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Can the theory of risk evaluation and management be applied to land-use safety planning?

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When a comparison is made between land-use safety policies in different countries or regions, it is quickly apparent how diverse the assessment is made, both between the different sectors and application domains as regions; (1) there are large variations when assessing the acceptability of different risk levels, (2) hazards with large effects but very small probability are sometimes dominating the assessment or completely absent (as they are not considered among the ‘credible’ or ‘representative’ scenario’s) and (3) there appears to be a difference between unacceptable risks according to the followed policy and the appreciation of the same risk by part of the population. Further, a lack of uniform and consistent standards for determining the nature of risks and assessing their magnitude is notable and confusing. At first glance, the various actors involved notice inconsistencies and feel the need to eliminate these inconsistencies.

However, the theory of risk evaluation and risk management reveals that (sometimes) such “irrationalities” can be made completely understandable and rational. In this paper, some concepts from risk theory are briefly introduced and applied to risk policy in spatial planning.

A primary principle is that of the relative unacceptability of risk. When applied correctly, this helps to set ambitious goals in land use safety planning, where the potential of land use planning (LUP) to avoid unnecessary risk in a very robust way can be fully utilized. At the same time, accepting the relativeness of unacceptability helps to place risks in other domains, which are sometimes of a different order of magnitude, in a different context. Most of us would in most circumstances see the loss of 50 human lives as catastrophic, but for a general in WWI it was apparently a negativity well within the ordinary range — a mere pinprick easily taken in stride. When the relative acceptability of risk is neglected for being as consistent as possible across policy domains, one runs the risk of imposing artificial standards of theoretical rationality that conflict with accepted factual practices or intuitions. The discussion on the applicability of the FN criteria for industrial installations used in the Netherlands to the off-sites risks from Schiphol airport, is a good example of this theoretical rationality that conflicts with accepted factual practices. Risk theory confirms a possible outcome that criteria can be inapplicable.

Furthermore, the risk aversion, which is present in some land-use safety planning criteria has been scrutinized in the context of the sequential priority order of the various principles of rational risk management: (1) reject extremely unlikely (“unrealistic”) possibilities! (2) avoid catastrophes (3) maximize expected values (by minimizing loss of life).

This paper attempts to show the gap between risk theory and land-use safety planning practices, that should be bridged. It is the ambition of the author that the theoretical underpinnings of risk theory, applied to land use safety planning criteria, can contribute in setting ambitious and righteous criteria and standards.

* 1. Introduction

In the 1980s, risk acceptance was integrated into the broader theory of rationality in choice and action, providing a conceptual framework rather than specific guidelines for practical applications. Risk acceptance involves making decisions between different courses of action, where at least one option poses a threat to life or health.

To address whether the theory of risk evaluation and management can be applied to land-use safety planning, we refer to Fischhoff et al.'s (1981) work on acceptable risk and Nicholas Rescher's (1983) book 'Risk'. These works outline essential elements for handling risk acceptance decisions but are not intended as practical guides for risk assessments. This analysis highlights key elements from these theories and uses examples to show their role in land-use safety planning and the criteria and methodologies involved. Despite the long-standing availability of these theories, addressing risk acceptance issues without contradictions and inconsistencies in risk management remains challenging. Common mistakes or pitfalls often occur during risk assessments.

Empirical investigations of risk-taking frequently reveal contradictions and inconsistencies in risk management practices. Researchers often find: (1) a lack of uniform standards for determining and assessing risks, (2) inconsistencies in handling significant but unlikely hazards, (3) violations of rational decision-making principles, (4) discrepancies between perceived and actual risks, (5) variations in assessing acceptable risk levels, and (6) inconsistencies in valuing human life or its quality. However, these "irrationalities" can often be understood and rationalized based on overlooked or misunderstood principles.

The following analysis, inspired by HSE (2003) 'good practice and pitfalls in risk assessment' and Rescher's book, illustrates the complexity of acceptable risk problems through examples. These pitfalls can occur in both risk management and its criticism, where contradictions and inconsistencies are frequently highlighted.

* 1. A Selection of elements in acceptable risks decisions embedded in the wider theory of rationality in choice and action

In selecting the elements for the analysis below, the focus was on aspects that are often underrepresented in land-use safety planning. This means that other equally important elements, such as uncertainty, the psychology of risk, the role of values, and the ethical and political dimensions of risk acceptance, are not covered here. The message for technology promoters, public servants, risk analysts, engineers, academics, and laypeople concerned about risks is to not limit themselves to this analysis but to refer to the broader theory when facing new challenges. The work of Rescher, in particular, is somewhat underexposed.

* + 1. The Concept of the Relative Unacceptability of Risk

Fischhoff et al. explicitly discuss the advantages and disadvantages of different approaches to acceptable risk decisions. One such approach is 'bootstrapping’ (the better known revealed-preferences approach and natural standards approach fall within this category), which uses implicit standards from past or current policies as prescriptions for future actions. A significant disadvantage of this method is that it transfers the judgement of acceptability without explicitly considering contextual alternatives, showing a strong bias toward the status quo. It assumes that whatever was acceptable in the past is right for the future.

