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TITTEL PÅ MASTEROPPGAVE: Risk regulation and risk perception – the link to risk perspectives

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Preface

This thesis has been prepared as the concluding part of my study for a Master's degree in Societal Safety (Samfunnsikkerhet) at the University of Stavanger. The thesis comprises two articles written in collaboration with my supervisor, professor Terje Aven. Both papers have been submitted for possible publication in international scientific journals. The main goal of the two articles has been to see different risk regulation regimes and diverging ways to perceive and judge risk in connection to two main theoretical risk perspectives. We have used examples of electromagnetic radiation to substantiate the dicussions in both papers.

I would like to thank professor Terje Aven for being inspirational and helpful in the process of writing this Master thesis. Without his gudiance and motivation these papers would never have seen the light of the day. I am very grateful for what I have learned throughout this process.

Contents

Summary and conclusions

The following issues are discussed in this thesis:

1. Risk perspectives

2. Risk regulation

3. Risk perception and judgements

The first paper treats the two first issues, the second paper looks into the first and the third issue. Both papers consider two main risk perspectives; an alternative and a traditional perspective. The main principles of these perspectives can be summarised as follows:

1. In the traditional perspective the main component of risk is probability, and this probability is interpreted as an objective property of the activity being studied. The aim of the risk analysis is to estimate these probabilities.

2. In the alternative perspective the main component of risk is uncertainty, and probability is considered a knowledge-based (subjective) tool for expressing these uncertainties. It is acknowledged that risk extends beyond probabilities.

Paper I provides comparisons with and links between different risk regulation regimes and these two risk perspectives. Paper II focuses on contrasting ways to perceive, assess and judge risks and how these can be described by the different risk perspectives.

Paper I: On the link between risk perspectives and risk regulation – a comparison between two cases concerning base stations and wireless networks

In this paper we study how two diverging regimes of risk regulation can be linked to fundamental theoretical concepts about risk. The discussion is illustrated by drawing comparisons between the risk regulation concerning wireless networks and base stations of Salzburg municipality and that of Stavanger municipality. We find that the traditional risk perspective can be compared to and tied to the risk regulation of Stavanger municipality concerning these technologies. Here, the form of risk regulation adopted is mainly governed by staying within limits of exposure. Salzburg has adopted a more precautionary approach to their regulation of sources emitting electromagnetic radiation (EMR), and is best described by the alternative perspective where uncertainty constitutes the main component of risk.

Paper II: The link between risk perception and risk perspectives – illustrated bt the exapmle of electromagnetic radiation

The second paper is related to the first paper but here we link the risk perspectives to two main categories of risk perception and judgments, more specifically to those of laymen and those of experts. We continue to use the example of EMR to illustrate the discussion. The nature and characteristics of electromagnetic radiation as a source of risks are typically found to produce high risk perceptions among laypeople and low risk estimates among experts.

The paper argues that the risk perceptions of laypeople better match the alternative perspective than the traditional perspective on risk. Laypeople often range technological risks as high, despite the fact that risk assessments indicate differently. Perceptional factors linked to the acknowledgments of uncertainties play an important role. The way experts define and assess risks is more in line with the traditional perspective on risk. Experts rely on the results of risk assessments to a greater extent than lay-men. The contrasting points of view concerning EMR between these two groups can be seen a result of the degree to which they focus on the different components of the risk concept. Laymen focus on uncertainties and consequences, whereas the experts typically emphasize probabilities. This corresponds with the weight put on the different components of the risk concept in the two risk perspectives.

Both the division between different risk regulation regimes and between experts and lay-men can be linked to two contrasting traditions and sets of ”thinking”. The alternative perspective challenges the main line of thinking behind common risk practise. A perspective where the main component of risk is uncertainty and not probability, like the alternative perspective, means a shift in thinking from traditional risk estimation based on probabilities to uncertainty characterizations. To many this perspective can be found to represent a new paradigm in that it allows for questions to be asked concerning existing knowledge, methods and established “truths”. Both papers suggest that the alternative perspective provides a better platform when addressing risks characterized by large uncertainties and where important stakes are at risk, like in the case of EMR.

3 June 2009

On the link between risk perspectives and risk regulation - a comparison between two cases concerning base stations and wireless networks

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Abstract

The purpose of this paper is to discuss how risk regulation is related to fundamental concepts about risk. It distinguishes between two risk perspectives: a traditional risk perspective where risk is considered an objective property of the activity studied and an alternative perspective where uncertainty is the main component of risk. The discussion is substantiated by drawing comparisons between two cases, namely the risk regulation concerning wireless networks and base stations of Salzburg municipality and that of Stavanger municipality. Salzburg, in having adopted a more precautionary approach to their regulation of sources emitting electromagnetic radiation, represents a more proactive form of risk management. Uncertainty constitutes not only an integral, but also a crucial part of decisions and decision-making processes, and gives grounds for the precautious measures that are taken by regulating authorities. Stavanger can be characterised as more reactive than Salzburg, in that its risk regulation heavily relies on some defined limiting values and is, to a large extent, guided by staying within these. Here, electromagnetic radiation is not perceived by many central parties as a real risk to our health. This has direct implications for the degree of regulatory intervention and measures taken (or not taken). The risk regulations of Salzburg and Stavanger are based on different pools of scientific evidence and different sets of assumptions, the result being two different "worlds" of risk regulation. In this paper we show that the traditional risk perspective and the alternative risk perspective to a large extent support the risk regulation of the Stavanger and

Salzburg cases respectively. We conclude that the alternative perspective provides the best foundation for regulation in situations like the one studied with large uncertainties and stakes involved.

1. Introduction

This paper addresses the issue of electromagnetic radiation (EMR) in relation to base stations and wireless networks. EMR is energy propagated through space between electric and magnetic fields. These fields produce waves of various lengths and frequencies (strengths) and the result is different types of EMR: microwaves, x-rays and radio waves etc. Both wireless networks and base stations are sources of electromagnetic radiation. Base stations use a frequency from 900 to about 2600 MHz and a transmitting effect of 0.5-20 Watt. Wireless networks use around 2400 MHz, but the transmitting effect is lower than for base stations. But as the distance is much lower, the received effect to the body might be of the same range as with base stations. The level of radiation produced by both is similar and the discussion in this paper holds for both sources of EMR.

The widespread use of technologies emitting EMR and the potential for adverse health effects due to EMR are subject to considerable debate. EMR represents an emerging health issue and has created a growing body of concerned citizens. There are, however, diverging opinions within the scientific community concerning the potential health consequences of these technologies. A multitude of reports providing contradictory conclusions is available. Some show no health effects following exposure to electromagnetic radiation. For example, the WHO (2006) found that "…there exists no element of scientific proof confirming possible harmful effects on health of base stations and wireless networks". Others demonstrate the reverse; here the effects range from cancer to concentration and sleeping problems. These two stands dominate the picture. Both are often found to brand the studies; documentation and results produced by the other position are considered as illegitimate and in some cases as unscientific. In Slovic's words: "New evidence appears reliable and informative if it is consistent with one's initial beliefs, contrary evidence is dismissed as unreliable, erroneous or unrepresentative" (Slovic et al. 1979:72). Alternative paradigms represent a threat to the current paradigmatic position and will consequently meet resistance due to their potential to undermine existing knowledge and affect what is considered as legitimate research. Subsequently, reports and documentation heavily relied on by some, are neglected by others.

A lot of research stresses the need for precautionary measures to be taken and the most frequently referred to is the The BioInitiative Report (2007). The scientific report reviews more than 2000 studies where various health risks from exposure to wireless technologies are analysed. It voices a serious concern about the present exposure limits and holds that these are inadequate to protect people. On the other hand, there are researchers finding that a certain degree of exposure yields beneficial health effects (e.g. Luckey 1991). Still others seek new and different measures in order to provide more reliable evidence, for example methods of proteomics (Leszczynski 2006).

The intrinsic characteristics and nature of the risk in question (involuntary, high consequence, invisible, unfamiliar, irreversible, man-made) are typically found to produce a high risk perception among the general population. Conversely, it is likely to be conceived as a low risk by many experts due to the low estimated probability of consequences. In other words, the nature of the risk is contested.

The issue we raise in this paper is how to regulate this risk. This is obviously a challenge due to the large uncertainties related to the health effects of base stations and wireless networks. Risk is assessed differently by different actors. Technological development and economic profit could be seen in conflict with issues of protection and safety. Policymakers and regulators need to prioritize, weigh and balance diverging considerations.

Risk regulation comprises a wide range of activities. Hood et al (2001) distinguish between context and content, but consider both equally important components of risk regulation. Context is the setting in which the regulation takes place. This is about the type of risk in question, the public attitudes and perceptions towards it, the various actors affected by and producing the risk. The context can also shape the content of risk regulation, which treats the degree of regulation, the threshold values that determine what are acceptable or tolerable risk, and the organization and structure of the regulating regime. It also takes into consideration the style of the regulation: namely the conventions and attitudes of the regulating actors. The content dimension of risk regulation is the most central to the aim of the paper.

