Risk informed decision-making and its ethical basis

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Abstract

In decision-making under uncertainty there are two main questions that need to be evaluated: (i) What are the future consequences and associated uncertainties of an action, and (ii) what is a good (or right) decision or action. Philosophically these issues are categorized as epistemic questions (i.e. questions of knowledge) and ethical questions (i.e. questions of moral and norms). This paper discusses the second issue, and evaluates different risk management approaches for establishing good decisions, using different ethical theories as a basis. These theories include the utilitarian ethics of Bentley and Mills, and deontological ethics of Kant, Rawls and Habermas. The risk management approaches include cost–benefit analysis (CBA), minimum safety criterion, the ALARP principle and the precautionary principle.

1. Introduction

In today’s society, risk based or risk informed decisions are made in design and operation of most technical systems. The idea of using such an approach is to ensure that the “right” decisions are made by addressing the overall performance of the system using the proper concept, namely risk. However, a risk approach does not provide answers on what is a good or right decision—risk just describes the possible consequences and associated uncertainties. Clearly, there are dimensions of the decision-making that goes beyond risk, for example ethical and political issues. This paper addresses the ethical dimension. To what extent can we justify the various risk approaches, such as the use of risk acceptance criteria and ALARP, by reference to ethical theories? Is there a link between a specific decision method and ethical principles?

The paper starts out with a brief description and discussion of ethical theories that are found relevant for risk-informed decision-making. Ethical theories ranging from John Bentley’s and John Stuart Mill’s Utilitarianism, to Kant’s, Rawl’s and Habermas’ ethics are described.

From this review we have a basis for discussing the ethical fundament for some common principles and methods used in risk informed decision-making, such as cost–benefit analysis (CBA), the precautionary principle, the ALARP principle and the use of minimum safety standards.

Risk and ethics have been discussed earlier by many researchers, see e.g. Körte [1], Shrader-Frechette [2], Gibbard [3], Leonard [4], Harasanyi [5]. Our work extends the work by Körte [1]. Shrader-Frechette [2] compares a rather extreme version of CBA, links this to Utilitarianism, and compares this with Rawls’ ethics. Harasanyi [5] discusses the CBA and how they are linked to Utilitarianism.

The aim of this paper has not been to give a complete and all-including review of the ethical theories and the risk decision principles. We just provide brief summaries, and the reader has to consult the references for further details. These summaries are, however, considered sufficient to give the proper context and sharpness for discussing common risk decision principles, using different ethical theories as basis. Our target group for this paper is the engineering risk community.

2. Ethical theories

This section gives a short review of deontological ethics and consequence ethics (consequentialism). Then the
utilitarianism—a version of consequentialism—and Kant’s ethical theories, Hans Jonas additional imperative, Rawls’ theory of justice, and Habermas discourse ethics—all versions of deontological ethics—are briefly described. The review is based on Johansen and Vetlesen [6], Skorupsle [7], Guyer [8], Freeman [9], Rasmussen [10], Encyclopaedia Britannica [11] and Wikipedia Encyclopædia [12].

2.1. Deontology versus consequentialism

Two of the main ethical directions are deontology and consequentialist theories. Deontology is the view that morality either forbids or permits actions, whereas consequentialist theories express that the rightness of an action depends on the consequences of the act. The most famous deontological theory is that introduced by the German philosopher Immanuel Kant. Also Rawls’ and Habermas’ ethics mainly fall into deontological ethics. Within the consequentialist ethical theories, utilitarianism is the most important ethical theory in this context.

In risk informed decisions, a deontologist may claim that there are right and wrong decisions up front, whatever consequences. He may claim that it is never right to expose a person to a certain risk, even if the consequence is an increased welfare of the society as a whole.

2.2. Utilitarianism

Utilitarianism [7] is both a theory of the good and a theory of the right. Utilitarianism would regard an action as good if the action yields value in form of pleasure to humans, and right if the action yields the greatest net value for the society. Jeremy Bentham originally proposed utilitarianism in 18th century England, and John Stuart Mill further developed the theory.

