Chapter 2
Uncertainty—Its Ontological Status and Relation to Safety

Ove Njå, Øivind Solberg and Geir Sverre Braut

Abstract The concept of uncertainty is difficult to comprehend, even when we restrict our focus to safety science. In a world with various scientific philosophical stances, "uncertainty" is debated in various contexts. However, in an effort to go deeper into a more basic understanding of uncertainty our knowledge is quickly challenged. What exists? How do we know what exists? What can we know about it? Aiming these questions at uncertainty reveals that interpreting uncertainty as existing in any ontological sense is difficult to defend. Does this imply that uncertainty can only be understood in an epistemological sense or merely as a construct? Epistemological understandings of uncertainty encompass, in principle, the whole rationality spectrum from relativism to positivism, thus not excluding any form of analyses or understanding of uncertainty. However, we recognize the need for an increased understanding of which elements the uncertainty concept comprises, and possible consequences of an unreflective discarding of elements. Within the framework of a linear time concept consisting of the past, the present and not least the future, we claim that uncertainty's ontological status exists on various levels. In the present uncertainty is a purely epistemological category, and in the past uncertainty has its meaning related to what has been observed, recognized and comprehended, thus a methodological challenge. In the futuristic perspective uncertainty exists and cannot be reduced.

Keywords Uncertainty · Ontology · Epistemology · Safety · Risk

O. Njå (✉) · Ø. Solberg · G.S. Braut
University of Stavanger, Stavanger, Norway
e-mail: ove.njaa@uis.no

G. Motet and C. Bieder (eds.), *The Illusion of Risk Control*,
Safety Management, DOI 10.1007/978-3-319-32939-0_2

2.1 Introduction

The rational actor paradigm is often used as a basis for decision making under uncertainty. Proponents of this paradigm consider the uncertainty concept to be something outside the risk concept [10]. Other researchers include the concept of uncertainty as an integral part of the risk concept, where risk is defined as "observable quantities and their associated uncertainties" under the context of a system or activity studied [2, 3]. Opposed to this there are researchers who relate uncertainty to accuracy of e.g. models, data and expert judgments [13]. However, there are very few concrete definitions of uncertainty applied in risk and safety analyses. Lipshitz and Strauss [11] offer interesting thoughts within the Naturalistic Decision Making-Paradigm, in which they relate uncertainty to individuals' cognitive reasoning based on: inadequate understanding, incomplete information or undifferentiated alternatives. They claim that these uncertainties lead to different coping strategies amongst people involved in crisis management. Furthermore Taleb's "black swan" metaphor has raised a vast number of studies trying to develop methodologies to cope with the phenomena of unknown unknowns.

A question worth raising is therefore: Does the safety, risk and uncertainty concepts applied to various infrequent phenomena make any sense in scientific perspectives?

2.1.1 From Risk to Uncertainty

Althaus [1] has presented a thorough analysis of various scientific disciplines' perspectives on risk as depicted in Table 2.1.

Table 2.1 Extract of the analysis presented by Althaus

Discipline	View on risk and safety	Knowledge applied to the unknown (domain)
Logic and mathematics	A calculable phenomenon	Calculations and modeling (method)
Science and medicine	An objective reality	Principles, postulates and calculations (ontology, epistemology and method)
Social sciences	A cultural or societal phenomenon	Culture, social constructs, (epistemology and method)
Economics	A decisional phenomenon	Decision-making theory and principles (epistemology and methods)
History and the humanities	As a story	Narrative (epistemology)
Philosophy	A problematic phenomenon	Wisdom (ontology, epistemology)

This table use a fairly large brush on each of the disciplines and treat them as uniform. Within the single disciplines there are of course different schools of thought and discussions, contributing to the continued development of each discipline.

For each discipline Althaus describes the related view on risk and what types of knowledge is applied to cope with what is termed the unknown. The brackets in the right column are added here as guide to which domain of world (or philosophy and science) this knowledge is related to according to our view. The different domains used are ontology, epistemology and method. Ontology and epistemology as presented in this article, and method as a domain not necessarily adhered to either ontology or epistemology, but an instrumental phenomenon aiming to produce valid argumentations.

When we use the term risk we relate to possible future events, something that has not happened yet, but might happen in the future. This something that might or might not happen often refers to an explicit danger and equally often does refer to an implicit reward. Typical examples of this can be: *the risk of driving, the risk of flying, the risk of oil exploration in Northern Norway, the risk of transporting dangerous goods* and so on. The challenge with the concept of risk is that risk is about the future. That is probably also the main reason for all the controversies and disputes over the concept of risk. Mastery of risk is the mastery of the all-time riddle: what will the future be like? In modern times, this has been modified to: what is most probable that the future would look like?