Risk regulation is strongly dependent on the risk perspective adopted. The degree to which uncertainty is recognized as a central component of the risk perspective by regulatory agencies, shapes the form and degree of regulatory intervention. An illustration of this is the diverging legislative positions that are taken in various countries, the inconsistencies in accepted levels of risk and reliance on different safety standards. In this paper we look more closely into the importance of the risk perspectives for risk regulation by considering the empirical cases of Salzburg and Stavanger. The Salzburg and Stavanger cases provide examples of two completely different regulation regimes and in the paper we question to what extent these can be traced back to differences in the underlying view on risk.

The complexity of risk regulation is emphasized by many analysts and researchers, and can be illustrated by the following citation of Power (2004): “Research has shown that there is very considerable variety in the manner in which risks are processed by state agencies; the ‘government of risk’ is by no means uniform across problems and functions, with public perceptions, moral frameworks, institutional arrangements and the nature of the risk itself giving rise to variation in ‘risk regimes'" (Power 2004:19). Similar conclusions are made by Baldwin et al. (2000). They argue that risk regulation is not straightforward because of varying definitions of risk and different views on what are appropriate limits of tolerability of risk. These are just examples of researchers who have addressed the issue of risk and risk regulation. However, not much attention has been devoted to the link between risk perspective and risk regulation. Perhaps the closest connection is provided by the work of Bartle (2008) where risk regulation and decision-making are analysed based on a scientific-technocratic and socio-political model. In the former model the processes of risk regulation and decision-making are led by experts and are characterised by the use of an objective risk concept. The socio-political model of risk regulation and decision-making is associated with more nuanced strategies. Here, subjective and objective dimensions of risk are not readily separable. An objective risk is not easily conceived and quantified. When using this approach, the risk regulation is "best off" by being a democratic process characterised by dialogue.

HSE (2001) and Renn (2005) also establish relationships between risk management policies and various uncertainty dimensions. See also Steen and Aven (2008). The main purpose of the HSE (2001) approach is to set out an overall framework for decision-making by the Health and Safety Executive and explain the basis for HSE's decisions regarding the degree and form of regulatory control of risk from occupational hazards. However, the framework is general and can also be used for other types of applications. The approaches for handling uncertainties are illustrated in Figure 1. The vertical axis represents increasing uncertainty in the likelihood that the harmful consequences of a particular event will be realised, while the horizontal axis represents increasing uncertainty in the consequences attached to the particular event. At the lower left corner, a risk assessment can be undertaken with assumptions whose robustness can be tested by a variety of methods. However, as one moves along the axis assumptions are increasingly made that are precautionary in nature and which cannot be tested (HSE 2001).

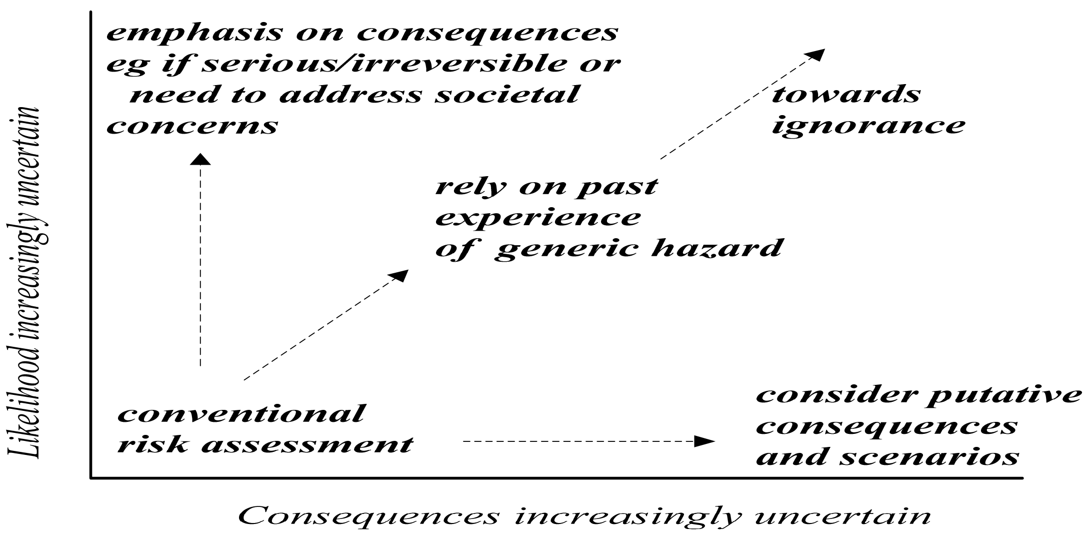

Figure 1: Procedures for handling uncertainty (HSE 2001)

Several researchers have used a similar model to link risk management policies and uncertainty dimensions, e.g. Stirling and Gee (2002). These researchers provide an interesting discussion of the precautionary principle by seeing the uncertainty dimension (referred to as incertitude) in relation to the strengths and weaknesses of risk assessments, as well as to the fundamental dimensions of incertitude. The precautionary principle applies in situations where we have poor knowledge about the likelihoods, and the outcomes are poorly defined. Also Hom et al. (2008) discuss the precautionary principle and risk regulation. They explicitly tie variations encountered in risk regulation regimes to differences in adaptations and interpretations of the precautionary principle resulting in regulatory actors allowing different levels of emissions of EMR, both within and amongst countries.

The risk governance framework (Renn 2005) has been developed to provide structure and guidance on how to assess and handle risk on the societal level. It distinguishes between different types of situations (risk problems), according to the degree of complexity (Simple – Complex), Uncertainty and Ambiguity (Aven and Renn 2009b):

Simplicity is characterised by situations and problems with low complexity, uncertainties and ambiguities.

Complexity refers to the difficulty of identifying and quantifying causal links between a multitude of potential causal agents and specific observed effects.

Uncertainty refers to the difficulty of predicting the occurrence of events and/or their consequences based on incomplete or invalid databases, possible changes of the causal chains and their context conditions, extrapolation methods when making inferences from experimental results, modelling inaccuracies or variations in expert judgments. Uncertainty may result from an incomplete or inadequate reduction of complexity, and it often leads to expert dissent about the risk characterisation.

Ambiguity refers to different views related to the relevance, meaning and implications of the risk assessments for decision-making (interpretative ambiguity); or the values to be protected and the priorities to be made (normative ambiguity). This can be illustrated by a few examples. What does it mean, for example, if neuronal activities in the human brain are intensified when subjects are exposed to electromagnetic radiation? Can this be interpreted as an adverse effect or is it just a bodily response without any health implication?

For the different risk problem categories, the IRGC framework specifies a management strategy, appropriate instruments and stakeholder participation. See Table 1 below which indicates the recommendations for the category uncertainty and ambiguity. These recommendations are in line with the findings of, for example, Bartle (2008) in that both find stakeholder participation, extended dialogue and information important strategies and measures in uncertain situations.

Table 1: Risk problem categories - uncertainty and ambiguity induced example - implications for risk management (Aven and Renn 2009b, adapted from Renn (2005))

Risk problem category	***Management strategy***	***Appropriate instruments***	***Stakeholder participation***
Uncertainty induced risk problems	Risk informed and Caution/Precaution based (risk agent)	Risk assessments. Broad risk characterisations, highlighting uncertainties and features like persistence, ubiquity etc. Tools include: • Containment • ALARP (as low as reasonably possible) • BACT (best available control technology), etc.	*Reflective discourse*: Include the main stakeholders in the evaluation process and search for consensus on the extra margin of safety in which they would be willing to invest in exchange for avoiding potentially catastrophic consequences. Deliberation relying on a collective reflection about balancing the possibilities for over- and under-protection.
	Risk informed. Robustness and Resilience focused (risk absorbing system)	Risk assessments. Broad risk characterizations. Improving capability to cope with surprises • Diversity of means to accomplish desired benefits • Avoiding high vulnerabilities • Allowing for flexible responses • Preparedness for adaptation	
Ambiguity induced risk problems	Risk informed and Discourse based	Political processes. Application of conflict resolution methods for reaching consensus or tolerance for risk evaluation results and management option selection	*Participative discourse*: competing arguments, beliefs and values are openly discussed.

		• Integration of stakeholder involvement in reaching closure • Emphasis on communication and social discourse	

The paper is organised as follows. In Section 2 we give a short review of risk perspectives as a background for the discussions in the coming sections. We focus on risk perspectives: the traditional risk perspective where probability is the main component of risk and an alternative risk perspective where uncertainty is the main component of risk. We argue that these perspectives are different from the scientific-technocratic and the socio-political model presented, for example, in Bartle (2008). In Section 3 we introduce the cases of Salzburg and Stavanger. These will be linked and compared with respect to risk perspectives and risk regulation in Section 4. Here, we will also provide a more general discussion concerning risk perspectives and risk regulation. Finally, in Section 5 we draw some normative implications concerning choice of risk perspective, and we conclude.

2. Basic introduction to risk perspectives

Many perspectives on risk exist (see e.g. Aven and Renn 2009a). In this paper we distinguish between the following two main categories:

3. The main component of risk is probability, and this probability is interpreted as an objective property of the activity being studied. This perspective is referred to as the traditional risk perspective.

4. The main component of risk is uncertainty, and probability is considered a knowledge-based (subjective) tool for expressing these uncertainties. It is acknowledged that risk extends beyond probabilities. This perspective is referred to as the alternative risk perspective.