Risk informed decisions following a utilitarian perspective would require that the outcome of the various choices are measured in some form of utility, and that these outcomes can be compared so that the choice with the best performance can be selected. This can be done in practice by using the maximum expected utility or the use of CBA [13,14]. The most common measure of utility is monetary values.

Making the utilitarianism operational is difficult, and using the theory of expected utilities and/or CBA the limitations and constraints of the tools need to be reflected in the way the analyses are used, see e.g. [15, Chapter 5]. These tools do not provide hard decisions, but decision support.

2.3. Kant’s deontology

Kant’s theory [8] includes the idea of a categorical imperative. A categorical imperative, generally speaking, is an unconditional obligation, or an obligation that we have regardless of our will or desires. Our moral duties can be derived from the categorical imperative. The categorical imperative can be formulated in three ways:

- The first formulation (the Formula of Universal Law) says: “act only in accordance with that maxim through which you can at the same time will that it become a universal law”, where a maxim is a subjective or internal rule for what action to take given a set of circumstances.
- The second formulation (the Formula of Humanity) says: “Act that you use humanity, whether in your own person or in the person of any other, always at the same time as an end, never merely as a means.”
- The third formulation (the Formula of Autonomy) is a synthesis of the previous two. It says that we should so act that we may think of ourselves as legislating universal laws through our maxims. We may think of ourselves as such autonomous legislators only insofar as we follow our own laws.

As mentioned earlier, the deontological ethics, as Kant’s ethics, are often seen as being in conflict with the consequential ethics such as utilitarianism. The conflict between Kantian ethics and Utilitarianism is e.g. in the Formulae of Humanity, as one could regard exposing other persons for higher risk in order to achieve personal or societal benefits or measuring the value of a person’s life in monetary value in a risk informed decision-making, to be treating the person merely as a mean. However, if the risk exposure is voluntary, the second formulation of the categorical imperative may not apply. If a person chooses to expose himself to risk, no other person is using this person as a mean.

A frequently used formulation for this ethics can be stated as: Those actions are right that equally respect each human as a moral agent. A moral agent is an individual capable of both formulating and pursuing purposes of his or her own and of being responsible for the actions taken to fulfill those purposes.

Many have pointed out that the Categorical Imperative is simply a reformulation of the Golden Rule: Do unto others as you would have them do unto you. Under the Categorical Imperative, we would only act in ways that we would want everyone else to act. Thus, we could murder with impunity only if we would allow others to do so.

2.4. Hans Jonas imperative

Hans Jonas [16] insists that human survival depends on our efforts to care for our planet and its future. Following Kant, he formulated a new imperative of responsibility, “Act so that the effects of your action are compatible with the permanence of genuine human life”; or as stated in [16]: “In your present choices, include the future wholeness of Man among the objects of your will”.

If the effects of our actions today on the future generations of Man should be assessed, the uncertainties
with respect to the consequences of a decision would be very large.

2.5. Rawls' principle of justice

Rawls’ [9] primary objective in A Theory of Justice is to develop an alternative systematic account of justice that is superior to the utilitarianism. The main problem with utilitarianism, as Rawls sees it, is that it allows the rights of some people to be sacrificed for the greater benefit of others, as long as the total happiness is increased.

Rawls defines what he calls The Original Position. In the original position, each person would not know his or her financial situation, race, creed, religion, or state of health. In this position we were to establish the just social contract that we would agree upon. Rawls deduces that a just society would be based on two principles.

2.5.1. The first principle of justice

First of all, each person would have the most extensive system of rights and freedoms which can be accorded equally to everyone. These include freedoms of speech, conscience, peaceful assembly, and so forth, as well as democratic rights. The first principle is absolute, and may never be violated, even for the sake of the second principle. However, various basic rights may be traded off against each other for the sake of obtaining the largest possible system of rights.