The main problem with this riddle is that our knowledge about the future in principle is zero. Anything could happen in the next instance. In current everyday language, many think of risk as synonymous with danger in the future, something to be avoided. This danger can also be seen as positive e.g. as a necessary component in an adventure. Another connotation that can be seen frequently is the adverbial risky with a meaning of probable; as in "it is risky", meaning it is very likely to occur. For others risk can be a business opportunity that can be exploited to maximize gains. We also speak about different types of risk e.g. objective, subjective and perceived risk.

Risk has become an increasingly important concept in the globalized world. From being based on individual and locally based assessments, risk is now a central part of global discussions and a driver of research on life threatening issues, such as climate change, terrorism and epidemics. The concept of risk is used as a tool for experts claiming to possess superior knowledge of future threats.

However, risk deals with the core of probability theory. The concept of probability is clarified by adopting Pierre Laplace's formulation of the mathematical theories of probability; "probability theory is only good sense reduced to calculus". When theories of probability conflicted with the intuition of "reasonable men", mathematicians went back to the drawing board and changed their theories: a clash between probability theory and intuition meant the theory was wrong, not the intuition.

Uncertainty in relation to the findings from risk analyses has become a much debated topic in the field of risk research. Pending how uncertainty is understood and used in risk analyses and risk management, uncertainty can be seen as something we can deal with and consequently reduce. The presumption is that if we have more knowledge, uncertainty could be further reduced. Consequently, the risk analyses will

become more reliable and accurate, corresponding more to contents of and frequency of future events. The underlying idea is that if we had sufficient knowledge there would be no uncertainty and thus we would be able to foresee the future, something which of course is not possible (see Laplace's Demon[1]).

Different schools of thoughts meet these challenges differently. Watson [18] presented "The meaning of probability in probabilistic safety analysis" as the degree of belief and proposed it to be a dialectical debate over safety, which is in sharp contrast to those who believes that there is a true underlying risk in the world. The conflict has been very visible between those who view risk as relative frequencies (classical approach) and those who view probabilities (and risk) as a tool to express uncertainty (Bayesian approach). Typical for risk research and practical risk management has been that it is predominately pragmatic in developing risk models, data gathering and risk assessments, neglecting underlying philosophies of science.

2.1.2 The Connotation and Use of the Concept of Safety, Security, Risk and (un)Certainty

Before we discuss the concept of uncertainty, we take a brief look upon the current denotations and etymological basis for some commonly used words in safety management.

The words safe and safety most likely are brought into English via French (adj: *sauf* = without danger) from the Latin verb *salvare*, keep well, live well, save, and the corresponding noun *salvus*, whole, uninjured, intact, not infringed. It is claimed that it is possible to trace the word back to Sanskrit with similar connotations [7].

The original meaning of safety points at an ideal situation or state. This is also parallel to one of the connotations of the word in current English, where safety is defined as the condition of being safe. But according to the Concise Oxford Dictionary, it may also be used as a modifier denoting something designed to prevent injury or damage: a safety barrier. The Macmillan English Dictionary defines safety as the fact that a thing is safe to do or use, but also a place or a situation in which you are protected from danger or harm.

The word security stems from the Latin adjective *securus* which may have a variety of meanings. Ways of translating it into English are free of care, free from worries, happy or cheerful. It has been used in English from late 1500 [7]. At that point of time it replaced the word *sikerte*, which is related to the word *sikkerhet* (Eng. safety) in Scandinavian languages.

Throughout history, the term risk has had varying connotations and uses. Its origin can be traced from the Greek word *rizha*. It denoted something that extended from the trunk of a tree, like a root. Later on in Crete, the beach cliffs "roots" were

[1]Laplace's Demon: a machine that has the capacity to know every detail about the existing world and its intrinsic cause-effect relations, and in addition holding the capabilities to calculate the future based on the preconditions.

given the same designation. It is not clear if these "roots" were seen as a danger for bypassing seafarers and thus were labelled *a risk*, but the word was used in Crete as a nautical expression, a metaphor for "difficult to avoid in the sea". So it may have referred to sub surface (known and unknown) reefs and other types of obstacles that presented a danger if encountered. The word was later absorbed in Latin as the word for *cliff* (*resicum, risicum*), which is the origin of the Italian *risco* and *rischio*, which means danger or risk. In respectively French and Spanish *risque* and *riesgo* were used denoting a similar meaning as in Italian. English borrowed it from Spanish and German borrowed it from Italian. We think it is worth noting that these expressions were spread to different European languages in a time of daring and discovery of new seaways and continents. In the 16th century it seems that risk had a positive connotation. For example in middle-high-German, *Rysigo* (1507) was a technical term for business, with the positive connotation "to dare, to undertake, to hope for economic success".