In the traditional risk perspective, risk is defined by a probability or probability distribution, expressing stochastic or aleatory uncertainties. A population of similar situations to the one studied are constructed and the probability p of an event A equals the fraction of situations where A occurs. The probability p is unknown and is estimated based on "hard data", i.e. measurements related to the occurrence of A for similar situations. Analogously, we define a probability distribution p_X associated with a random variable X. Modelling of the phenomena may also be used, linking the probability p to a set of parameters q on a more detailed system level. More generally, we may consider the perspective based on a probability model F which is assumed dependent on some unknown parameters μ. The estimation of μ is based on traditional statistical methods, e.g. regression analysis.

Hence, risk is defined by p and p_X, and the associated risk description covers the estimates of these quantities. Uncertainties of these estimates relative to the “true” values of p should be addressed but are often neglected or restricted to simple confidence intervals reflecting only statistical variation.

In the alternative risk perspective, uncertainty and not probability is the main component of risk. Different definitions of risk can support such a perspective, as discussed in Aven and Renn (2009a) and Aven (2008). In this paper we adopt the following perspective (Aven 2008):

By risk we understand the two-dimensional combination of

i) *events A and the consequences of these events C, and*
ii) *the associated uncertainties U (will A occur and what value will C take?)* (I)

We refer to this as the (A,C,U) perspective.

We may rephrase this definition by saying that risk associated with an activity is to be understood as (Aven and Renn 2009a):

Uncertainty about and severity of the consequences of an activity (I’).

Here, severity refers to intensity, size, extension, scope and other potential measures of magnitude, and is with respect to something that humans value (lives, the environment, money, etc.). Losses and gains, for example expressed by money or the number of fatalities, are ways of defining the severity of the consequences. The uncertainties relate to the events and consequences, the severity is just a way of characterising the consequences (Aven and Renn 2009a).

The main features of this risk perspective are illustrated in Figure 2.1.

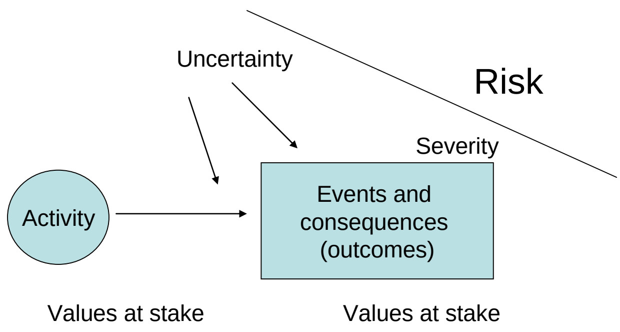

Figure 2.1: Illustration of the risk definition (Aven and Renn 2009a)

It is acknowledged that risk extends beyond probabilities. Probability is considered a knowledge-based (subjective) tool for expressing these uncertainties. If the probability equals 0.1 (say), this means that the assessor compares his/her uncertainty (degree of belief) about the occurrence of the event *A* with the standard of drawing at random a specific ball from an urn that contains 10 balls (Lindley 2006). A risk description based on this perspective includes the following elements: (A,C,U,P,K), where A refers to the initiating event, C represents the consequences given occurrence of the event A, U is the uncertainty about A and C, P is the probability of specific events and consequences, and K is the background knowledge (assumptions etc.) that the probabilities are based on.

Hence objective risk and objective risk descriptions do not exist, as the U component is epistemic. The risk description (A,C,U,P,K) covers 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 $C^* = E[C|A]$.

The distinction we make between these risk perspectives resembles the common dichotomy in risk regulation modelling, as summarised by Bartle (2008) and mentioned in Section 1: the science-technocratic model and the socio-political model. However, a further look into the building blocks of these models shows important differences compared to the risk perspectives studied in the present paper.

The science-technocratic model sees risk and uncertainty as two different concepts, in line with the classic work by Knight (1921). Under risk, the probability distribution of the quantities of interest can be assigned objectively, whereas under uncertainty these probabilities must be assigned or estimated on a subjective basis. To us, however, uncertainty is a main component of risk. The Knightian terminology is in conflict with the common interpretation of risk and should not, in our view, be used (Holten 2004, Aven 2003). Referring to the former situation as risk and the latter as uncertainty is unfortunate as it would exclude the risk concept from most situations of interest. We seldom in practice have known, objective distributions, and should we adopt Knight's definition we cannot refer to the risk concept in these situations. If we adopt the subjective or Bayesian perspective on probability, Knight's definition of risk becomes empty. There are no objective probabilities. The terminology violates the intuitive interpretation of risk, which is related to situations of uncertainty and lack of predictability.

Furthermore, the science-technocratic model is based on the "risk = statistical expected value" thesis. However, expected value decision-making is misleading for rare and extreme events (e.g. Haimes 2004, Aven and Renn 2009b). The expected value (the mean or the central tendency) does not adequately capture events with low probabilities and high consequences. All risk perspectives that we consider are seeing beyond expected values.

The science-technocratic model makes a sharp distinction between objective risk and subjective (perceived) risk. However, the presumed objective risk is not known and, hence, the interesting comparison is between risk assessed by experts on the one hand and perceived risk on the other. It is also essential to distinguish between assigned subjective probabilities (and related risk assignments) and risk perception. The main difference is that risk perception is based on personal beliefs, effects and experiences irrespective of their validity. Subjective probabilities used in risk assessments are representations of individual and collective uncertainty assessments based on available statistical data, direct experience, models and theoretical approximations which all need justification that must also be plausible to others (Aven and Renn 2009a). The risk perspectives that we consider are precise on these issues, in contrast to much of the literature on common risk regulation models, which contrasts objective risk and subjective (perceived) risk.

The socio-political model gives weight to people's risk perception – it can make as much sense as assessed risk by professionals. However, the probabilistic framework adopted is not defined. Rejecting the idea of objective probabilities and risk does not mean that we cannot use probabilities to assess uncertainties. Subjective probabilities are a recognised tool for this purpose and the risk perspectives analysed in the present paper clarify their role in the risk assessment and risk management.

The socio-political model acknowledges the limitations of the probabilistic analyses. The probabilities cannot be ascribed with certainty. The model is criticising the "risk = statistical expected value" thesis but also the lack of objectivity of probability assignments. However, as mentioned above, the socio-political model does not present a risk perspective which defines risk and probability in line with the ideas of the model.

3. The Salzburg and Stavanger cases

No coherent framework exists on how to regulate the risk of EMR. There is a complete lack of agreement and standardisation between countries in relation to EMR regulation (Hom et al. 2009). Also within countries, there are contradictory views on how to regulate the matter. We find disagreements at state, regional and local level. The two cases studied in this paper, Salzburg and Stavanger, display two different sets of local arrangements. The cases are selected because they represent two diverging positions regarding risk regulation concerning EMR. Each case represents one end of the extreme regarding both the form and degree of their risk regulation. It is important to be aware that many other countries have similar risk regulation to that of Norway and Stavanger and that more precautionary cases than Salzburg exist (e.g. Germany, Lichtenstein). The contrasts between the cases are sought to highlight the topic of this paper: the link between risk regulation and risk perspectives.

3.1 Risk regulation of Salzburg

Salzburg has adopted a precautionary approach to its risk regulation in lowering the permitted level of exposure to electromagnetic radiation (0.6 volts per meter V/m). In Salzburg one also distinguishes between permitted levels of radiation inside and outside, the permitted level of exposure inside is lower (0.02 V/m) than outside (0.06 V/m). These marginal values diverge from those used by the Austrian government which allows levels of radiation close to those provided by ICNIRP (International Commission of Non-Ionising Radiation Protection). The marginal values set by Salzburg are far below the standards set by ICNIRP (which allows values between 28 and 61 V/m depending on frequency). Salzburg municipality does not accept the ICNIRP's marginal values for EMR. They find these outdated and inadequate to protect its citizens. Furthermore, the Public Health Department of Salzburg Region officially advises schools, kindergartens etc. not to implement wireless networks (Oberfeld 2005). Additionally, a political resolution to remove all wireless networks from all primary and secondary schools has just recently been passed (Klock 2009). Other schools in Salzburg are the responsibility of the Austrian state. Plans are also being made to regulate the issue of EMR from wireless networks in the regional school law (primary and secondary schools (Klock 2009). El-sensitivity is officially accepted as a medical diagnosis, and a formal medical procedure of diagnosis and treatment is currently being made by a working group consisting of members from the Austrian Medical Association.

Every planned deployment of base stations in Salzburg close to sensitive areas (these being areas where people stay for longer periods of time, for example schools, flats, workplaces etc.) is required to provide data on V/m and levels of EMR and on location concerning vicinity to buildings. The operators must negotiate and discuss with local authorities in order to arrive at the best suited location for base stations, these being as far away from sensitive areas as possible. All stakeholders in the surroundings of 300 – 500 metres of the planned location of a base station are informed and have a say in the matter before decisions are reached. The plans for the base station remain open for everyone to see for four weeks. This procedure was established in 1995 by the town government and has been followed since. Still there is no law regulating this.

