A Conceptualistic Pragmatism in a Risk Assessment Context

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Abstract: The use of probabilistic models, as in Bayesian analysis, assumes some sort of model stability: populations of similar units need to be constructed. But such stability is often not fulfilled. An extended approach is thus required, and a framework for such an approach is conceptualistic pragmatism which links the probabilistic analysis with knowledge theory and the quality movement with its focus on continuous improvement. In this paper we restrict attention to the applications of probabilistic models in a risk assessment context. The purpose of the paper is to investigate how conceptualistic pragmatism may work as a suitable framework for such an extended approach in a risk assessment context. The key to make the framework operational is to perform broad analyses of uncertainties.

Keywords: Risk assessment, Bayesian analysis

1. Introduction

Bergman [1] argues for an extended framework, conceptualistic pragmatism, for the subjectivist (Bayesian) approach to statistical decision making—the judgements made for incorporating new information should be carefully reflected upon. Inspired by the Harvard professor of philosophy Clarence I. Lewis he presents a framework for this type of reflections based on a philosophical action-oriented approach. The philosophy of Lewis has very much influenced the originators of the quality movement ([2], [3], [4], [5]). The framework constitutes a link between two important learning-oriented approaches in the current statistical discourse—the subjectivist theory of statistical inference and the quality movement with its focus on continuous improvements.

Bayesian analysis is a well-established tool for learning. The idea is to first establish adequate probabilistic models representing the variation in the phenomena studied, for example the lifetimes of a type of units. Then the task is to assess epistemic uncertainties (knowledge, lack of knowledge) about the unknown parameters of these models by assigning prior probability distributions. Next Bayes’ formula is used to update the uncertainties (knowledge, lack of knowledge) in light of new data to obtain the posterior distributions. Finally the predictive distributions of the quantities of interest (the observables), for example the lifetime of future units, are derived using the law of total probability. The predictive distributions are epistemic but they also reflect the variation expressed by the underlying probability models.

The use of the probabilistic models in the analysis assumes some sort of model stability: populations of similar units need to be constructed. But such a stability is often not fulfilled, and it is here that conceptualistic pragmatism enters the arena. Given the new observations, the data, a reinterpretation of the knowledge basis might be needed. This applies in particular to the probability models adopted. The data could be surprising relative to the models used, and new insights about the phenomena studied could challenge basic assumptions of the analysis. Good Bayesian analysts should of course...
explore the robustness of the assumptions made and the probability models used [1], but in practice such reinterpretation of the knowledge basis is seldom carried out unless the framework adopted allows for and encourages such reinterpretations. Conceptualistic pragmatism offers a more dynamic framework requiring reflections and, when needed, reinterpretations.

In this paper we discuss the need for and the possible adoption of conceptualistic pragmatism in a risk assessment context. The main purpose of the paper is to show that conceptualistic pragmatism provides a suitable framework for risk assessment. Often risk assessments are carried out without reflection on the probability models used (and other key assumptions of the assessments): are the models adequate (inadequate)? Although the dependencies of the probability models may be recognised as a problem, we seldom see that this problem is given much attention in practice. In this paper we are particularly concerned about the introduction of chances, reflecting the variation in large (in theory) infinite populations. Loosely speaking, a chance is the Bayesian term for a frequentist probability (cf. the representation theorem of de Finetti ([6], see Bernardo and Smith [7], p. 172). In theory these concepts, the chance and the frequentist probability, are not the same but from a practical point of view it is difficult to see much difference [8]. In the case of a die we would establish a probability model expressing that the distribution of outcomes is given by \( p_1, p_2, \ldots, p_6 \), where \( p_i \) is the chance of outcome \( i \), interpreted as the fraction of outcomes showing \( i \). The variation generating the \( p_i \)s are often referred to as aleatory uncertainties in this setting [9], [10]. However, in a risk assessment context, the situations are often unique, and the establishment of chances means the construction of fictional populations of similar situations. Then chances, and probability models in general, cannot that easily be defined as in the die example. In many cases they cannot be meaningfully defined at all. For example, it makes no sense to define a frequentist probability (chance) of a terrorist attack (Aven and Renn [11]). In other cases the conclusion may not be so obvious. For example, a chance of an explosion scenario in a process plant may be introduced in a risk assessment, although the underlying population of infinite similar situations is somewhat difficult to describe.