2.5.2. The second principle of justice

Secondly, economic and social inequalities are only justified if they benefit all of society, especially its most disadvantaged members. Furthermore, all economically and socially privileged positions must be open to all people equally. Unlike the utilitarians, Rawls does not allow some people to suffer for the greater benefit of others.

Shrader-Frechette [2] links Rawls’ ethical principles with the maximin principle, saying that policies having the worst possible consequences should be avoided. She argues that Rawls is taking the maximin principle as equivalent to the difference principle, saying one society is better than another if the worst-off members of the former do better than the worst-off in the latter.

Shrader-Frechette [2, p. 117], also gives a clear argument for the difference between Rawls’ ethics and the utilitarian ethics: “If all members of a society have an equal, prima facie right to life, and therefore bodily security, as the most basic of human rights, then allowing one group of persons to be put at greater risk, without compensation and for no good reason, amount to violating their rights to life and to bodily security.”

2.6. Habermas's discourse ethics

Habermas’s [10] starting point for his discourse ethics is the Kantian imperatives. However, the problem of how to claim universality for a rule of conduct is of major concern in the Kantian ethics. According to Habermas, to be able to establish whether a rule is universally acceptable involves that, ideally, all affected must have participated in establishing the rule or norm and consent to it. A requirement for this approach is that all involved are committed to achieving consensus. Habermas proposes to solve this by stating that only the norms that can find (or could find) agreement between all involved parts in a discourse can claim to be universal.

In risk informed decisions this would mean that there is a need for a common ground between the involved parties in the activity. The involved parts in a petroleum activity, or stakeholders, would be the society, the workers, the government and the owners/investors. In order for all these stakeholders to be involved in the decision, thorough and balanced background documentation is needed from the risk analyst. The risk analyst’s responsibility in this context will be to provide the necessary documentation in order to make it possible for the stakeholders to make such a decision.

3. Common decision principles in risk informed decision-making

Risk informed or risk based decision methods may be seen as utility based or rights based. Among the utility based decision methods are CBA and multiattribute analysis. Among the rights based decision methods are zero risk, bounded or constrained risk using risk acceptance criteria. These principles are briefly reviewed in the following.

3.1. Cost–benefit analysis

As an example, consider the search for an optimal design of a technical facility. Following economic theory we may formulate the design as a decision problem within the framework of Bayesian decision analysis as presented in [13]. In short, the decision problem may be formulated as an optimization problem, where the expected life cycle benefit is maximized. Due to the fact that income and costs occur at different times, the expected benefit is capitalized (by means of its net present value) to the point in time when the decision is made. The benefit can be calculated taking into account the income including the possible loss of income in case of failure/breakdown, the cost of developing the facility including the additional cost of increasing the safety of the facility, and the cost of a failure of the facility. The formula used is

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where \( E[B] \) is the total expected benefit, \( E[I] \) is the expected income, \( E[C_0] \) is the expected operational cost, \( E[C_D] \) is the expected development cost and \( E[C_F] \) is the expected failure cost.
According to traditionally CBA, the optimal decision is the alternative that has the best expected benefit. The analysis is based on the transformation of loss of lives, injuries and environmental damage to monetary values. This is done by introducing for example an expected cost per expected saved lives.

Monetary numbers for the costs of avoiding a statistical fatality have been established and used in various ways. Ranges from 1 MNOK to 200 MNOK have been used in CBA [17]. A possible method to take into account possible fatalities was developed by Nathwani et al. [18] as the life quality index (LQI). From this index, Skjong and Ronald [19] derived the amount of money, which should be invested to avert a fatality ICAC (implied cost of avoiding a fatality), see e.g. [20,21]. According to Rackwitz [21], the societal loss due to losses of lives, can and should be taken into account in the design decision problem by including its cost equivalent, i.e. the expected number of fatalities NF multiplied with ICAC.