Answering the question, "How safe is safe enough?" by evaluating past choices among alternatives provides only a contextual answer. The risk associated with the most acceptable option might be defined as an acceptable risk, but this definition ignores the conditional, context-dependent nature of the choice. As a result, there are no universally acceptable options or risks.

This limitation also arises when risk acceptance is left to 'professional judgment.' Professionals may be more comfortable solving problems within their expertise than defining them, often not considering alternatives outside their field. This can lead to a narrow view of what is acceptable.

The first conclusion from the analysis is that acceptable-risk problems are decision problems requiring a choice between alternatives. This choice depends on the alternatives, values, and beliefs considered. Therefore, there is no single all-purpose number that expresses "acceptable risk" for a society. At best, one can hope to find the most acceptable alternative for a specific problem, representing the values of a specific constituency.

Fischhoff et al. consistently contextualize 'acceptable risk' as 'acceptable-risk problems,' indicating that no level of risk can be universally specified as acceptable or unacceptable. Fischhoff (1994) concludes that no reasonable individual would want their life governed by a rigid acceptable level of risk, nor should a society want a single level of risk for all technologies. It is not logically defensible to set a single level of acceptable risk for all technologies unless a principled decision has been made to ignore all other factors.

Rescher's analysis similarly addresses disparate risks and catastrophes. A disparate risk arises when there is a serious imbalance in the relative magnitude of the negative, making the prospect of such negativity unacceptable relative to the benefits or losses in the situation, regardless of probability. Unacceptability is not absolute but contextually specific. Outcomes are not absolutely unacceptable but comparatively unacceptable relative to certain alternatives. Life circumstances may require accepting the unacceptable, as illustrated by the example: “Most of us would see the loss of 50 human lives as catastrophic, but for a general in WWI, it was a mere pinprick easily taken in stride.”

* + 1. Risk management strategies

Although both works provide a comprehensive overview of risk, risk perception, and risk management, they emphasize that a prescribed approach to risk acceptance can never be definitive. Unlike Fischhoff, Rescher offers a risk management strategy with several cardinal rules for risk-taking, each with a specific order of priority.

When applied to land-use safety planning, these rules are as follows:

1. Minimize expected loss of life.
2. Avoid catastrophes.
3. Dismiss extremely remote ("unrealistic") possibilities.

These rules have a clear priority order: Rule III takes precedence over Rule II, which in turn takes precedence over Rule I. Thus, the strategy for risk management becomes: avoid all 'realistic' catastrophes and minimize the expected loss of life.

However, applying such a strategy does not eliminate the challenges in risk management overnight. What is frequent, widespread, or long-lasting for one person may differ significantly for another. Estimating probabilities and distinguishing between real and unrealistic possibilities ("effective zerohood") is not straightforward. Defining what constitutes a (relative) catastrophe often requires abandoning the usual expected value calculations. Generally, setting a conservative position (best minimum vs. best average vs. best maximum interval comparison) is necessary.

Despite these challenges, the cardinal rules and their priority order help define the decision problem and facilitate communication in assessing relevant facts and values, whether among professionals or between professionals and laypeople. This structured approach aids in overcoming the complexities and inconsistencies often encountered in risk management discussions.

* 1. Examples illustrating pitfalls in risk management
		1. the mixing of means and ends in the use of land-use safety planning criteria and land-use (safety) quality.

After several large-scale incidents involving dangerous substances, it has been concluded that controlling these risks requires a multi-faceted approach: (1) avoid or control risks at the source, (2) implement emergency planning, and (3) ensure good spatial separation between vulnerable populations and hazardous activities as part of effective land use.

Even with these incidents and insights into potential effects, it is incorrect to assume that the final conclusion is based solely on the absolute risk posed by hazardous installations to external parties. Despite everything, this risk remains limited compared to other risks existing in society. The context that plays a crucial role in this decision is that the benefits are easily achievable, with few to no significant disadvantages associated with such a policy. This is also illustrated by the use of location-specific risk criteria in LUP. The location-specific risk, expressed per year, is the chance that a person at a certain location near an institution will die as a result of a serious accident in that institution, if this person were to be at that location permanently and unprotected for one year. In the Netherlands, Flanders and the United Kingdom, the assessment of a risk contour relevant to habitation is not carried out on scattered dwelling units, but on areas with a residential function (several grouped housing units). The absolute risk for a resident (or family) is therefore clearly not assessed as unacceptable. Nevertheless, it is considered good practice to maintain this greater safety distance for residential areas, as the benefits are easily achievable without significant disadvantages.

This explains the notable difference or 'discrepancy' between risks that are not deemed unacceptable and the stringent land-use risk criteria designed to robustly avoid unnecessary risks. For instance, HSE (2001) in R2P2 cautiously suggests that an individual risk of death of one in a thousand per annum should represent the threshold between what is just tolerable for most workers over a large part of their working life and what is unacceptable for all but exceptional groups. Conversely, land use still cautiously addresses zones where the risk of irreversible damage is around 10-8 per year.