Many risk analysts define risk through chances. Risk is equal to the combination of chances and consequences (e.g., [9], [12], [13]). Following such a perspective one cannot expect that there is a reflection on the appropriateness of the probability model (i.e., the chances). It is taken as granted. However, as argued above, the premises of this type of modelling is often not fulfilled.

This motivates alternative approaches, broader risk perspectives and several exist as shown in the review of Aven and Renn [14]. Here we focus on perspectives where uncertainty replaces probability. In these categories of perspectives probability (i.e., subjective probability) is used to express uncertainties, but it is acknowledged that subjective probability is just a tool and risk extends beyond the calculated probability numbers. Chances and probability models are not introduced if they cannot be justified. There is a strong element of reflection as in conceptualistic pragmatism. In the paper we will show that these extended risk perspectives are in fact in line with conceptualistic pragmatism. Or rephrased, the conceptual pragmatist approach is an overall framework for proper risk assessment, a framework that allows for and encourages considerations and reinterpretations of the risk assessment approach at different stages of the risk assessment process.

The remainder of this paper is organised as follows. In Section 2 we elaborate on the above mentioned risk perspectives, and in Section 3 the basic features of conceptualistic pragmatism is explained in more detail. Then in Section 4 we formulate and discuss a
conceptualistic pragmatism framework for the risk assessment context. Section 5 provides some conclusions.

2. Basic Risk Perspectives

This section gives a brief review of the two types of risk perspectives described in Section 1. The presentation is based on Aven [15], [16].

We consider an activity and make the following definitions of risk associated with this activity:

i) \( \text{Risk} = (A, C, P_f) \), where \( A \) refers to initiating events (occurring as a result of the activity), \( C \) their consequences and \( P_f \) the related chances (frequentist probabilities) (or related parameters such as the expected number of occurrences of the event \( A \) per unit of time, where expectation is with respect to a chance distribution)

ii) \( \text{Risk} = (A, C, U) \), where \( U \) is the uncertainty about \( A \) and \( C \) (will \( A \) occur and what will the consequences \( C \) be?), including uncertainty about underlying factors influencing \( A \) and \( C \).

We refer to i) as the frequency-based perspectives, and ii) as the alternative perspectives.

The events and consequences need not be specified to define risk: the activity may lead to new types of events/consequences, for example a new type of virus. Writing risk equal to \( (A, C, P_f) \) or \( (A, C, U) \), we should interpret this as saying that the activity could lead to some events and consequences \( A \) and \( C \), and to these events and consequences we associate frequentist probabilities (chances) \( P_f \) and uncertainties \( U \) (we do not know what events/consequences that will be the result of the activity), respectively.

Next we will look into the risk descriptions associated with these definitions i) and ii).

Risk Description for the Relative Frequency Perspective i)

In case i), the risk is unknown as \( P_f \) is unknown. Risk assessment is introduced to describe the risk. The description covers an estimate \( P_{f*} \) of \( P_f \), as well as assessments of uncertainties about \( P_{f*} \) and \( P_f \). Thus if the relative frequency perspective to risk is the starting point, we are led to a risk description:

i) Risk description in the relative frequency case \( (A, C, P_{f*}, U(P_{f*}), K) \), where \( A \) and \( C \) now are some specified events and consequences (for example the number of fatalities) and \( U(P_{f*}) \) refers to an uncertainty description of \( P_{f*} \) relative to the true value \( P_f \), \( K \) is the background knowledge that the estimate and uncertainty description is based on. We refer to \( U(P_{f*}) \) as a second-order uncertainty description. If we use subjective probabilities \( P \) to express our uncertainties about \( P_f \) in line with the so-called probability of frequency approach [9], the risk description takes the form:

i') Risk description according to the probability of frequency approach

\[ = (A, C, P_{f*}, P(P_{f*}), K), \]

where \( K \) now is the background knowledge that the estimate \( P_{f*} \) and the probability distribution \( P \) is based on. Kaplan and Garrick [9] refer to this description as the second level definition of risk – it is combined with the first level \( (A, C, P_f) \).