In the last decades the connotations of risk have become increasingly negative, risk equals dangers and hazards. This can also be seen in several current definitions of risk (examples), and also, as mentioned, in common language connotation. Another explanation for the negative connotation can be found in risks relation to the term *hazard*. Hazard has evolved from the Arabic *al zahr*, which means *the dice*. In Europe playing dice took on a negative connotation as dice games were seen as a possibility for being cheated by con artists. In English as a noun, hazard denotes danger but more interestingly as a verb it denotes *to risk* or *expose to danger*. This is the co-notational connection between the English words risk and danger. If nothing else, this shows that risk and danger are somewhat "related" through the word *al zahr*.

The words certainty and uncertainty appeared in English during the period 1300—late 1400 [7]. It came into English through French from Latin *certanitatem*, which means something that is given or cannot be doubted. Uncertain thus should signify something that can be doubted or discussed.

2.1.3 MSc Students' Perception of Uncertainty When Studying Societal Safety at the University of Stavanger

In the period from 2009–2013, masters students studying societal safety in their second semester have been given a survey. The survey was presented for them when starting up a course in risk management containing the following questions:

1. Describe what you relate to the term uncertainty.
2. Discuss whether uncertainty is related to single persons, or whether groups or entire societies can be connected to uncertainty.
3. Can uncertainty be measured? How would you characterize degrees of uncertainty?
4. If you were asked to express uncertainty related to societal safety, what would you think of?

The response to the survey was organized with two or three students discussing and taking notes, and the responses were then discussed in plenary. There are 59 responses, which are all provided as bullet points or free text sentences.

In general the students listed more than three aspects of the term uncertainty in each questionnaire. The most prominent were firstly, an individual, subjective doubt or lack of knowledge. The second most mentioned characteristic was that uncertainty became related to future outcomes and predictions. Thirdly, uncertainty was closely related to probability, but some also mentioned risk. Furthermore, the students mentioned perceptions like fear and unknowns frequently.

Most of the answers described above were related to individuals, but when students were asked to relate uncertainty to various actors (individuals, groups or society), they usually listed all. However, the answers indicate that it was difficult for them to distinguish between societal systems and societal actors, and similarly for groups the discussions varied from risk exposure to group decisions.

Amongst the students there were a major confusion about measuring uncertainty, they were ambiguous both claiming that it was possible to quantify uncertainty and not. Some equaled uncertainty with probabilities, some claimed that uncertainties could be expressed by risk indices (fatal accident rates, potential loss of life, statistical variation etc.), while many related more qualitative interpretative values (minor, some, much, major) to uncertainty. When the students claimed that lack of knowledge was the premise for uncertainty, they also related psychological characteristics (cognitive, emotional), and even value based considerations (cost-benefit, preferences).

There were no tendencies seen in the students' responses to uncertainty and society. Media communication, disagreement of priorities, disagreement in definitions, vulnerabilities, major accidental events, climate changes, emergency preparedness, diplomacy and politics were some concepts mentioned. Several described complexity as a characteristic that must be given attention when uncertainty should be related to societal safety.

The conclusion to this five-year survey is that even though the students think that uncertainty is an important concept for societal safety, there is no clarity what uncertainty is, how it should be expressed and with what measurement tools it should be considered. Students in 2013 were not different from students in 2009, the responses indicate major confusion about the uncertainty concept. Now we will discuss how uncertainty relates to the scientific stance of risk and safety.

2.1.4 Uncertainty and Its Relation to Risk Theory and Conceptualizations

A crucial issue of any interpretational approach with respect to a scientific theory is the relational elements of the theory on one hand and the elements of the domain of reality for which the theory is designed on the other. This so-called relation of reference cannot be exhaustively addressed within the scope of the scientific discipline concerned. For its proper discussion, genuinely philosophical issues must be taken into account explicitly. One

of the most general demands on a sound philosophical discussion is the distinction between epistemological and ontological statements [4].

Most of the existing scientific and philosophical literature concerning the concept of uncertainty describes uncertainty in epistemological terms. The same can be said about textbooks concerning uncertainty analyses. Much of this literature reflects a normative approach, implicitly stating that the epistemology presented is the most appropriate for solving problems related to uncertainty analyses and decision-making. Seeking the ontological status of uncertainty may yield implications concerning epistemological claims about uncertainty. For example, if uncertainty does not exist as something that is objectively real it cannot be objectively measured as such. If uncertainty can be said to be objectively real it is not a logical or necessary consequence that uncertainty can be objectively measured. Take the core temperature of the sun. The physical state of the core of the sun is an ontological reality, and we can fairly accurately estimate its temperature according to our knowledge of the sun's physical state, but we cannot actually measure the core temperature as such. Further if uncertainty is objectively real; can it be measured objectively?