In Salzburg "The BioInitiative report" (2007) and research providing knowledge about adverse health effects are heavily relied upon. Decisions and measures are taken in favour of uncertainties and the potential seriousness of consequences. Information about regulatory measures and possible effects of EMR is provided to the public through the local government by, for example, giving information and official recommendations.

3.2 The risk regulation of Stavanger

The situation in Stavanger is different. Stavanger operates with radically different marginal values regarding exposure to electromagnetic radiation from those of Salzburg. The Norwegian Radiation Protection Agency (NPRA) has adopted the limits set by ICNIRP (1999). These permit the highest degree of electromagnetic radiation internationally (5.8 V/m), but are used by many other countries. Stavanger is in the process of implementing wireless networks in all primary schools and in the many public buildings. Base stations are placed without informing or consulting stakeholders and many are placed in sensitive areas, for example on roofs of apartments, workplaces and kindergartens. Information about location of base stations is not readily available and many do not know where these are placed. Information on this has long been withheld and claimed to be a matter of safety for the Norwegian state. This has resulted in a growing body of frustrated and concerned stakeholders. The media picture is characterised by divergent opinions, aggressive "attacks" between authorities and laymen. The debate is initiated from the "bottom-up" by interest groups, parents, workers, teachers etc. The municipal Chief of Health and Care does not recognize their concern regarding EMR and potential health consequences (Bjørlow and Haarr 2008). Action is not justified and not taken by the local authorities as long as measurements of EMR are below the level of the marginal values. The risk regulation is characterised as being more reactive and the risk is understood in a different manner from that in Salzburg. It relies on marginal values and does not question the judgements made by the NRPA (Norwegian Radiation Protection Agency). Decisions are taken isolated from stakeholders. Here, el-sensitivity is not recognised as a medical diagnosis. NPRA holds that el-sensitivity is a "myth"; this is due to the fact that no evidence of a causal relationship can be proved. NPRA and Stavanger do not recognize much of the information on which Salzburg bases its decisions (SSV 2008).

In Stavanger, the risk communication between authorities and citizens is, to a large extent, characterised by the citizens voicing their concerns through the media. The debate is characterized by verbal attacks, frustration, the assigning of blame and discussions of responsibility. There has long been a clear distance between authorities and the concerned public.

This illustrates the differences between the attitudes and conventions of the regulating actors of Salzburg and Stavanger. The issue addresses the content dimension in Hood et al.'s (2001) risk regulation regime.

Just recently the chief administrative officer of Stavanger publicly recommended in the local newspaper the use of cabled network as a precautionary measure (Stavanger Aftenblad 2009). However, this recommendation will not be followed if the costs are judged as large compared to the benefits of continuing using wireless networks. The precautionary measures will not apply to schools as the benefits of using wireless networks are considered too great. The chief administrative officer of Stavanger informs that investigations will be conducted to see if there are legal grounds to introduce requirements to apply for deploying base stations. This may indicate that things are stirring in Stavanger, but the practical reality of the risk regulation has not yet been affected.

4. Discussion of the link between risk perspectives and risk regulation

The crucial point of the discussion in this paper is uncertainties and how one relates to these. These uncertainties are epistemic, i.e. a result of lack of knowledge, and are related to a certain point of time where decision-making about what measures to be taken, is required. As earlier emphasized, the information base concerning public health effects due to exposure to EMR is not conclusive and is, in many cases, contradictory.

Table 2 (next page) summarizes the main distinctions between the two risk perspectives considered and provides links to risk regulation. It will be used as a reference for the discussion in this section. The risk regulations of Salzburg and Stavanger are not founded on specified risk perspectives. However, we will argue that the regulations fit in with the two main lines of thinking described in Section 2.

Table 2: Characterisation of the two risk perspectives considered and links to risk regulation

Risk perspective	Characterisation of the perspective		Possible link to risk management policies	
Traditional risk perspective	Focus on estimation of "objective" probabilities and risk	The background knowledge K that the probability estimates are based on is narrow in the sense that it is based on "hard data" only	A null hypothesis is assumed to be true: the activity is safe, the probability P of an adverse event is below a threshold P_0. Strong evidence is needed to prove that $P > P_0$ and thus the risk is too high	The cautionary and precautionary principles play no important role. They are not considered consistent with the scientific method People's risk perception not given much weight Cost-benefit type of analysis provides strong decision guidance
Alternative risk perspective (A,C,U)	Focus on description of uncertainties	All types of information and knowledge are used as a basis for the uncertainty description	There is no underlying hypothesis about the activity being safe or not	The cautionary and precautionary principles are given strong weight People's risk perception considered an important input to the uncertainty characterisation Cost-benefit type of analysis is recognised as a decision support tool, but it is

				acknowledged that the analyses do not adequately reflect uncertainties and risk

4.1 What risk perspective supports the risk regulation of Stavanger?

In the case of Stavanger, decisions are based on the assumption that EMR does not represent a risk to our health as long as exposure does not exceed the marginal values set by ICNIRP and adopted by the NPRA. This is the null hypothesis of Stavanger. The regulatory actors heavily rely on the fact that research has not yet been able to prove a causal relationship between EMR and public health effects. Consequently, knowledge that is not able to demonstrate that this null hypothesis is not true is not given weight in the risk management.

Using a traditional statistical set-up, we may formulate the null hypothesis as a statement of the probability P of an adverse event to be below a threshold P_0, see Table 2. Only if sufficient data exist "proving" $P > P_0$, can it be concluded that the safety level is unacceptable. Errors of type I (rejecting the null hypothesis when it is true) are considered more serious than errors of type II (accepting a null hypothesis when it is false). In other words, it is more serious to wrongly conclude that EMR is not safe, than to wrongly conclude that EMR is safe. This is, of course, a highly controversial stand but is often associated with the traditional perspective. Proponents of this perspective would argue that only by such a perspective can innovation and progress in society be ensured; the uncertainties should not be given too much focus. This view is also supported by cost-benefit analyses which are based on expected net present value calculations and give little weight to uncertainties (Aven and Vinnem 2007). Consequently, the cautionary and precautionary principles play no important role in the risk management in this case. The cautionary principle (HSE 2001, Aven and Vinnem 2007) expresses that in the face of risks and uncertainties, caution should be the ruling principle. The precautionary principle may be viewed as a special case of the cautionary principle and is applicable when there is a lack of scientific certainty about what will be the consequences of an activity.

The ALARP principle is an example of how the cautionary principle can be implemented in practice. This principle holds that risks should be reduced to levels that are As Low As Reasonably Practicable (HSE 2001). The principle states that risk-reducing measures should be implemented provided that one cannot demonstrate that the costs of implementing these measures are in gross disproportion to the benefits gained. Thus, the burden of proof is reversed. A safety measure should normally be implemented. This means a trade-off between safety and costs, but the principle puts safety first. Application of the ALARP principle could, in theory, also produce a rationale for implementing precautionary measures for the Stavanger case. However, as the effect of these measures on the "true" risk is typically considered small, the gross disproportion criterion applies and the measures are not justified. Hence, a possible implementation of the ALARP principle would not necessarily lead to changes in the risk regulation in Stavanger.

The premise for the traditional risk perspective is the null hypothesis that EMR is safe, and a judgment of risk concluding that the available evidence is not strong enough to "prove" that EMR is not safe. Precautious measures are not to be justified in Stavanger until EMR is proved detrimental to public health. Hence, there is no basis for increased regulatory intervention as long as values are kept inside the limits established by the marginal values. Limited weight is given to uncertainties in the risk regulation of Stavanger. This can be illustrated by the Chief of Health and Care claiming that no risk exists and that, therefore, no measures need to be taken (e.g. Bjørlow and Haarr 2008). The focus is on the non-existence of reports to demonstrate the causal relationship between EMR and damage to health. Accordingly, when faced with people claiming to be el-sensitive, the regulatory actors point out that this can not be proved causally. People's perceptions of EMR as a risk source are not given strong weight. This can also be found to be in line with the idea of risk as an objective property existing independently of us. The search for certainty and objectivity which is associated with the traditional perspective supports this belief and faith in the marginal value approach.

Formalised risk assessments have not been conducted in the Stavanger case and as long as the regulatory actors do not believe EMR to represent a risk, no rationale exists for conducting such assessments. If, however, such assessments were to be conducted, it would be likely that they would be conducted in line with the traditional perspective. Here, estimated probabilities are derived based on historical data, for example earlier cases of brain tumours due to EMR and standard statistical inference methods are commonly used (e.g. confidence intervals) to express the uncertainties based on these data. In the traditional perspective, a key quantity of interest is the uncertainties between the true underlying values of the probabilities and the estimates of these probabilities, and a comprehensive risk assessment would have addressed these uncertainties. However, prevailing risk assessment practice often hides or camouflages these uncertainties (Reid 1992, Stirling 2007, Renn 1998, Aven 2008). In this way, risk estimates are generated with a stronger basis than justified. Given the constant redefinition of the state of knowledge and the fact that situations that may seem unlikely today may prove to be the case in the near future, this suppression of uncertainties may obviously lead to poor predictions of the future.

4.2 What risk perspective supports the risk regulation of Salzburg?

The risk regulation of Salzburg needs to be linked to a broad and encompassing risk perspective which acknowledges uncertainty as the main component of risk. The (A,C,U) definition represents such a perspective.