Following the probability of frequency approach, we are led to the Bayesian set-up. In cases of observations \( X \), Bayesian updating of the subjective probabilities \( P \) are carried out using the standard Bayesian machinery going from a prior distribution to the posterior distribution. Bayesian theorists would not, however, refer to the \( P_f \) values as probabilities, but chances or propensities. A pure traditional statistical approach would not allow for subjective probabilities \( P \). The uncertainty \( U(P_{f*}) \) in i) would only reflect statistical
variation, and could be expressed for example using a confidence interval. The degree of relevancy of the data would then not be taken into account. For this approach we obtain a risk description

\[ \text{Risk description according to the pure traditional statistical approach} = \langle A, C, P_f, d(P_f), K \rangle, \]

where \( d(P_f) \) is a traditional confidence interval for \( P_f \).

**Risk description for the alternative perspective ii)**

Next we look closer at the alternative definition ii) where risk equals \( (A, C, U) \). A risk description based on this definition would cover the following components:

\[ \text{Risk description} = \langle A, C, U, P, K \rangle, \]

where \( A \) and \( C \) are some specified events and consequences (for example the number of fatalities), \( P \) is a subjective probability expressing the uncertainties based on the background knowledge \( K \). What the \( U \) component covers is discussed below. This description may cover probability distributions of \( A \) and \( C \), as well as predictions of \( A \) and \( C \), for example a predictor \( C^* \) given by the expected value of \( C \), unconditionally or conditional on the occurrence of \( A \), i.e., \( C^* = EC \) or \( C^* = E[C|A] \), where the expectation is with respect to \( P \). The consequences can to varying degree be expressed by numbers. Also qualitative or semi-quantitative descriptions could be used, for example consequence categories expressing different severity classes.

We adopt the following interpretation of the subjective probability: the assessor compares her uncertainty about the occurrence of the event \( A \) with the standard of drawing at random a favourable ball from an urn that contains \( P(A) \cdot 100\% \) favourable balls [17]. If the assessor assigns a probability of 0.2 (say) for an event \( A \), the assigner compares his/her uncertainty (degree of belief, likelihood) of \( A \) to occur with drawing a red ball from an urn having 10 balls where 2 are red. The uncertainty (degree of belief, likelihood) is the same. The assignments are judgments based on the assessor’s background knowledge, which we denote by \( K \). To show the dependency on \( K \) we write \( P(A|K) \). The background knowledge could be based on hard data, expert judgments and models. We refer to a subjective probability also as a knowledge-based probability.

This perspective acknowledges that risk extends beyond probabilities. Probability is just a tool used to express the uncertainties but is not a “perfect” tool. As an example, consider offshore diving activities, and the risk, seen through the eyes of a risk analyst in the 1970s, related to future health problems for divers working on offshore petroleum projects [18]. An assignment is to be made for the probability \( p \) that a diver would experience health problems (properly defined) during the coming 30 years due to the diving activities. Let us assume that an assignment of 1% is made. This number is based on the available knowledge at that time. There are not strong indications that the divers will experience health problems. However, we know today that these probabilities led to poor predictions. Many divers have experienced severe health problems ([18], p. 7). By restricting risk to the probability assignments alone, we see that aspects of uncertainty and risk are “hidden”. There is a lack of understanding about the underlying phenomena, but the probability assignments alone are not able to fully describe this status. The \( U \) component in the risk description seeks to capture such uncertainty factors “hidden” in \( K \). See examples in Section 4.

As subjective probabilities are used, this perspective is also Bayesian, although it has a different focus and is based on other building blocks than the probability of frequency approach.
3. Basic Features of the Conceptualistic Pragmatism

To illustrate the conceptualistic pragmatism we consider the following simple example: observations \( X_1, X_2, \ldots \) is a sequence of similar (exchangeable) random quantities taking 1 if a specific type of event A occurs and 0 otherwise. The frequency of successes is denoted \( \theta \), it is the parameter of the model.

