the bus was natural given the uncertainties, probabilities and risks; they were not necessarily negligible for him, when allowing risk to also reflect the uncertainties. As the above analysis demonstrates, there is no truth about the bomb probability or the risk, and hence the term 'overestimation' is problematic – there is no objective reference or standard for their comparison.

A decision to not take a bus if there is an alternative, would probably also be supported by an expected utility analysis, as any assigned probability for a bomb would give weight to an event that is highly undesirable. However, this theory is not very relevant in supporting the decision making in this particular case. Specifying the probabilities and the utilities is difficult and would lead to a number exercise that tries to replace difficult value judgments by mathematical formulas. What people would do is to assess and perceive risk, compare these with the benefits/costs of the various alternatives, and make a decision. No formal procedure is needed, beyond this. We are all used to this, and it works.

The key challenge is the uncertainties; we do not know what is coming next. Risk assessment cannot eliminate all these uncertainties and provide an optimal decision for you. The issue is a question of how much weight we are to give to the uncertainties. In situation like those described in Section 2, people may be frightened and lean heavily on cautionary thinking. Of course, it is possible to become too cautious, the uncertainties make one passive, afraid that the activity will lead to a negative outcome. Life is about balancing different concerns and aspects, including benefits and risks/uncertainties, and we all agree that being too cautious is not the recipe for a good life. However, taking unnecessary risks, like traveling frequently on the bus in this period if alternatives are possible, could be seen as playing Russian roulette – it should not be undertaken unless it is extremely important for you to play this game (take the bus).

Much of the above discussion also applies to the airport security example. Here the decision making is an organizational one, and not individual, but the need for balancing different concerns and aspects is the same. The authorities assess the risk and uncertainties, the consequences of attack situations, as well as the effect of the control measures, and make a decision. The conclusion of implementing the extensive cautionary measures after September 11 may at a first glance seem unnecessary, but a further reflection shows that the authorities had no choice. If a new terrorist event had occurred, having disastrous consequences, the authorities would for sure have

been massively criticized if sufficiently strong preventive measures had not been implemented.

To make a decision on for example taking the bus or not, the risk judgments are informing us, not prescribing what to do. This is the risk assessment contribution in general – informing the decision-maker [2]. When people make decisions under risk/uncertainty there are many attributes that influence the decision; the risk assessment results is just one of them [23]. And for the decision-maker to make a decision the risks and uncertainties need not be expressed using probability or other quantitative tools. Only if a risk-based approach is sought, where a direct link is established between the risk assessment results and the decision, the risk/uncertainty must be explicitly expressed. However, as argued for in this paper and for example by Slovic [23], Apostolakis [2] and Aven [5], such a risk-based approach cannot be justified as risk is more than a quantified measure of uncertainty and there are other concerns than risk that determine what is the right decision.

## 4. Conclusions

The thesis that small risks in many practical situations are over-estimated (and hence are inadequately dealt with – are treated out of proportion to their importance), is common among scientists and in the public discourse about risk. This paper has argued that it cannot in general be justified. In the paper two real-life examples have been presented, demonstrating the invalidity of the thesis. The key is that when there are large uncertainties about the consequences of the activity considered, there is no reference for making judgments about under- or over-estimation of risk. The above thesis is commonly built on an idea of risk (and probability) as an objective quantity that exists independent of the assessor, reflecting the true states of the activity, determined on the basis of observations. However, both the objectivity and the belief in an ability to perform accurate estimation using historical data represent serious misconceptions: There is no objective way of measuring the level of probability and risk that a specific person will be a victim of a terrorist attack tomorrow. The situation is unique with no stable repeatable process justifying a probability model reflecting variation of similar units, as the objectivity would require. What characterizes the situation is not true probabilities but uncertainty. Faced with uncertainties, we are in a situation that needs value judgments balancing different concerns and aspects, the risk (including the uncertainties) and the benefits of the activity.

To understand and guide the decision making in situations of risk, a proper risk perspective is needed. In the paper we show how such a perspective can be formulated meeting the challenges raised by the examples here discussed. The key is that probability is replaced by uncertainty. Following this perspective the importance of uncertainty in understanding risk and the consecutive decision making, is highlighted. The balancing act of risk management also means giving weight to the cautionary principle, which states that, in the case of uncertainties, measures are needed to reduce risk and uncertainties, or even to avoid the activity. It is a principle in line with how people behave, and it is completely rational (in a wide sense of the word).

## Acknowledgments

The author is grateful to three anonymous reviewers for their useful comments and suggestions to earlier versions of this paper. The work has been partly funded by the Norwegian Research Council (Grant number 228335/E30) – as a part of the Petromaks 2 program. The support is gratefully acknowledged.

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