Here no initial standpoint is taken concerning whether EMR is detrimental to public health or not. This approach is more sensitive and adaptive to new information and changes in the knowledge base than the traditional perspective. Decisions are based on a broader and more diverse knowledge base. Causal evidence is not the only type of information considered. The more precautious nature of the Salzburgian risk regulation is based on an acknowledgement of the existence of scientific uncertainties about the consequences of EMR. The fact that the bodies of children are more receptive to EMR than fully developed ones, provides supporting arguments for a cautious approach. The assumptions of the regulatory actors of Salzburg deviate strongly from those made in the risk regulation in Stavanger. In Salzburg the marginal values provided by ICNIRP are considered to be out of date and not providing protection against the detrimental effects of EMR. The regulatory actors also place emphasis on the fact that health effects are reported as low as 0.06 V/m, far below the levels of exposure set by ICNIRP (1999). This limit for exposure to EMR does only account for thermal effect and short-term exposure not exceeding six minutes. Furthermore, the regulatory actors in Salzburg acknowledge that non-thermal effects may have the potential of being more detrimental to our health than thermal effects. They use different scientific reports (for instance Kundi 2009, Havas 2000, Bio-Initiative report 2007), and place emphasis on reports branded by NPRA as unscientific (see NPRA 2008). They also interpret the results produced by the Stewart Report (2000) differently from NPRA.

The sets of assumptions and pools of evidence the cases base their decisions upon produce notably different levels and forms of regulatory intervention. The assumptions and the knowledge base of Salzburg legitimate the precautionary measures taken, for instance the lowering of marginal values, the banning of wireless networks in primary schools, the formal procedure arranged to avoid deployment of base stations in so-called sensitive areas and the involvement of stakeholders in decision-making concerning the location of base stations.

In Salzburg risk communication is not only voiced through the media; local authorities and members of the public communicate openly. This is illustrated by the official letters of recommendation and the active role of regulatory actors in providing readily available information for the public.

The risk regulation of Salzburg is proactive in the sense that possible scenarios are sought, "identified in advance" and the possibility that these might occur affects the results of risk assessments and the following decision-making. The uncertainties are recognized as important and significantly affect the form and policies of their risk management. The traditional perspective does not provide a strong basis for the risk regulation of Salzburg, as the uncertainties are not adequately reflected in this perspective. Possible scenarios are addressed, the uncertain nature of the risk (concerning both the occurrence of an event and the associated consequences) are considered. In Salzburg the uncertainty dimension is given more weight than probabilities. Risk extends beyond probabilities.

4.3 The two cases viewed in relation to existing risk problem classifications

Following the risk classification scheme of HSE (2001), the risk of EMR can be classified under ignorance (refer to Figure 1), where we find large uncertainties about the consequences and about the likelihoods, or, in other words, poor background knowledge for the assigned probabilities. For such situations precautionary measures are required. However, such a conclusion is based on assessments of uncertainty and on what constitutes uncertainty. Obviously there are different views on the degree of uncertainties. It is likely that the regulatory actors in the Stavanger case would not agree with this classification of EMR as they do not recognize the uncertain nature of EMR. Salzburg, on the other hand, would most likely agree with this classification of EMR. These diverging standpoints can be illustrated by the practical implications manifested in the differing nature of their risk regulation; the one finding rationale for precaution and higher levels of regulation, the other not.

If we adopt the Renn (2005) classification, the risk of EMR would be characterised by complexity, uncertainty and ambiguity (for definitions see Section 1). EMR can be said to involve the complexity dimension; this is due to the difficulty of establishing the causal nature of the risk, and the uncertainty dimension in that the consequences are difficult to predict. Furthermore, the ambiguity dimension is found in that the cases demonstrate that uncertainties are viewed and weighted differently. Again we see that this leads to different levels of precaution and affects risk regulation Correspondingly, and as earlier pointed out, the connection between the (A,C,U) perspective and cautionary and precautionary measures is closer than for the traditional perspective. The appropriate risk management instruments, as recommended by Table 2, are more in line with the (A,C,U) perspective than the traditional perspective. The management framework of Renn (2005) is, to a large extent, founded on similar ideas as the (A,C,U) perspective (Aven and Renn 2009b).

5. Normative implications and conclusions

Examining the scientific basis for risk assessments and the assumptions that underlie them can give valuable input for politicians and decision-makers. It can also be seen as an expression of the risk perspective that is adopted by the risk assessors and challenge the common idea of experts and analysts as neutral assessors of risk. It is imperative that the assumptions and background knowledge are made explicit and communication on how they affect the result is provided by the risk assessment. This can have crucial effects on the decision reached, the regulatory measures taken and the corresponding levels of public protection provided.

Risk regulation needs to be based on a risk management framework, which provides key concepts and principles, and clear direction and guidance on how to identify, assess and manage risk. The aim is to balance the conflicts inherent in exploring opportunities on the one hand, and avoiding losses, accidents, and disasters, on the other. Many such frameworks have been established, e.g. the AS/NZS 4360 Risk Management Standard (AS/NZS 2004) and ISO IEC standard on risk management (ISO 2002, 2005); see Ale et al. (2009). Although the different frameworks differ considerably when it comes to jargon and definitions, they are broadly similar when it comes to basic underlying ideas. Considerable agreement, for instance, exists on the steps needed for proper risk management: from the definition of critical functions to risk assessment, risk evaluation, and risk control (Ale et al. 2009).

However, the risk perspective is often not properly defined in these frameworks, and this is a serious weakness since the perspective influences the way risk is understood, assessed and managed. The terminology of most of these frameworks seems to indicate a traditional risk perspective, but some are more in line with the (A,C,U) perspective as uncertainty is considered a main component of risk. We believe that it is possible to support risk management frameworks with different risk perspectives, but care has to be shown when using the traditional perspective in the case of situations of large uncertainties and high stakes involved, such as the EMR risk. We have seen that this perspective is often linked to a null hypothesis expressing that EMR is safe, and strong evidence is required to prove that risk-reducing measures should be implemented. Furthermore, when conducting risk assessments according to this perspective, important uncertainty factors are often hidden or camouflaged as pointed out in Section 4. One may discuss to what extent this is an aspect of the perspective or whether the perspective is used for a specific purpose, to demonstrate that the activity (here the use of EMR) is safe. Too much focus on uncertainties would not serve the interest of those who are in favour of EMR.

The traditional perspective has been reviewed and discussed thoroughly in the literature; see e.g. Aven (2003). Ways of trying to solve the above problems have been suggested by implementing more comprehensive methods for revealing and assessing uncertainties. An example is the so-called “probability of frequency approach”, which is based on assessing epistemic uncertainties about the underlying "true" risk indices by means of subjective probabilities. In this approach there are two levels of probability introduced: i) the relative frequency interpreted probabilities reflecting variation within populations (also referred to as stochastic or aleatory uncertainty), and ii) the subjective probabilities reflecting the analyst's uncertainty about what the correct relative frequency probabilities are; see e.g. Kaplan and Garrick (1981), Paté-Cornell (1996) and Aven (2003). However, this approach is also probability-based and uncertainties may be hidden in the background knowledge (assumptions) that the assignments are based on. In the case of large uncertainties in the phenomena studied, it is difficult to assign probabilities with a sufficient rigour. More qualitative approaches may then be preferred. Yet, any assessment of risk following a perspective where the purpose of the assessment is to accurately estimate the risk may suffer from the problem of suppressing uncertainties as a comprehensive representation of the uncertainties is difficult to carry out in practice and does not necessarily serve the interest of the parties involved.

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 accurate risk estimation to uncertainty characterisations. To many this perspective represents a new paradigm 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 traditional perspective and is, in our view, more suited for assessing and managing risk in situations of large uncertainties and stakes involved. This 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. Adopting such a perspective means that the practices may be as those in Salzburg, or in Stavanger. The process leading to these practices would, however, be more in line with the Salzburg case than that of Stavanger; this is because Stavanger has not revealed and reported a sufficiently broad risk and uncertainty picture to support the decision-making process of the politicians in the municipality.

References

Ale, B., Aven, T. and Jongejan, R. (2009) Review and discussion of basic concepts and principles in integrated risk management. ESREL 2009.

AS/NZS 2004. Risk Management Standard, AS/NZS 4360: 2004. Jointly published by Standards Australia International Ltd, Sydney & Standards New Zealand, Wellington.

Aven, T. (2003) Foundations of risk analysis: A knowledge and decision-oriented perspective. New York: Wiley.

Aven, T. (2008) Risk analysis. New York: Wiley.

Aven, T. and Renn, O. (2009a) On risk defined as an event where the outcome is uncertain. Journal of Risk Research, 12, 1-11.

Aven, T. and Renn, O. (2009b) The role of quantitative risk assessments for characterizing risk and uncertainty and delineating appropriate risk management options, with special emphasis on terrorism risk. Risk Analysis, 29, 587-600.

Aven, T. and Vinnem, J.E. (2007) Risk Management, with Applications from the Offshore Oil and Gas Industry. New York: Springer-Verlag.