Here a dilemma arises [1]. While the Bayesian acknowledges the importance of a subjectivist uncertainty approach based on subjective probabilities, some “reasonable assumptions” or “judgements,” concerning which we can have no absolute knowledge, are left as “absolutely true” without a possibility (at least within the frame of the approach) for making revisions. The problem is the closeness of the approach—once the model is chosen, it does not seem to be possible to escape—whatever we observe, we cannot escape [1].

This is in contrast to the quality movement. One of the main points of the approach of Walter A. Shewhart [2], [3], one of the pioneers of this movement, was the challenge of the “reasonable judgements” behind the prediction of future events. Predictability is a central issue in the subjectivist approach but is not much discussed in relation to the assumptions leading to predictability [1]. However, in the quality movement this is one of the main issues. As mentioned by Bergman [1] Shewhart discussed predictability in terms of a constant system of chance causes, i.e., a cause system which always produces similar patterns of variation. He concluded that in mass production there are some systems for which the outcome variation may be described as coming from a constant system of chance causes, while other systems have what he called “assignable causes of variation”—causes of variation which do not give a predictable pattern of variation.

A system with only chance causes is considered in statistical control and its outcome is “predictable within limits,” [2]. Formally the criterion of exchangeable random quantities is introduced—a sequence of random quantities is exchangeable if their joint probability distributions are independent of the order of the quantities in the sequence [3], [6].

Another key feature of the quality movement is the weight on learning processes, as illustrated by the learning cycle PDSA which is an acronym for Plan-Do-Study-Act [4], [5]. As highlighted by Bergman [1], if the basic mental model behind a planned action is corroborated from the observations the planned action could be taken. If, however, based on reflections on the mental model and its conformance to the observations made, the mental model is not considered adequate for the decision problem at hand, this mental model has to be revised.

The quality movement has been strongly influenced by the Harvard professor of philosophy, Clarence I. Lewis. Lewis’ [19] ideas are based on the concept a priori. This concept is not the same as in Bayesian analysis. To avoid misunderstandings we refer to this a priori as extended a priori in line with Bergman [1]. The extended a priori is interpreted as something similar to that of a “mental model,” a concept made popular by Peter Senge [20] in the context of learning organizations. We can think about the extended a priori more or less as an axiomatic scheme constituted by concepts and their relations [1]. In our usage of the extended a priori, we associate concepts with phenomena in “the sensuously given,” that is in the world such that we perceive it. In our interpretation of the “sensuously given” it is “filtered” through the extended a priori. Only after this filtered interpretation do we experience [1]. Thus, experience is an interpretation of the sensuously given utilizing our extended a priori.

The extended a priori in Lewis’ philosophy is not given once and for all. On the contrary, depending on our intentions we are able to choose our a priori as well as to
change it when there is mismatch between our extended a priori and subsequent experiences, i.e., when we are unable to make sense of the experience; by reflection we are able to make corrections and even major changes [1].

In the world view of Lewis there is no simple systematic means for the updating of the extended a priori when we have accumulative learning. In the Bayesian updating there is a fixed procedure, but applying the conceptualistic pragmatism would mean to see beyond a chosen probability model, as suggested by Bergman [1] in his combined approach – the Bayesian approach and the conceptualistic pragmatism. Bergman’s [1] discussion is mainly related to reflections on the probability model based on observations – make changes if the variation pattern of the observations does not fit well with the judgments made a priori. Different techniques such as control charts and TTT-plots can be used as tools to check for this type of fitness [1].

The need for seeing beyond the numbers is an important feature of the conceptualistic pragmatism. While the Bayesian focuses on measurable aspects of the world, the conceptual pragmatist is worried about all aspects of the world [1]. In the risk assessment framework presented and discussed in the coming section this feature of the conceptualistic pragmatism is a main point.