3.2. Risk acceptance criteria

Decisions based on risk acceptance criteria imply that an acceptable risk level is defined in some form, and the calculated risks are compared to this level. The criteria typically relate to human lives and the environment. For the former case, criteria are normally formulated based on individual risk and societal risk, see e.g. [22]. The development of these acceptance criteria can differ from pre-defined acceptance criteria from regulatory bodies, acceptance criteria developed from CBA, or acceptance criteria defined by evaluating the safety level in the industry practice. Our focus here is the pre-defined criteria, not based on CBA or similar types of analysis. The Norwegian regulation of the offshore industry is an example of using such risk acceptance criteria (PSA) [23], where major safety systems should tolerate a load level with an annual probability of $10^{-4}$. The use of risk acceptance criteria is a mechanical decision tool, the risk is either less than the acceptance criterion or it is not.

3.3. The cautionary and precautionary principle

The cautionary principle [23,24] states that in face of uncertainties, caution should be the guiding principle. In safety applications, there exist uncertainties about the possible occurrence of hazardous situations and accidental events. Following the cautionary principle, one should seek solutions that are robust in the sense that such events are avoided and the consequences reduced in the case that such events should occur. For example in the Norwegian petroleum industry it is a requirement by regulation that living quarters on an installation should be protected by fireproof panels of a certain quality, for walls facing process and drilling areas. This is a standard adopted to obtain a minimum safety level. It is based on established practice of many years of operation of process plants. A fire may occur, it represents a hazard for the personnel, and in the case of such an event, the personnel in the living quarter should be protected. The assigned probability for a fire exposing the living quarter on a specific installation may be judged low, but we know that fires occur from time to time in such plants. It does not matter whether we calculate a fire probability of $x$ or $y$, as long as we consider the risks to be significant; and this type of risk has been judged to be significant by the authorities. The justification is experience from similar plants and sound judgments. A fire may occur, it is not an unlikely event, and we should then be prepared. We need no references to analysis and risk informed decision-making. The requirement is based on a cautionary thinking.

Risk analyses, CBA and similar types of analyses are tools providing insights about risks and the trade-offs involved. But they are just tools—with strong limitations. Their results are conditioned on a number of assumptions and suppositions. The analyses are not expressing objective results. Being cautious also means to reflect this fact.

The precautionary principle [25,26] states that in the case of lack of scientific certainty about the consequences, the activity should be avoided or measures should be implemented. Hence, it is e.g. lack of scientific certainty about the causal links between an action or incident and the possible consequence of this action or incident that is the focus of the precautionary principle. In such cases the precautionary principle should be followed, and focus should be on whether the possible consequences could be avoided, if there is an alternative better and safer solution.

3.4. The ALARP principle

The as low as reasonably practicable (ALARP) principle gives strong weights to the cautionary principle [24,27,28]. The ALARP principle expresses that the risk should be reduced to a level that is as low as reasonably practicable. The ALARP principle implies what could be referred to as the principle of ‘reversed onus of proof’. This implies that the base case is that all identified risk reduction measures should be implemented, unless it can be demonstrated that there is gross disproportion between costs and benefits. To verify ALARP, procedures mainly based on engineering judgments and codes are used, but also traditional CBA and cost effectiveness analyses. When using such analyses, guidance values are often used, to specify what values that define ‘gross disproportion’. The ALARP principle may be considered to give a stronger weight to the cautionary principle than the industry would find adequate, but it is a way for the society to control the risks for human beings and the environment.

The ALARP principle is usually applied in a three region context, where low risks (probability of occurrence lower than say $10^{-6}$) are called negligible (acceptable), and high risks (probability of occurrence higher than say $10^{-4}$) are intolerable and must be reduced. In between these two, we
find the ALARP region where risks should be reduced according to the ALARP principle.

3.5. Multiattribute analysis

The basis for decision-making as presented here, is taken from Aven [15], Aven and Vinnem [17] and Aven et al. [29]. The method may be described as a multiattribute analysis with managerial review and judgment.

A multiattribute analysis is a decision support tool analysing the consequences of the various measures separately for the various attributes (technical feasibility, economy, safety, etc.). Thus there is no attempt made to transform all the different attributes in a comparable unit. In general the decision-maker have to weight non-market goods such as safety and environmental issues with an expected net present value, \( E[\text{NPV}] \), calculated for the other attributes (market goods) in the project. An alternative way to weight the different attributes is to use different ratios, based on a cost-effectiveness analysis.