If you sit in a chair reading, isn't it most likely that you will be in the same situation in ten seconds from now given that you don't choose to do otherwise?. That would be a reasonable assessment. But, it's not absolutely certain that the *status quo* will be upheld. Someone could knock on your door, the phone could ring, the fire alarm might go off, or an airplane might crash into your building. The future is a myriad of different possibilities and thinkable outcomes, but just one is being forever manifest as we go from future, via present to past.

To be able to cope with this myriad of possibilities we need to control or at least attain some sense of control of future events. We do this by making choices. We choose amongst different alternatives of what we would like the future to be. We are constantly being faced with "small" and "big" choices, and we more or less consciously choose amongst the alternatives that present themselves relative to the different choices. The goal of choosing is to satisfy our moment-to-moment or long term needs by choosing the seemingly best (whatever best would mean) alternative at the moment.

The list of "small" and "big" choices that present themselves per day is huge. The choices imply that there are alternate ways of taking action, each action containing the possibility for both losses and gains. Future events, like it could start raining, or I could have an accident on my bike on my way to work, or the land slide occurring at the chemical plant site in 15 years are unknowns at the time of decision. We cannot foresee what all possible and relevant consequences of our choices will be. Nevertheless, we use the concept of risk to help us manage the alternatives that more or less present themselves. We manage risk by using the total sum of all our knowledge, experience and capacity for reasoning to make a decision. The decisions span wide, from the spur of the moment "small" decisions to "big" well considered decisions. We have the "small" minute-to-minute choices we make almost constantly,

and the "large" risks as launching the space shuttle or deciding on building nuclear reactors and so on. The risk connected to the different choices can thus be labelled "small" or "large", but seemingly small decisions can have the potential for large consequences and *vice versa*.

2.2 Contextual Prerequisites for the Uncertainty Concept

Safety and risk are concepts addressing future state of affairs that either is employed for decision making under uncertainty or to characterize an activity's or system's ability to avoid undesired events and outcomes. Thus, the time factor plays a crucial role in order to discuss the ontic status of risk [17].

2.2.1 Time—Past, Present and the Future

2.2.1.1 Uncertainty and the Problem of Tensed Time

The everyday usage and conception of time is its use as a measurement denoting the interval between events. Events are ordered in three main categories consisting of the past, the present and the future. This is sometimes referred to as Newtonian time because this was the scientific interpretation of time until the arrival of the theory of relativity. Measuring time is a human invention, and thus a construction which, according to some philosophers[2] has nothing to do with time per se. In a so called Newtonian time concept the term future is used as an abstraction of all time beyond now. The past being all time before now. Now or present is the term for the transition between past and future.

The philosophical debate on time focuses on the reality of events related to the different tenses. The main controversy has revolved around the status of the future; is the future real? The so called "eternalists" argue that past, present and future events all exist. "Possibilists" hold that past and present events exists. And finally "presentists" argue that only the present is real as such. Discussions concerning the ontic status of time per se have also been a focal point in the philosophical debates. McTaggart [12] formulated what he referred to as an inconsistency in his argument concerning the unreality of time. He argued that since an event E will "move" from future, via present to past as time unfolds, the three states that event E would "go through" would be incompatible, hence the time could not be real as such. McTaggart introduced the terms A-series and B-series of time. These terms have later evolved into separate theories concerning the concept of time. The terms denote two mutually exclusive ways of understanding the concept of time. The A-series is a tensed perception of

[2]See for example Leibniz' correspondence (1715–1716) with Samuel Clarke on Space, Time, and Indiscernible.

time as in past, present and future. Events are seen in relation to one another in the temporal sense of before after and simultaneously. In addition events are categorized as being in the past, the present or the future. The A-series theory is in line with our intuitive understanding of time as tensed, but is not in line with the basic principles of the theory of relativity.

In the B-series theory, time is regarded as tense less. Series of events are related to one another as in the A-series theory, all the way from the Big Bang through present time and into the future. All events in this time series are seen as equally real, thus the ontic status of events that have not yet been manifested are seen as real. This theory is in line with the theory of relativity because tenses are absent.

At least since McTaggart wrote his famous essay "The Unreality of Time", there have been ongoing debates about the ontic status of time and how we should understand the concept of time. This debate has also branched out in debates concerning the ontological status of past, present and future states of the world [6, 9]. An interesting question in the light of the time "controversy" is therefore; does the existence of uncertainty rely on how the concept of time is interpreted? The answer to this is, in part yes. We have previously explained uncertainty as something belonging in the future. Thus we make use of the concept of the future to give meaning to the concept of uncertainty. Consequently one can argue, pending ones philosophical convictions that uncertainty, as something belonging in the future is unreal, hence the "problem" of tensed time and uncertainty. The "problem" being that uncertainty could not be granted a status as objectively real.