Baldwin, R., Hutter, B. and Rothstein, H. (2000) Risk regulation, management and compliance – a report to the BRI Inquiry. London: LSE.

Bartle, I. (2008) Risk-based regulation and better regulation in the UK: towards what model of risk regulation. Proceedings 2nd Biennial Conference of the ECPR Standing Group on Regulatory Governance, 05-06 June 2006, Utrecht University, Netherlands.

BioInitiative Report (2007) Sage, C. and Carpenter, D.O. BioInitiative Working Group Report BioInitiative Report: A rationale for a biologically-based Public Exposure Standard for Electromagnetic Fields (ELF and RF). www.bioinitiative.org

Bjørlow, E. and Haarr, P. (2008) Reply to parental complaints concerning base stations in Stavanger. Municipality of Stavanger, 3 November 2008.

Haimes, Y.Y. (2004) Risk Modelling, Assessment and Management, 2nd ed. New York: Wiley.

Havas, M. (2000): Biological effects of non-ionizing electromagnetic energy: A critical review of the reports by the US National Research Council and the US National Institute of Environmental Health Sciences as they relate to the broad realm of EMF bioeffects. Environmental Reviews, 8, 173-253.

Holton, G.A. (2004) Defining risk. Financial Analysis Journal, 60, 19-25.

Hom, A.G, Plaze, R.M., Sergi, F.F. and Palmén, R. (2008) From precautionary inadequacy to participatory risk management. Futures, in press.

Hood, C., Rothstein, H. and Baldwin, R. (2001) The government of risk. Understanding risk regulation regimes. Oxford: Oxford University Press.

HSE (2001) Reducing risk, protecting people. London: HSE books.

ISO (2002) Risk management vocabulary. International Organization for Standardization ISO/IEC Guide 73.

ISO (2005) Risk Management – General Guidelines for Principles and Implementation of Risk Management. Preliminary version. (2005).

Kaplan, S. and Garrick, B.J. (1981) On the quantitative definition of risk. Risk Analysis, 1, 11-27.

Klock, M. (2009) Personal communication, 12-13 Feb. 2009

Knight, F.H. (1921) Risk, Uncertainty and Profit. Washington DC: Boardbooks. Reprinted 2002.

Kundi, M. and Hutter, H.P. (2009) Mobile phone base stations – Effects on wellbeing and health. Pathophysiology, ahead of print.

Leszczynski, D. (2006) Mobile telephony - Do we need precaution? A scientist's perspective. Proceedings VALDOR, 14-18 May, 2006, Stockholm, Sweden.

Lindley, D.V. (1985) Making decisions. London: John Wiley & Sons Ltd
Luckey, T.D. (1991) Radiation hormesis. Florida: CRC Press.
NPRA (2008) The specification of marginal values in relation to EMR. www.npra.no/archive/Internett/div_document/Nyheter/2008/grenseverdier.ppt
Oberfeld, G. (2005) Official advice of the Public Health Department of the Salzburg Region concerning WLAN and DECT in Schools or Kindergardens. http://www.scribd.com/full/3494899?access_key=key-1pif9o39rd4nudx9bo73
Oberfeld, G. (2009) Personal communication, 09 Feb. 2009.
Paté-Cornell, M.E. (1996) Uncertainties in risk analysis: Six levels of treatment. Reliability Engineering & System Safety, 54(2-3) 95-111.
Power, M. (2004) The risk management of everything- rethinking the politics of uncertainty. London: PrintFlow.
Reid, S.G. (1992) Acceptable risk. In Blockley, D.I. (Editor), Engineering Safety. New York: McGraw-Hill.
Renn, O. (1998) Three decades of risk research: accomplishments and new challenges. Journal of Risk Research, 1 (1), 49–71.
Renn, O. (2005) Risk Governance: Towards an Integrative Approach. White Paper No. 1, written by O. Renn with an Annex by P. Graham. International Risk Governance Council, 2005, Geneva, Switzerland.
Rothstein, H.F. (2003) Neglected risk regulation: the institutional attentuation phenomenon. Health, Risk and Society, 5 (1).
Sage, C. and Carpenter, D.O. (2009) Public health implications of wireless technologies. Pathophysiology, ahead of print.
Slovic, P., Fischhoff, B. & Lichtenstein, S. (1979) Rating the risks. Environment, 21, 14-20.
Stavanger Aftenblad (2009) Interview with Chief administrative officer in Stavanger. 30 May 2009.
Steen, R. and Aven, T. (2008) Comparisons and discussion of different integrated risk perspectives. ESREL 2008.
Stewart, Sir W. (2000) Independent Expert Group on Mobile Phones. The Stewart Report www.iegmp.org.uk/.
Stirling, A. and Gee, D. (2002) Science, Precaution and Practice. Public Health Reports, 117 (6), 521-533.
Stirling, A. (2007) Science, Precaution and Risk Assessment: towards more measured and constructive policy debate. European Molecular Biology Organisation Reports, 8, 309-315.

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The link between risk perception and risk perspectives – illustrated by the example of electromagnetic radiation

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Abstract

The focal point of this paper is to demonstrate that a connection exists between risk perception and risk perspectives. Two main categories of risk perception and judgments, those of laymen and those of experts, will be linked to two different risk perspectives. In the traditional risk perspective, probability constitutes the main component of the risk concept. Here the probabilities are interpreted as objective properties of an activity. In the alternative perspective, uncertainty is considered to be the main component of risk. The paper argues that the risk perceptions of laypeople better match the alternative perspective than the traditional perspective on risk. Conversely, the way experts define and assess risks is more in line with the traditional perspective on risk. The connections between risk perceptions and risk perspectives are discussed in the paper and are accompanied and illustrated by an example of electromagnetic radiation from base stations and wireless networks. The nature and characteristics of electromagnetic radiation as a source of risks are typically found to produce high risk perceptions among laypeople and low risk estimates among experts.

1. Introduction

In today's society, the use of wireless technologies emitting electromagnetic radiation (EMR) is widespread and is continuously increasing. Examples of sources of EMR are wireless networks and mobile masts. The potential for adverse health effects due to exposure to EMR has been and is subject to considerable debate. EMR represents an emerging health issue and has created a growing body of concerned citizens. There are, however, diverging opinions about the risk posed by EMR. Within the scientific community, we find a multitude of reports providing contrasting findings and conclusions about the possible effects of exposure to EMR.

EMR as a source of risk is used to illustrate the issue addressed in this paper: the link between risk perception and risk perspectives. EMR possesses characteristics which commonly produce diverging perceptions and judgments among the general public and experts, and in the paper we show that these perceptions and judgments closely match two main perspectives on risk. We find that the way experts assess and define risk is best described by a traditional perspective on risk where probability is the main component of risk, whereas risk perceptions of laymen are more in line with perspectives on risk where uncertainty is the main component of risk. Examples of risk definitions underpinning these two categories of perspectives are

- Risk is the combination of probability of an event and its consequences (ISO 2002)
- Risk equals uncertainty about and severity of the consequences of an activity (Aven and Renn 2009).

There is a tendency that experts generally rate technological risks lower than the general public. Probabilities form a central part of how experts relate to and assess risks, whereas uncertainties constitute the main pillar of risk perceptions of laymen. In the case of the general public, the probabilities do not shape the risk perceptions to the same degree as for experts. When uncertainty related to the consequences of an activity (for example EMR) exists, the mere possibility that these adverse effects could occur can lead the public to judge this source as a high risk. This phenomenon is well known from the risk perception literature; see e.g. Sjøberg and Drottz-Sjøberg (1994). In their work Sjøberg and Drottz-Sjøberg (1994) found that people who used the term "risk" as mainly related to or synonymous with the probability for an event, overall rated risks lower than those who define risk in terms of consequences of an event. This is also in line with what Siegrist et al. (2006)

find, namely that many laypeople are concerned with technological risk despite the fact that risk assessments often indicate a low probability of adverse effects.

The uncertainty concerning the effects of EMR and how one relates to these in different manners, can serve to illustrate important points of the analysis provided in this paper. Contrasting risk perceptions can be a result of the degree to which one focuses on and emphasizes the uncertainty component of the risk. Correspondingly, we also find different levels of emphasis on uncertainty in the two perspectives on risk presented and discussed in this paper.

The paper is organised as follows. In Section 2 we give a short review of the two risk perspectives introduced above and basic theory of risk perception. This provides a background for the discussions in the coming section, where we link the different perceptions to the risk perspectives. Finally, some conclusions are drawn in Section 4.

2. Basic introduction to risk perspectives and risk perception

2.1 Risk perspectives

Many perspectives on risk exist; see e.g. Aven and Renn (2009). In this paper we distinguish between the following two main categories:

5. The main component of risk is probability, and this probability is interpreted as an objective property of the activity being studied. This perspective is referred to as the traditional risk perspective.
6. The main component of risk is uncertainty, and probability is considered a knowledge-based (subjective) tool for expressing these uncertainties. It is acknowledged that risk extends beyond probabilities. This perspective is referred to as the alternative risk perspective.