A simple model of the decision process is shown in Fig. 1 and covers the following items:

1. Stakeholders. The stakeholders are here defined as people, groups, owners, authorities that have interest related to the decisions to be taken. Internal stakeholders could be the owner of the installation, other shareholders, the safety manager, labour organizations, the maintenance manager, whereas external stakeholders could be the safety authorities (the Petroleum Safety Authority, the State Pollution Control Agency) and environmental groups (Greenpeace, etc.).

2. Decision problem and decision alternatives. The starting point for the decision process is a choice between various concepts, design configurations, sequence of safety critical activities, risk reducing measures, etc.

3. Analysis and evaluation. To evaluate the performance of the alternatives, different types of analyses are conducted, including risk analyses and CBA (cost-effectiveness). These analyses may, given a set of assumptions and limitations, result in recommendations on which alternative to choose.

4. Managerial review and judgment. The decision support analyses need to be evaluated in the light of the premises, assumptions and limitations of these analyses. The analyses are based on a background information that must be reviewed together with the results of the analyses. Considerations should be given to factors such as

- The decision alternatives being analysed.
- The performance measures analysed (to what extent do the performance measures used describe the performance of the alternatives?).
- The fact that the results of the analyses represent judgments and not only facts.
- The difficulty of assessing values for burdens and benefits.
- The fact that the analysis results apply to models, i.e., simplifications of the real world, and not the real world itself. The modelling implies that a number of limitations are introduced, such as replacing continuous quantities with discrete quantities, extensive simplification of time sequences, etc.

In Fig. 1 we have indicated that the stakeholders may also influence the final decision process in addition to their stated criteria, preferences and value tradeoffs.

The approach acknowledges that there exist no simple and mechanistic method or procedure for balancing different concerns. We have to see beyond the analyses—they have strong limitations. The tools are supporting the decisions—they are not proving hard decisions. The analyses have to be put into a broader process of managerial review and judgment.

The approach may be further detailed [29]:

- Focus should be on meeting defined overall objectives; which should be formulated using quantities that are...
observable (such as the number of fatalities, the number of injuries, the occurrence of a specific accidental event, etc.). Probabilistic quantities should not be used to express such objectives.

- Safety management is a tool for obtaining confidence in meeting these objectives.
  - Emphasis should be placed on generating alternatives, to be compared with respect to projected performance.
  - Overall risk acceptance criteria should not be used.
  - To ease the planning process for optimizing arrangement and measures, requirements on safety systems and barriers are useful.
- What is acceptable from a safety point of view, and what constitutes a defensible safety level, cannot in principle be determined without incorporating all the pros and cons of the alternative, and the decision needs to be taken by personnel having formal responsibility at a sufficiently high level.

Generally speaking, a criterion or requirement related to safety cannot be isolated from what the solution and measure mean in relation to other attributes, and in particular costs. It is impossible to know what should be the proper requirement without knowing what it implies and what it means when it comes to cost, effect on safety etc. In other words, first we need the alternatives. Then we can analyse and evaluate these, and then we should make a decision. This is the theoretical platform for this multi-attribute approach. In practice, a more pragmatic implementation is required. It is necessary to simplify and use some type of requirements and sub goals, for example related to the reliability of a safety system. Through such requirements and sub goals, safety personnel could more easily follow up and management does not need to be involved in difficult value judgments too often.

4. Discussion and conclusions

4.1. Cost–benefit analysis

The calculation of optimal safety based on CBA can be justified with reference to the utilitarian moral philosophy [2]. However, the use of CBA does not necessarily require a utilitarian basis. If the CBA is used mechanically to produce decisions, it could be seen as a way of making the utilitarian theory operational. On the other hand, a CBA used only to inform the decision maker on the economic aspects of the decision, but acknowledging that the decision is made from a broader information basis, does not need to be utilitarian at all.