However, we think that whether we refer to uncertainty as something of the future or not, is not essential for several reasons. Firstly, it is not absolutely clear that uncertainty is something of the future only, or in part or at all. Secondly, if we referred to the B-series theory and stated that uncertainty is something occurring past a certain point in the time series, the problem would be resolved because tensed time and hence an unreal future would not be of relevance. Thirdly, if the future as such is unreal it does not exclude that logically possible future states of the world can be real, a topic we will discuss later in the article.

What we see as essential to our question concerning the ontic status of uncertainty is whether we in principle can make statements about the outcomes, possible manipulations of situations or actions and to what extent we can render such statements a truth value or a degree of objectivity. Our main conundrum here is that upcoming situations are beyond the present. It is consequently not yet observable, subsequently possible outcomes are in principle unknown. This would imply that our information of what will take place beyond now is in principle zero. In principle anything could happen.

2.2.1.2 What Is Our Knowledge of the Future?

A general view is that if we had adequate knowledge we could reduce the uncertainty and hence predict the future with a greater accuracy. We find this line of thinking inadequate from two positions. First, acquiring adequate knowledge would increasingly

imply a sort of Laplace Demon problem which of course would be impossible to overcome, also philosophically speaking. Second, we think that uncertainty related to the future is of ontic origin not epistemic, because in principle we cannot know the future or future events, thus the uncertainty must be inherently ontic, the uncertainty is a characteristic of the future.

How we can have knowledge of the future is of course dependant on what we mean by the term knowledge. If by knowledge we mean the same as factual knowledge or knowing with certainty it is clear that we cannot know the future in principle, consequently the term "knowledge of the future" would be void of meaning. On such premises one might say that a statement like "the sun will rise tomorrow" would be neither true nor false since we simply cannot know for certain. But if we regard knowledge of the future as an expectation as to what tomorrow will bring or that tomorrow more or less will resemble today, then the term "knowledge of the future" is not meaningless, and the statement "the sun will rise tomorrow" will have a meaningful content. In addition to more linguistic issues related to the knowledge problem there is also the more serious issue of experience. If we did not have any knowledge about possible outcomes of situations or actions, then experience as such would be worthless.

This means that there must be some principles regarding what we could call the stability or regularity of the world, which implies that the world of today will resemble the world of tomorrow. These principles are of course the laws of nature. The laws of nature can at least in part be described as predictive in the sense that they can predict the outcome of experiments (Fig. 2.1). For example the natural law of gravity will predict that if you drop an object in the present it will move in a certain direction with a certain acceleration, and after a specified time the object will be in a specified position in space. But there is a main point to be taken here; it is not absolutely certain that the prediction will be accurate. Something could happen

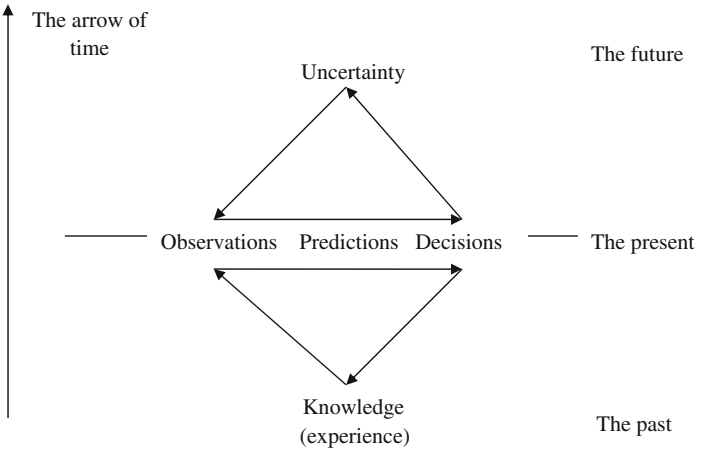

Fig. 2.1 Past, present and future and the concepts of knowledge and uncertainty

which may cause the outcome of the experiment to deviate from the prediction. This is also the core problem with predictions and consequently knowledge of the future; predictions can be made but they are not absolutely certain, they cannot be given any truth value such.

As we see it, this is also the case with the origin of uncertainty as such; we cannot know with certainty what will happen in the future. It is in principle impossible. But we can of course make predictions based on our knowledge about natural laws and other regular phenomena in nature or society. This means that uncertainty is of ontic origin. It is a characteristic of the future and cannot be handled exclusively by increasing our knowledge. Even if there was such a thing as perfect knowledge we still have the problem of imperfect observations and entropic effects thereof. The Danish philosopher Hartnack phrased the problem like this [8]:

> Even in cases where we can have no doubt what so ever about the coming events it is not correct to speak of knowledge. And the reason he gives for this skepticism is well known: All so-called knowledge about the future is based on inductive inferences. We have observed past instances and infer that future instances will be similar. But we can find no reason for assuming that what so far has been repeated will continue to be repeated. Repetition may afford the explanation for our conviction but cannot constitute a logical justification.