In the traditional risk perspective, risk is defined by a probability or probability distribution, expressing stochastic or aleatory uncertainties. A population of similar situations to the one studied is constructed and the probability p of an event A equals the fraction of situations where A occurs. The probability p is unknown and is estimated based on “hard data”, i.e. measurements related to the occurrence of A for similar situations. Analogously, we define a probability distribution p_X associated with a random variable X. Modelling of the phenomena may also be used, linking the probability p to a set of parameters q on a more detailed system level. More generally, we may consider the perspective based on a probability model F which is assumed dependent on some unknown parameters μ. The estimation of μ is based on traditional statistical methods, e.g. regression analysis.

Hence, risk is defined by p and p_X, and the associated risk description covers the estimates of these quantities. Uncertainties of these estimates relative to the “true” values of p should be addressed but are often neglected or restricted to simple confidence intervals reflecting only statistical variation.

In the alternative risk perspective, uncertainty and not probability is the main component of risk. Different definitions of risk can support such a perspective, as discussed in Aven and Renn (2009) and Aven (2008). In this paper we adopt the following perspective (Aven 2008):

By risk we understand the two-dimensional combination of

iii) *events A and the consequences of these events C, and*
iv) *the associated uncertainties U (will A occur and what value will C take?)* (I)

We refer to this as the (A,C,U) perspective.

We may rephrase this definition by saying that risk associated with an activity is to be understood as (Aven and Renn 2009):

Uncertainty about and severity of the consequences of an activity (I').

Here, severity refers to intensity, size, extension, scope and other potential measures of magnitude, and is with respect to something that humans value (lives, the environment, money, etc.). Losses and gains, for example expressed by money or the number of fatalities, are ways of defining the severity of the consequences. The uncertainties relate to the events and consequences, the severity is just a way of characterising the consequences (Aven and Renn 2009).

The main features of this risk perspective are illustrated in Figure 1.

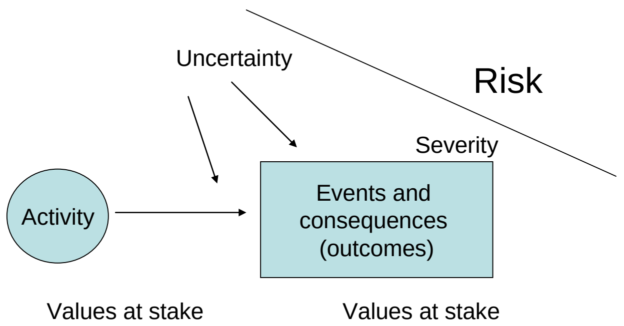

Figure 1: Illustration of the risk definition (Aven and Renn 2009)

It is acknowledged that risk extends beyond probabilities. Probability is considered a knowledge-based (subjective) tool for expressing these uncertainties. If the probability equals 0.1 (say), this means that the assessor compares his/her uncertainty (degree of belief) about the occurrence of the event *A* with the standard of drawing at random a specific ball from an urn that contains 10 balls (Lindley 2006). A risk description based on this perspective includes the following elements: (A,C,U,P,K), where A refers to the initiating event, C represents the consequences given the occurrence of the event A, U is the uncertainty about A and C, P is the probability of specific events and consequences, and K is the background knowledge that the assessments are based on. This background knowledge comprises data, expert judgments and models and is often expressed through assumptions.

Hence objective risk descriptions do not exist, as the U and P components are epistemic. The risk description (A,C,U,P,K) covers 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 $C^* = E[C|A]$.

2.2 Risk perception

Risk perception is a judgment (belief, appraisal) held by an individual, group, or society about risk. These perceptions are based on personal beliefs, ideas about effects and experiences. Irrespective of their validity, these factors form risk perception. Risk perception covers both perceived seriousness of risk and also judgments about acceptability of risk (Renn 2008).

Risk perceptions may be influenced by professional risk assessments, the individual's own risk assessment and perceptional factors such as fear, affect and perceived control. Often the latter factors are the most important in shaping risk perception. This is well known from risk perception research (see e.g Fischhoff 1995, Renn 2008, Slovic 1992). The intrinsic characteristics and nature of the technological risk in question, EMR, typically elevate risk perception among the general population relative to experts. Examples of characteristics that serve to heighten the risk perception are: large uncertainties concerning consequences, potential for serious and irreversible effects, involuntariness and invisibility of exposure, man-made and unnatural sources, negative associations attached to words like 'radiation' and 'base station', and the fact that the risk is being controlled by others.

Scientific assessments influence individual responses to risk only to the degree that they are integrated in the individual perceptions (Renn 2008). This is in line with the citation of Slovic: "New evidence appears reliable and informative if it is consistent with one's initial beliefs, contrary evidence is dismissed as unreliable, erroneous or unrepresentative" (Slovic et al. 1979:72). Siegrist et al. (2006) studied how one relates to studies and results concerning wireless technologies and found support for this phenomenon. Furthermore, they found that one relies to a greater extent on studies and reports showing risk than on those showing no risk. Siegrist et al. (2006) hold that the results of their study suggest that these biases may be part of the reason why laypeople are concerned with technological risk despite the fact that risk assessments indicate a low probability of adverse effects.

Risk perceptions are, to a varying degree, governed by results of risk assessments and for many, risk perceptions extend far beyond the risk assessments' results. Different factors form the risk perception of the public and experts. Experts generally rely on risk assessments to a greater extent than laymen. Even if risk assessments demonstrate low risk, laymen can perceive the risk as high and unacceptable. In the words of Sjøberg and Drottz-Sjøberg (1994), “risks exist in a cognitive framework of values and standards”. Laymen and experts tend to evaluate and judge risk differently. This is common for the type of technological risk discussed in this paper.

3. Discussion

The focal point of the discussion in this section is to show how differently one can relate to uncertainties and how this can shape risk perceptions. Using the two risk perspectives defined in the previous section as points of reference, we are able to link the diverging role of uncertainty in forming risk perceptions and the different ways of addressing uncertainty in the risk assessment following the traditional and the alternative perspectives.

Table 1 (next page) summarizes the main distinctions between the two risk perspectives considered and provides links to risk perception. It will be used as a reference for the discussion in this section. We do not hold that the different ways we perceive risks are founded on specified risk perspectives, but we argue that they fit in with the two main lines of thinking described in Section 2.1.

Table 1: Characterisation of the two risk perspectives considered and links to risk perception

Risk perspective	**Characterisation of the perspective**		**Possible link to risk perception**	
Traditional risk perspective	Focus on estimation of “objective” probabilities and risk	The background knowledge K that the probability estimates are based on is narrow in the sense that it is based on “hard data” only	Experts place weight on risk assessments’ results; they view the results as representing the real risk Experts have limited focus on uncertainties. If uncertainties are described, narrow perspectives are often used (key uncertainty factors not included) For the experts, low computed probabilities equal low risk, and perceptional factors such as dread and fear are considered irrelevant for describing risk Laypeople may perceive risk as high even if the computed probabilities are relatively low and below levels normally considered as acceptable	A null hypothesis is assumed to be true: the activity is safe, the probability P of an adverse event is below a threshold P_0. Strong evidence is needed to prove that $P > P_0$ and thus the risk is too high
Alternative risk perspective (A,C,U)	Focus on description of uncertainties	All types of information and knowledge are used as a basis for the uncertainty description	Experts acknowledge that risk is more than computed probabilities. Uncertainty is a fundamental component of risk and risk perception (in particular for laymen)	There is no underlying hypothesis about the activity being safe or not

		is strongly influenced by the uncertainties. For laymen, the potential for serious consequences often means high risk perception Laymen in their risk perceptions typically give more weight to the uncertainties and the perceptional factors (dread, fear, etc.) than the computed probabilities

3.1 What risk perspective best matches the risk judgments of experts?

Experts rely to a great extent on risk assessments and these are central in forming how they rate risks. These risk assessments are of the traditional type. In the traditional perspective, risk is defined by probabilities and is seen as an objective property of the activity studied. Risk assessments provide risk estimates of an assumed "objective" and "real" risk. Uncertainty is taken into account only to the degree to which the estimates deviate from the "real" and "true" underlying risk. Prevailing risk assessment practice often hides or camouflages these uncertainties (Reid 1992, Stirling 2007, Renn 1998, Aven 2008) as discussed in the following.

In this way, risk estimates can be generated with a stronger basis than justified. Given the constant redefinition of the state of knowledge concerning "new" technologies and the fact that situations that may seem unlikely today may prove to be the case in the near future, this suppression of uncertainties may lead to poor predictions of the future.

Risk numbers are based on available statistical and historical data, and these data can in some cases be good indications for some future situations. But for the case of EMR and possible adverse consequences, where we experience large uncertainties and contradictory scientific findings, this historical database would not provide reliable information for future situations. Consequently, risk estimates based on historical data available would indicate that EMR represents no risk to human health. Possible extreme scenarios are given little weight because available data provide no evidence of these to be realistic. Solely relying on results from risk assessments of the traditional approach could cover surprising situations and lead to significant under-estimations/under-prediction of the true values.