The CBA can be taken to be a rather extreme tool used for societal decisions. In this case, all societal investments in safety should be evaluated by a CBA, and only accepted if the CBA shows a positive benefit by implementing the safety investment. All attributes should be included in the CBA, including the societal costs associated with loss of lives and environmental damages. The CBA will then be a political tool for decisions, and could to large extent replace political processes. Such an implementation of CBA could be seen as a way of making the utilitarian theory operational as a political process. Schrader-Frechette [2] argues against such an implementation of CBA, as it is more designed for risk taking than risk control. She further argues that in such a decision scheme, highly improbable accidents would not be a significant concern in decision-making. The authors find this extreme version of CBA totally unacceptable, as it means that complicated political processes are replaced by more or less arbitrary mathematical one-dimensional exercises, which cannot be justified.

A more common use of CBA, is the micro-economic implementation of the CBA, where a single company and the benefits for this company is the focus of the CBA. In pure economic evaluations, where human and environmental safety is not an issue, such a use of the CBA is not problematic. In this case the decision is rather simple, as the purpose is to optimize the economy for the company. However, companies also need to include safety of personnel and environment issues in their studies, in e.g. investments projects. Then the decision-making also need to incorporate ethical issues, for example related to exposure of personnel to risk for the sake of additional income. The CBA may then provide useful information for the company as a decision support. However, a mechanical use as described above cannot be justified.

The values that should be optimized according to Utilitarian theory, does not necessarily have to be cost related. The value in traditional Utilitarian theory is linked with happiness, and happiness may be measured on a totally different scale than monetary values, for example perceived safety.

One argument supporting the CBA as a basis for decision-making is that in the long run it pays off [30]. The control of risks (in the sense of mastering them effectively and efficiently) must obey the rules of modern decision theory and uncertainty. However, according to Høybråten [31], studies indicate that countries that choose a balanced approach to growth (balance between health and life of individuals, protection of environment, and economic values for industry and society) are the very same countries that perform best economically. This does not, in our opinion, mean that that you can prove that a balanced approach is the right approach in risk based decision-making, but rather indicate that the CBAs have strong limitations and weaknesses.

4.2. Pre-defined risk acceptance criteria

In principle, we consider the use of pre-defined risk acceptance criteria to be mainly a deontological decision principle, as the criteria should be fulfilled without a reference to other attributes such as costs. Risk acceptance criteria have the form of clear rules and obligations.
People, individuals and groups, and the environment should not be exposed to a higher risk than specified by certain limits. If risk is above these limits, risk-reducing measures need to be implemented.

The deontological theories presented here (Kant, Jonas, Rawls and Habermas), all clearly focus on the individuals right with respect to risk exposure. Hans Jonas is also clearly including the environmental concerns into the ethical basis for decisions. A zero accident philosophy would in many aspects be the right philosophy based on deontological thinking. However, in practice it is impossible to obtain a zero risk as anything more than a vision when facing uncertain future events and consequences. This would lead to more pragmatic implementations of the deontological ethics in practical decision-making.

Elliot and Taig [32] develop the practical pragmatic implementation of the deontological ethics starting by stating that “No person or organization has a moral right to expose another to risk”. This is the starting deontological principle, as mentioned earlier. They go on and state some reasonable exceptions to this statement. First it is argued that “It is morally acceptable to expose another person to risk if the purpose of the action is to reduce the net risk for this person”. This is exemplified by a patient undergoing surgery for a medical condition. It is recognized that the risk creator in such situations has a moral obligation to explain the risk to the person who will face it and secure informed consent before starting out. The next extension of this exception would be “It is morally acceptable to moderate risk in order to reduce risk for others”. This can be exemplified by the work of a rescue crew or the fire department. The final extension that is formulated by Elliot and Taig [32], is that “It is morally acceptable to ask someone to take a modest health or safety risk in order to accrue other, non-health or safety benefits for others”. This is exemplified by people working in hazardous jobs. This will however, require that those at risk should, where possible, give their informed consent and that those creating or managing risks should be competent in minimizing them within reason. The general principles for responsibility of organizations that should apply in such situations are as follows [32]:

- Ensure openness and transparency about risks and how they are controlled.
- Continually search for ways to reduce risk, unless they compromise other desirable outcomes.
- Use resources competently and effectively to control risk.
- Involve people in decisions that affect them as far as practicable.
- Work across the spectrum of areas for which the organization is responsible, those for which it shares responsibility with others, and those it can influence but not control.