4. Conceptualistic Pragmatism as a Framework for Risk Assessment

First, let risk be defined by the frequentist probability, i.e., $\text{Risk} = (A,C,P_f)$, where $P_f$ is a chance (frequentist probability). Here the underlying model is the chance set-up as introduced in the previous section: observations (real or thought-constructed) $X_1, X_2, \ldots$ is a sequence of similar (exchangeable) random quantities taking 1 if a specific type of event $A$ occurs and 0 otherwise. The frequency of successes $\theta = P_f$ defines the parameter of the model.

The pure Bayesian analysis is confined to this model. The conceptualistic pragmatism motivates reflections based on experience to modify the model. However, the risk perspective makes it difficult for us to escape, to use the words from Bergman [1]. Whatever we observe, we cannot escape from the Bayesian model. Risk is per se defined through the chance and consequently there is no “acceptance” for rejecting this model. As noted by Bergman [1] good Bayesians should open up for broader considerations (refer to discussions by Lindley [21] related to the so-called Cromwell’s rule), but in practice this is not so often done. If however $\text{Risk} = (A,C,U)$, where $U$ is the uncertainty about $A$ and $C$ (will $A$ occur and what will the consequences $C$ be?), including uncertainty about underlying factors influencing $A$ and $C$, reflection on the model is easier to incorporate. Following this approach chances are not automatically introduced. The extended a priori can include a chance description but the reflection based on observations/experience may lead to rejection of this model. Or the extended a priori can be based on absence of chance models, but the observations/experience can lead to the introduction of such models. We see that the risk perspective is in line with and supports the conceptualistic pragmatism. An example is needed to clarify these issues.

5. An Example: LNG (Liquefied Natural Gas) Plant

The example relates to the location of a new LNG plant outside the city of Stavanger in Norway [22]. The operator would like to locate the plant not more than some few hundred metres from a residential area. Risk assessments are performed demonstrating that the risk is acceptable according to some pre-defined risk acceptance criteria. Risk is expressed using computed probabilities and expected values. Both individual risk numbers and Frequency-Number of fatalities (F-N) curves are presented. However, the assessments and
the associated risk management are subject to strong criticism. The neighbours and many independent experts do not find the risk characterisation sufficiently informative to support the decision-making on the location and design of the plant. Reflections on uncertainties are lacking. The risk figures produced are based on a number of critical assumptions, but these assumptions are not integrated in the risk characterisation presented nor communicated by the operator [23]. This type of risk assessment has been conducted for many years for process plants [24], but the problems seem to be the same. Still a narrow risk characterisation is provided.

Now how is this problem related to the conceptualistic pragmatism? The risk approach taken by the operator is in line with the Risk = (A,C,P_f) perspective. Probabilities are defined as relative frequencies (chances). For example a chance is defined for the event that an accident occurs leading to more than 1000 fatalities. We refer to this chance as \( \theta \).

The set-up is as above, we have to define a sequence of observations (real or thought-constructed) \( X_1, X_2, \ldots \) of similar (exchangeable) random quantities taking 1 if this event A occurs and 0 otherwise. However, the stability that this model presumes does not exist, and based on reflections we have to reject this model. The risk perspective cannot be justified.

Following the risk perspective (A,C,U), risk is expressed by (A,C,U,P,K), where P is a knowledge-based (subjective) probability based on the background knowledge K. According to this perspective the uncertainty assessments are not restricted to standard probabilistic analysis, as this analysis could hide important uncertainty factors as discussed in Section 2. For example, you may assign a probability of fatalities occurring based on the assumption that the plant structure will withstand a certain accidental load. In real life, however, the structure could fail at a lower load level. The probability did not reflect this uncertainty. Or you may assign a low probability of health problems occurring as a result of some new chemicals, but these probabilities could produce poor predictions of the actual number of people that experience such problems.

In this case the extended prior is not likely to be based on the definition of a chance. Rather the framing is just based on the following world view: events (accidents) A may occur leading to few or many fatalities C depending on how the barrier works etc. There are uncertainties about the occurrence of A and the value of C. The analysts will use knowledge-based probabilities to express these uncertainties. The analysts perform the assessments and based on observations/experience the analysts reflect and conclude that there is a need for assessing uncertainties beyond the knowledge-based (subjective) probabilities. The extended a prior is updated and so are the following assessments. It is beyond the scope of the present paper to discuss in detail how to perform the assessments of these uncertainty factors. We refer to Aven [25], [16].