Experts emphasize probabilities, whereas laymen tend to focus on consequences and uncertainties. Risk assessment is a significant factor in forming how experts define and rate risks. The results provided by the risk assessment would typically be seen by experts as representing the real risk. So, if the risk assessments are in line with the traditional statistical approach and if risk numbers demonstrate low risk values for EMR, experts will generally find EMR as representing an acceptable risk irrespective of the potential for negative consequences. One relies on the fact that research has not yet been able to prove a causal relationship between EMR and public health effects. In the traditional perspective, it is only when sufficient data exist "proving" that the probability of an adverse event P is exceeding a given threshold value P_0, that it can be concluded that EMR is risky. This can be seen as a reactive approach to risks. It would be more serious to wrongly conclude that EMR is risky, than to wrongly conclude that EMR is safe. This is, of course, a highly controversial stand, but it is often associated with the traditional perspective. This requirement for "sufficient" causal evidence can be interpreted to be in line with the idea of risk as an objective property existing independently of us and in line with the search for certainty associated with the traditional perspective.

Furthermore, perceptional factors like dread, fear and affect are considered irrelevant for describing risk in the eyes of the experts and in the traditional perspective on risk. Together with value judgments, these factors may describe why laypeople may perceive risk as high irrespective of the fact that computed probabilities are relatively low and below levels normally considered as acceptable.

3.2 What risk perspective best matches the risk perceptions of laymen?

The risk perceptions of laymen need to be seen in relation to a broader and more encompassing risk perspective than the traditional perspective. The (A,C,U) definition represents such a perspective. Here, uncertainty is considered the main component of risk. This uncertainty addressed in this perspective is epistemic and refers to a lack of knowledge at a certain point in time. Risk perceptions of laymen are based on a broader and more diverse knowledge base than in the case of experts. Risk assessments' results and causal evidence shape the risk perceptions of the general public, but often only to a limited degree. Despite scientific studies and risk assessment demonstrating low risk, the public may perceive the risk as high and unacceptable. Furthermore, as noted in Section 2.2, laymen are susceptible to relying more heavily on risk assessments consistent with prior beliefs and attitudes and those demonstrating risk, than on those contradicting prior standpoints and those showing no risk (Siegrist et al. 2006). The leniency towards evidence integrated with prior standpoints can also be said to hold for experts, but this phenomenon is more pronounced for laymen.

This alternative approach is more sensitive and adaptive to new information and changes in the knowledge base than the traditional perspective. The existence of scientific uncertainties about the consequences of EMR is acknowledged. The sets of assumptions and pools of evidence the cases base their judgments on can be notably different from those of experts. Many citizens want wireless networks out of schools and want base stations located further away from public areas. This is not the case for the majority of the experts.

This approach can be said to be more proactive in the sense that more extreme and uncommon scenarios are addressed and can be “identified in advance” than in the traditional perspective. Possibilities of such situations occurring will, to a greater extent, be included as a part of the results of risk assessments conducted following the alternative approach. This is in line with how laymen generally perceive technological risks; the uncertain nature of the risk is recognized as important and it significantly affects their judgments. It is more likely that possible extreme situations and outcomes will be identified, than when the point of departure for the risk assessments are historical data and historical-based probabilistic analyses based on strong assumptions. Such data may prove to be irrelevant for future situations and will not be weighted in the same manner as in the traditional perspective.

The traditional perspective does not provide a strong basis for the risk perceptions of laymen, as the uncertainties are not adequately reflected in this perspective. For laymen, risk extends beyond probabilities, as in the alternative perspective. This can be clearly illustrated by the fact that despite much research finding that exposure to EMR within the established marginal limits is safe, many laymen hold that exposure to EMR is risky. The risk perception is based on a broad set of factors, as illustrated by Figure 2. In the figure we see that risk perception is not the same as professional risk characterisations, if we make a clear distinction between risk and uncertainty assessments and value judgments. An event, A, and its consequences, C, are subject to uncertainties, U. We may use probabilities, P, to express these uncertainties, but one needs to note that this is a separate domain from judgments about to what extent we like or dislike A, C, U and P. This latter domain is the value judgments. So again, we see that risk perception includes both an assessment aspect and a value judgment aspect. Furthermore, this figure captures the cornerstone of the alternative perspective as it illustrates the uncertainties in the risk concept concerning both the events and the consequences of these. The figure merges the two concepts of risk perspective and risk perception.

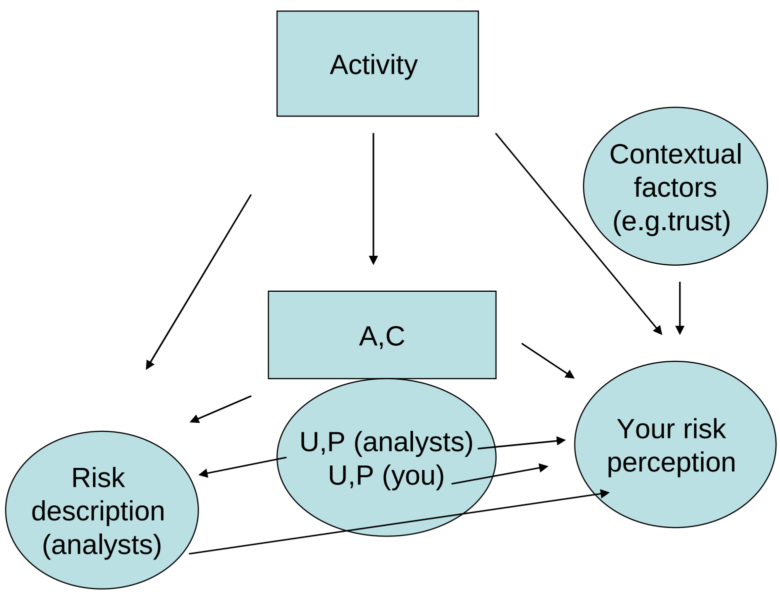

Figure 2. Illustration of what influences risk perception. A: Events, C: Consequences, U: Uncertainty, P: Probability (Aven 2010)

4. Conclusion and normative implications

We have provided links between risk perspectives and risk perceptions. We have found that a connection and similar lines of thinking exist between the traditional perspective and how experts assess risks.

The risk perceptions of laymen best match the alternative (A,C,U) perspective, where uncertainties are emphasized and treated as the most central component of risk. There is a tendency for experts to range technological risks as low, whereas laymen generally label these as high and unacceptable risks. The example of EMR illustrates this tendency. EMR possesses characteristics that typically elevate risk perceptions among laymen and typically produce low risk estimates among experts. Examples of such characteristics are: large uncertainties concerning consequences, potential for serious and irreversible effects, involuntariness and invisibility of exposure and the source of exposure being man-made.

Laypeople often range technological risks as high, despite the fact that risk assessments indicate a low probability of adverse effects. This also holds for the example of EMR and can be explained by the fact that risk perceptions cover two dimensions: how we relate to assessment results and our value judgments. Laymen relate to uncertainties concerning the effects of EMR in a manner different from experts. The contrasting points of view concerning EMR between these two groups can be seen a result of the degree to which they focus on the different components of the risk concept. Laymen focus on uncertainties and consequences, whereas the experts typically emphasize probabilities. This corresponds with the weight put on the different components of the risk concept in the two risk perspectives.

We find that the alternative perceptive is better suited to assess risks where large uncertainties exist and stakes are high, as in the case of EMR where scientific studies provide contradictory conclusions and findings and the potential consequences can be serious. Only using historical data to assign probabilities in relation to EMR, as in the traditional perspective, can prove to be dangerous and can be seen as a reactive approach. To fully express risk, we need to see beyond historical data and traditional probability estimates. This is secured in the alternative perspective where the main component of risk is uncertainty and not probability. This perspective represents a shift in thinking from accurate risk estimation to uncertainty characterisations.

References

Aven, T. (2008) Risk analysis. Chichester: Wiley.

Aven, T. (2010) Misconceptions of risk. Chichester: Wiley. In press (January 2010).

Aven, T. and Renn, O. (2009) On risk defined as an event where the outcome is uncertain. Journal of Risk Research, 12, 1-11.

Fischhoff, B. (1995) Risk perception and communication unplugged: Twenty years of process, Risk Analysis, 15 (2), 137–145.

Lindley, D.V. (2006) Understanding uncertainty. New York: Wiley

Reid, S.G. (1992) Acceptable risk. In Blockley, D.I. (Editor), Engineering Safety. New York: McGraw-Hill.

Renn, O. (1998) Three decades of risk research: accomplishments and new challenges. Journal of Risk Research, 1 (1), 49–71.

Renn, O. (2008) Risk Governance. London: Earthscan.

Siegrist, M., Keller, C. and Cousin, M-E. (2006) Implicit attitudes toward nuclear power and mobile phone base stations. Support for the affect heuristics. Risk Analysis, 26, 1021-1029.

Sjøberg, L. and Drottz-Sjøberg, B-M. (1994) Risk perception. In Radiation and Society: Comprehending radiation risk. Vol. 1, pp. 29-59. Vienna: International Atomic Energy Agency.

Slovic, P., Fischhoff, B. and Lichtenstein, S. (1979) Rating the risks. Environment, 21, 14-20.

Slovic, P. (1992) Perception of risk reflections on the Psychometric paradigm', in S. Krimsky and D. Golding (eds) Social Theories of Risk, Praeger, Westport, pp 117–152.

Stirling, A. and Gee, D. (2002) Science, Precaution and Practice. Public Health Reports, 117 (6), 521-533.