Such pragmatic ways of deontological thinking may be extended in many different directions. The point is that the level of risk acceptance is difficult to determine without looking at the full spectra of risk attributes. Strict adherence to the deontological principle is not easy to follow in practice.

As discussed in [17,29] the use of risk acceptance criteria easily gives focus on reaching these criteria, rather than focussing on obtaining alternatives that are good with respect to safety, cost and other strategic criteria used in the decision-making process. The use of risk acceptance criteria is also based on the assumptions that risk can be accurately determined and compared with the criteria. However, as shown in [15] such assumptions are not, in general, valid.

4.3. The cautionary and precautionary principles

Both these principles are in general based on deontological ethics, and can be viewed as pragmatic implementations of the deontological ethics.

In all risk based or informed decisions, we are facing uncertainty. Hence the cautionary principle would make itself applicable in all risk informed decisions. Following this way of thinking, we should always act with caution and not necessarily chose the economic “optimal” solution.

According to Shrader-Frechette [2, p. 127] “If technological rulemaking created a climate of maximin, a climate in which decision makers aimed at avoiding worst cases, both they and society would likely be more aware of potential accident consequences, ..., and more aware of human errors in risk assessment.” We see here a link between the cautionary principle and the ethics of Rawls, Caution may be seen as the implementation of Rawls’ maximin principle, to choose the risk distribution where the least well off are least disadvantaged. Rawls gives the following argument to support the maximin strategy [2, p. 116]: (1) It would lead to giving the interest of the least advantaged the highest priority; (2) It would avoid using a utility function, designed for risk taking, in the areas of morals, where it does not belong; (3) It would avoid the utilitarian use of interpersonal comparisons of utility in defining justice; (4) It would avoid making supererogatory actions a matter of duty, as do utilitarian theories; (5) It would avoid the utilitarian dependence on uncertain prediction about the consequences of alternative policies.

The precautionary principle is being used in the case of lack of scientific certainty about the consequences, for example related to future environmental consequences (for following generations) of an action. If we were to follow Hans Jonas’ imperative, we should “including the future wholeness of Man” as an object in our decision. With the limited scientific certainty we can claim for the future wholeness of man, it is difficult to see any other means of meeting Hans Jonas’ imperative then to follow the precautionary principle.
A practical way of fulfilling both these principles would be to require robustness for the unknown and uncontrollable, e.g. using barriers, and to focus on some worst case scenarios. Barriers can be used in risk reduction and accident prevention in various ways, but will in general mean that one identify the possible hazards and the failure modes following these hazards, and implement barriers to prevent these failure modes to occur. The number of barriers and the robustness, reliability and availability of these barriers may be implemented according to the probability of the hazard and the consequence of the failure.

4.4. ALARP principle

The ALARP approach can be interpreted to have a deontological element, as its purpose is to achieve as low as possible risk exposure. The ALARP principle puts strong weight on the cautionary principle. Risk and uncertainties should be reduced. However, the focus on “reasonably practicable” means a reference to the consequences, and would thus also include an element of consequentialism. An ALARP evaluation may be performed with focus on these consequence elements within a cost benefit approach, resulting in a process similar to a CBA.

The three region version of ALARP includes two acceptance criteria into the evaluation, where low risks are called acceptable, and high risks are intolerable and must be reduced. The ALARP principle is, in this implementation, only applicable in between these two risk levels. The focus for a risk assessment following the three-region ALARP principle will often be on these limits. The primary goal would be to avoid the intolerable region, and if possible enter the acceptable region. The focus of the general ALARP principle for obtaining a good solution with respect to safety and cost can easily be lost by the focus on the acceptance criteria (tolerability limits).