2.2.2 System States Through Lenses of Scientific Disciplines

2.2.2.1 Present and logically possible future states of the world

Ontologically, uncertainty is represented by the logically possible future states of the world. In principle, every imaginable logically possible future states of the world represent uncertainty because we do not know what will happen in the future. The future state of the world at time t is uncertain. Therefore we can say that uncertainty is an intrinsic property of the future. The future is, among other things, uncertainty. Thus uncertainty is one of the properties of the future. This is one of the main points in this article. We really do not need any further characterization of the future as uncertain, unknown and so on because the future is per se unobservable and thus unknown. This is the only statement needed to place uncertainty ontologically. Further we must ask what the future contains that is uncertainty.

If we have assessed a specified possible future state of the world, we can monitor and update our assessment as history unfolds. But, if we look at the assessment of a specific state of the world e.g. an offshore installation, it does not imply that after the specified installation were removed that we could measure the total uncertainty of that platform on the grounds that this particular uncertainty has ceased and we now have the complete history. The point being that the uncertainty never ceases. As a result of bringing this installation into production, the logically possible future states of the world will be changed forever, as opposed to not installing the platform that would have rendered different logically possible future states of the world. This means that first you would need a sort of Laplace's demon to render such a calculations possibly

and secondly the calculation would never end. Also observing what happened during the platforms lifespan is not the same as assessing possible future states of the world, thus one would look at uncertainty in retrospect which is quite contrary to what the uncertainty concept is used for.

Ontologically uncertainty is anchored in possible future states of the world, because uncertainty is something of the future in that it is linked to what may or may not happen. But that is not the same as saying that uncertainty *is* some specified logically possible future states of the world per se. The logic for this claim is that no logically possible future state of the world is an unambiguous representation of some specified relation per se. Further, there is no single logically possible future state of the world that would yield a universal agreement of what those possible future states represent. This implies that we do not see any logical argument for separating the logically possible future states of the world and the interpretation of the same because a logically possible future will have no meaning unless we can put meaning into it e.g. by assessing it. Therefore uncertainty is the end product of assessing logically possible future states of the world. The assessment decides whether the logically possible future states present an uncertainty or not, the state of the world in itself does not represent uncertainty implicitly by its own virtue. The different possible states of the world can certainly represent possible dangers and hazards, but then they are just that: possible dangers or hazards. This is because just implying that a logically possible future state of the world represents a danger or a hazard also implies a sort of pre-assessment of those states, which exactly proves our point: who is to decide what is an uncertainty and what is not? This implies that uncertainty is an epistemological category of the present. An implication of this is that if the uncertainty assessor does not exist, uncertainty also does not exist.

2.2.2.2 Present and Logically Possible Future States of the World in Relation to Uncertainty

In principle anything could happen in the future, but intuitively it seems unreasonable that any possible future state of the world should be equally likely. That would mean that life was in a constant state of randomness where nothing could be assessed or predicted and thus leaving the concept of future more or less useless since the chaos today would only be replaced by the "same" chaos of tomorrow. Much to our luck the state of affairs are fairly stable. The earth will most likely continue its orbit around the sun tomorrow, the sun will most likely be producing huge amounts of energy tomorrow and your car will probably be in the garage when you want to go to work tomorrow. The two domains described are contrasting observations of future, but both are equally valid because the unknown future observations exist within the ontological domain and the stable state of affairs observation rests in the epistemological domain. The existence of such a contrasting future in the two domains has obvious implications for the concept of uncertainty on which we will elaborate on below.

We have argued that logically possible future states of the world exist as objectively real. How does this argumentation relate to the ontological status of uncertainty? We argue that it is in principle impossible to claim that any logically future states of the world can be uncertainty free. This would be impossible in principle because the future is unknown. A consequence of this is that logically possible future states of the world represent uncertainty per se, which is our main point in this article.

One could argue that one could theoretically be able to specify *an uncertainty free logical future state of the world* or that such a state is easily imaginable and that this would prove the existence of such an uncertainty free future state. Such an argument would be faulty because it could never be anything but a rhetorical statement, again because the future is unknown in principle. The specification of an uncertainty free future state of the world would just be an epistemological claim since ontologically speaking the future is unknown. However, another and perhaps more eye-catching problem with this relation is that the relation itself is based upon an epistemological claim, namely: no future state of the world can be claimed to be uncertainty free. If our argumentation of an objectively real uncertainty should rest on this would not that implicate an argument of only epistemological value and thus destroying the line of argument? Even if there were no one to observe the future, the future state of such a world could not be uncertainty free because as long as something exists (is objectively real) it will always be exposed to future events, and the consequences of those events cannot in principle be claimed to be uncertainty free (similar as to the previous argumentation). There is a difference between what we in principle do not know and that some future states of the world are more likely to manifest than others. The point being that the future does not become more known or less uncertain because of this difference, this difference is the basis for all claims concerning uncertainty; which again implicitly states that all claims concerning uncertainty is subjective or relative.