A perspective where the main component of risk is uncertainty and not probability, like the (A,C,U) perspective, means a shift in thinking from risk estimation to uncertainty characterisations. To many this perspective represents a new type of approach in that it allows for questions to be asked concerning existing knowledge, methods and established “truths”. The aim of the risk assessments is to reveal uncertainties and describe them. Different parties may have different views and this is reflected in the risk picture established. Such a perspective is completely different from the (A,C,P_f) perspective. The (A,C,U) perspective does not make it easier to take a stand on what is an acceptable risk or safety level, but puts the ball in the right basket: managers and politicians have the responsibility to balance different concerns and give weight to the uncertainties. The use of the (A,C,P_f) perspective often leads to situations as in the LNG case where the risk assessment produces a “narrow” risk picture telling the “truth” about the risk (\( \theta \)).
framing of the analysis does not allow for sufficiently broad reflections. We cannot escape from the θ model. The model means a focus on “accurate” estimation of the “true” risk – and in practice this is commonly interpreted as the experts’ estimates θ* of θ. There is no need then for giving weight to uncertainties raised by lay people as their view is commonly considered disturbed by perceptual factors such as dread. The “true” risk is not related to such uncertainties. However, following the (A,C,U) perspective there is no true, objective risk and the knowledge basis would typically be broader. It is acknowledged that there is a strong need for reflection on how to frame and analyse the problem. The approach taken must be carefully considered.

We see that the risk perspective and the level of reflection on the approach implemented are extremely important for the risk management. In the LNG case we will argue that it was decisive for the conclusion about acceptance of the location of the plant.

The above analysis has revealed a relationship between conceptualistic pragmatism and the risk perspective. The main aspects of this relationship are schematically shown in Figure 1 for the (A,C,U) risk perspective.

![Figure 1: Schematic Relationship between Conceptualistic Pragmatism and the Risk Perspective (A,C,U)](image)

The extended prior covers how to understand risk and how to describe risk given the background knowledge. Then a risk assessment is carried out according to these ideas. The assessments are seen in relation to observations and data available, and we gain experience which constitutes the basis for the reflections. From these reflections the approach to risk description may be changed, for example, by adding aspects of uncertainty not covered earlier.

6. Conclusion

Probability models constitute the basis for statistical analysis, and are considered essential for assessing the uncertainties and drawing useful insights and making decisions [26], [27]. The probability models coherently and mechanically facilitate the updating of probabilities. All analysts and researchers acknowledge the need for decomposing the problem in a reasonable way, but often we see that such models are introduced and used without reflection. The conceptualistic pragmatism represents a framework for this type of reflections. In this paper we indicate how this approach can be used in a risk assessment context. We show how the approach is supported by different risk perspectives. Special focus is placed on the (A,C,U) type of perspectives in which uncertainties replace
probability in the definition of risk. The reflective dimension of conceptualistic pragmatism is an integrated feature of these perspectives. In these perspectives we do not presume the existence of probability models (chances). They have to be justified. In contrast, the relative frequency-based perspectives (A,C,P) are founded on the existence of probability models and chances. This makes the (A,C,P) perspectives less open for this type of reflections. It is more difficult to escape from the initial assumptions. The implications of this are not only of theoretical interest, it strongly affects judgments about risk acceptance and risk management in general. See discussion in Section 4. We would like to highlight the continuous improvement strategies of the quality movements. The conceptual pragmatist framework as well as the (A,C,U) approach allow for and encourages considerations and reinterpretations of the way risk is assessed at different stages of an activity, which are essential features of a management regime supporting continuous improvements. The alternative (A,C,P) perspectives are considered to be less adequate for this purpose as the framework presume some stronger level of stability in the processes analysed.

References


**Terje Aven** – Please refer to page 319 of this issue for Aven’s biography.

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