4.5. Multiattribute analysis with managerial decision

The multiattribute analysis with managerial decision may be seen as a method for balancing the deontology and consequentialist theories. The focus of the risk analysis in this approach is to produce good alternatives with respect to safety, economy and other attributes. It includes risk reduction without high-level risk acceptance criteria, and includes an element of deontology. It also includes CBA. The decision process is, however, not mechanical on the basis of the risk analyses and these decision analyses. The decision process can be seen as a process of evaluating and weighing the different stakeholder interests. The stakeholders may to some extent have different means, and hence different agendas for the decision-making. However, by including these views and presenting them clearly, the decision-making process would be open and finally end in a discourse that can be audited by the stakeholders. A managerial decision based on such a process would to large extent be in line with Habermas’ discourse ethics.

A critic to this way of thinking may ask whether anything is acceptable within the multiattribute analysis with managerial decision, as long as the decision makers find discourse. The answer is obviously “No”. The decision makers should take into account the relevant goals, criteria and preferences by the stakeholders, but the acceptance should not be based on direct use of risk acceptance criteria. The interests of the stakeholders would in most cases be that the safety is at least in accordance with normal practice, which means that the decision process should be able to account for some indications of a reasonable risk.

Let us look at an example: Imagine an offshore platform concept where personnel risk acceptance is specified through an acceptance criterion; FAR (fatal accident rate)<10. The FAR value is defined as the expected number of fatalities per 100 million exposed hours. According to the multiattribute approach, the decision of the acceptance of this project for further optimisation should be based on a broader evaluation than this criterion. Maybe the concept is very attractive on a number of other attributes, for example costs, and then it would be meaningless to exclude it because of the risk calculation giving a FAR value of say 12. The starting point is evaluation of all attributes without unnecessary constraints. The safety for personnel has to be given due considerations, but is not dependent on whether the calculations give FAR = 9 or 12 say. The precision level of risk calculations is not that sharp. Confidence in meeting the high level goals is not a direct function of the calculated FAR values. We have to look at a number of aspects, to conclude that safety is acceptable, such as

- Are company and authority requirements met?
- Is best available technology used?
- Is the concept robust with respect to safety?
- Is risk reduced to a level which is ALARP?

The results of risk analyses cannot alone provide the basis for determining whether a concept is acceptable or not from a safety point of view. We refer to the discussion in [17,29].

An advantage of this type of risk informed decision is that the moral dilemmas are not hidden in the decision method. The dilemmas need to be addressed by the decision makers and the assessments being available for evaluation by auditors. By using a pure CBA, the moral dilemma is hidden inside the method, and the best solution according to the computed expected NPV is chosen. Similarly with fixed risk acceptance criteria, the solution that just meets the criteria is chosen. The moral dilemma is not highlighted and not addressed. It may not even be visible for an auditor. With the multiattribute decision-making, the moral dilemma are clearly defined. The dilemma needs to be discussed by the decision makers,
and result in a documented argument supporting the final decision. The documentation should be available for a possible audit by stakeholders, making a discussion about the decision possible, in a better way than if the moral dilemma is hidden in the decision method. The decision may not be altered, but the dilemma has been focused and discussed, and a defense for the decision is available.

5. Conclusions

All the evaluated decision methods seem to have a reasonable basis in sound ethical theories. There is no clear guidance on which ethical position that is preferable to others. Hence, it is difficult to use the ethical theory as a guiding principle to choose between the decision methods. However, it can be concluded that there seems to be a rational logical link between the decision methods available and the major ethical theories available.

The authors are of the opinion that awareness of the ethical element of a risk informed decision is an important aspect. Hence, methods where the ethical dilemma of the decision making is brought to attention for the decision makers is preferred, and methods where the ethical dilemma is hidden in the decision making method should be used with care.

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