If a logically possible future state of the world is being uncertainty, then any thinkable future state of the world would represent an uncertainty, because it would with certainty affect someone in some way (positively or negatively). This implies that the ontological status of uncertainty is totally irrelevant for any epistemological claims about uncertainty, because uncertainty is, ontologically speaking, everything. Certain states of the world can be interpreted as holding a potential for certain consequences by the possible potential effects they represent, but then they would represent just possible effects. Whether we choose to interpret those effects as an uncertainty, is a different matter. This means that uncertainty is an epistemological category only, and this implies that all uncertainty assessments are subjective or relative. This also implies that uncertainty does not have an objective existence per se. What ontologically exist as such are the different logically possible future states of the world and the possible effects they represent. Whether they constitute an uncertainty or not is a different matter.

2.3 Perspectives on Uncertainty in Various Enterprises/Sectors

2.3.1 Health Sector

The concept of risk has no uniform definition in medicine and health care. One of the normative dictionaries merely defines a risk as *a danger or hazard, the probability of suffering harm or other unfavorable outcome* [5].

In epidemiology, which is the part of medicine where the concept of risk has been most thoroughly studied, a quite common definition is *probability of an event during a specified period of time*, where the relevant events e.g. are deaths or appearance of individuals with a defined disease [14–16]. Also in contemporary academic based clinical work (evidence based medicine) this approach seems to be prevailing.

This approach implies that the concept of risk has at least three important properties. Firstly, risk is regarded as something that can be expressed in a quantitative way. Secondly, the calculation of risk emphasizes available historical data of a statistical nature. Thirdly, risk is regarded as a property applicable to populations. Uncertainty is in this context related to aleatory uncertainty and expressed by statistical procedures. The underlying connotation is that there is true risk and probability distributions in which an image of the future is embedded.

The implications of these properties are that risk as a means for prediction of future events to a high degree is an extrapolation of the past. In turn there are principal as well as practical problems connected with judgments of risk on the level of an individual patient.

Thus one may claim that the current concept of risk as described above is more convenient when dealing with populations and public health challenges than with individuals and specific clinical problems.

To deal with practical, clinical problems there has been a lot of work done on medical decision theory, at least since the 1980s. Partly this work has relied on the Bayes' theorem, and partly even has the characteristics of a more fundamental Bayesian approach to the understanding of probability [19]. A typical clinical (diagnostic and treatment) process on individual level carries close similarities with a Bayesian way of thinking. The clinician uses a broad spectrum of general medical knowledge combined with specific information on the single patient to establish a risk picture of the current situation. And this picture is more or less continuously updated when new knowledge appears and hypotheses are tried and proved false.

A short conclusion on the medical approach to risk can be that the clinician, when dealing with individuals behaves according to a Bayesian model, but as a scientist analyzing properties of populations he or she clearly relies on a frequentist's way of thinking.

2.3.2 Aviation/Helicopter Transport

In aviation the concept of risk is closely linked to the concept of safety.

In the guidance material and regulations given in international regulations (ICAO, EASA), the basic idea is to obtain and maintain an acceptable level of safety. In order to achieve that, you need to manage risk. Risk is to be managed with reference to the ALARP principle. Further risk is defined as a combination of frequency and consequence. The management of risk is seen as a typical risk assessment process divided in different stages. You identify potential hazards, you judge the associated risks, and you define an acceptable level and finally you compare the risk to this level to see if further mitigations are necessary. In short, a standard approach based on rational decision processes where politics are obsolete or not considered.

The guidance material or regulations do not mention uncertainty explicitly. Thus implicitly the definition of risk implies that uncertainty is "handled" on at least two levels. Firstly through the frequency approach, where the probability for an event is containing an element of uncertainty in the classical frequency sense, and secondly uncertainty is introduced through the use of the ALARP principle. The ALARP principle, as dictated in the SMM,[3] states that risk is to be reduced to a certain level which should be acceptable. Given a subjective interpretation of risk (and its related consequences) the accepted level of risk is also subjective and thus related to the stakeholder's interpretation of the risk in question and also the subjective interpretation of what is safe enough, i.e. when are we safe (enough)? In relation to the ALARP principle we can see uncertainty in at least two aspects. Uncertainty related to what constitutes a safe (enough) level and uncertainty related to any mitigation put in place to obtain such a level and the uncertainty of the possible effects of those mitigations. We observe that there are different types of uncertainty on different levels, all related to the use of the concept of risk and the use of the ALARP principle.

To have implemented a safety management system is more or less mandatory throughout the world of aviation. Risk as a concept is fairly new in aviation and that can probably explain a lot of the variation in use. Uncertainty as a term is not used at all in any prescriptive or descriptive documentation within aviation. Thus any interpretation of its use must rely on the use of the concept of risk and its interpretation.

2.4 Concluding Remarks

First, we need to address some remarks upon the risk concept. The epistemological claims with regard to risk promote values that are important to humans, such as life and health, environment, and assets. They also focus on preventing negative social values such as social instability, lack of governance or democracy. Being the predominant and acknowledged risk assessor allows for increased power to infer decisions

[3] ICAO Safety Management Manual, 2009.

and influence risk strategies. Risk can therefore become a powerful political tool in areas way beyond the political arenas. The lack of understanding and agreement or lack of focus concerning risk's ontological status fuels the scientific controversies and research on risk. It appears to be expanding in line with the second law of thermodynamics.

We use risk to help us manage decisions and acts based on all our knowledge, experience and capacity for reasoning. It is at best misleading to use the term uncertainty when describing the future. At worst it brings confusion into the picture. There can be epistemological uncertainty related to models and statistical data, but that has nothing to do with the ontological uncertainty concerning risk. It is absolutely certain that we do not know the future. That is not the same as saying that the future is uncertain. The future is unknown, and will remain unknown. Traditional risk analyses, though, can support decisions related to well-known processes, but how this influences uncertainty related to what the future may look like is not clear. Consequently when facing totally new challenges the expectations related to use of risk analyses and the concept of risk should not be exaggerated.

Within the framework of a linear time concept consisting of the past, the present and not least the future, we claim that uncertainty's ontological status exists on various levels. In the present uncertainty is a purely epistemological category, and in the past uncertainty has its meaning related to what has been observed, recognized and comprehended, thus a methodological challenge.

According to how uncertainty is understood and used in risk analyses and risk management, uncertainty can be handled and consequently reduced. The thought is that if we have more knowledge uncertainty could be further reduced, and the uncertainty analyses will be more reliable and accurate (correspond more to the future). That is to say that if we had all knowledge there would be no uncertainty and thus we would know the future, which of course is impossible (see Laplace's Demon). So where goes the limit of our knowledge? Can we have a little knowledge and thus reduce uncertainty with a small amount or can we have a lot of knowledge and thus reduce the uncertainty a lot? No, the uncertainty of the future cannot be handled. What can be handled is uncertainty in methods and measuring (epistemological). But that only contributes to narrowing the quantification; it has nothing to do with the possible future state of the world per se. In the futuristic perspective uncertainty exists and cannot be reduced.

References

1. Althaus CE (2005) A disciplinary perspective on the epistemological status of risk. Risk Anal 25(3):567–588
2. Aven T (2010) Misconceptions of risk. Wiley, Chichester
3. Aven T (2014) Risk, surprises and black swans. Routledge, New York
4. Castell L, Ischebeck O (eds) (2003) Time, quantum and information. Springer, Berlin
5. Dorland WAN (2000) Dorland's illustrated medical dictionary. Saunders, Philadelphia

6. Hamlyn DW (1984) Metaphysics. Cambridge University Press, Cambridge
7. Harper D (2015) Online etymology dictionary
8. Hartnack J (1959) Knowledge of the future. Philos Stud 10(6):89–96
9. Jacquette D (2002) Ontology. McGill-Quenne University Press, Montreal
10. Jaeger CC, Webler T, Rosa EA, Renn O (2001) Risk, uncertainty, and rational action. Earthscan, London
11. Lipshitz R, Strauss O (1997) Coping with uncertainty: a naturalistic decision-making analysis. Organ Behav Hum Decis Process 69(2):149–163
12. McTaggart JE (1908) The unreality of time. Mind: Q Rev Psychol Philos 17:456–473
13. Morgan MG, Henrion M, Small M (1990) Uncertainty: a guide to dealing with uncertainty in quantitative risk and policy analysis. Cambridge University Press, New York
14. Porta M (2008) A dictionary of epidemiology. Oxford University Press, Oxford
15. Rothman KJ, Greenland S, Lash TL (2008) Modern epidemiology. Lippincott Williams & Wilkins, Philadelphia
16. Saracci R (2010) Epidemiology: a very short introduction. Oxford University Press, Oxford
17. Solberg Ø, Njå O (2012) Reflections on the ontological status of risk. J Risk Res 15(9):1201–1215
18. Watson SR (1994) The meaning of probability in probabilistic safety analysis. Reliab Eng Syst Saf 45(3):261–269
19. Wulff HR (1976) Rational diagnosis and treatment. Blackwell Scientific, Oxford