Generally, when land-use safety planning criteria are exceeded, it indicates a failure to optimally utilize the opportunity provided by good spatial planning to avoid avoidable risks. While this may be serious, it does not automatically mean that the resulting situation is unacceptably risky.

* + 1. Justification of risk criteria by revealed preferences, and omitting the context dependency (of alternatives) on the acceptability of risk

The comprehensive report by Baecher et al. (2015) delves into the concepts underlying risk criteria for water resources projects. It explains that the concept of revealed preferences, which supports the use of F-N curves for acceptable and tolerable risk criteria, assumes that risks are at least tolerable to the public. The report identifies three main challenges in justifying risk criteria based on revealed preferences:

1. Societal risk tolerance is inconsistent.
2. Risk perception is a complex psychological and sociological phenomenon.
3. Risk tolerance is not balanced with the benefits provided.

The report also notes the difficulty in quantitatively determining the threshold for de minimis risk (risks considered too small to be of concern), with suggested individual risk numbers ranging from 10-4 to 10-9. This difficulty arises because the benefits of the risky activity are not considered, leading to an acceptable risk level that may not be tolerable when balancing risks and benefits.

This analysis assumes that risk acceptability is absolute rather than relative. Revealed preferences provide information about the risks associated with the most acceptable option given the alternatives. Perceived inconsistencies may stem from the lack of alternatives for the most acceptable option. The primary rule is to avoid risks that could threaten human life if easily avoidable. The residual risk taken depends largely on the available alternatives, making it challenging to compare risk criteria across different sectors and technologies.

* + 1. The scale of the activity (or data collection)

Literature often rightly points out (Spouge et al., 2015; Pitblado et al., 2012) that societal risks are inherently larger for more extensive activities. However, this does not necessarily mean they are less acceptable. Larger ferries and planes carry more passengers, and when incidents occur, they can result in more casualties. The concept of tolerable risk (Baecher et al., 2015) balances these risks with the benefits provided by the activity. Approaching risk acceptance from a decision-making perspective and rationality in choice and action leads to the same conclusion.

Nevertheless, this fact is sometimes overlooked when comparing risk criteria across different technologies or applying them to activities of incomparable scales. Vrijling et al. (2005) provide a comprehensive overview of risk policy in the Netherlands, focusing extensively on the risk acceptance of Schiphol National Airport. It is often assumed, without clarification, that the societal risk criterion for hazardous substance installations should also apply to the airport. This leads to the conclusion that the criterion is exceeded. A government policy decision stating that the same criteria do not apply to Schiphol is dismissed as a new policy, and it is noted with surprise that the airport's economic importance results in a different tolerable risk than other industrial activities.

In Flanders, the societal risk criterion for Seveso establishments has also been applied to hydrogen and LPG filling stations without considering the scale difference between Seveso establishments and car filling stations. The same criterion is used for wind turbines, although the scale, context, and alternatives (see 3.2) of the technology differ fundamentally.

Like above, Vrijling et al. and risk practitioners in Flanders implicitly assume that risk acceptability is absolute rather than relative, failing to define the decision problem.

* + 1. Evaluation of the societal risk criterium used in Flanders

In Flanders, the evaluation of risks for high-threshold Seveso establishments involves comparing societal risk, depicted as an F-N curve, against a criterion curve. As can be seen in *Figure* ***1***, the criterion curve has a maximum number of casualties, whereby, regardless of the probability, the criterion is always exceeded.



*Figure 1: An example of a societal risk curve (blue), and the evaluation criterium used in Flanders (red)*

This criterion has been debated, with critics arguing that it is illogical to use a probabilistic approach alongside an effect-based approach. Additionally, for some worst-case scenarios, preventive measures taken by companies (which prevent rather than mitigate consequences) are not recognized in eliminating criterion exceedances. The lack of clear rationale for this maximum casualties criterion complicates the discussion.

However, according to Rescher's risk management strategy, this criterion is understandable. Following Cardinal Rule II, all catastrophes must be avoided. Realistic scenarios where hazardous installations could cause over 1,000 casualties are considered avoidable catastrophes.

Should the maximum number of victims extend to an infinitely small value? How does this align with Cardinal Rule III, which dismisses extremely remote possibilities? Extending the criterion line to zero does not provide a definitive answer. Instead, the focus should shift to the F-N curve calculation method, maintaining quality. The discussion should then determine which scenarios are so unrealistic that they should be excluded from societal risk calculations.

Providing transparent information about which scenarios are included in the evaluation, and which are not, offers stakeholders clearer insights into the risk evaluation's scope and content than a mere quantitative limit.

* + 1. Complexity in how to define the decision problem

The complexity of risk analysis, even for well-informed professionals, is illustrated by an example from Ahmad's (2009) doctoral thesis. To demonstrate that Rescher's perspective on risk is more ontological than epistemological, he considers the following scenario:

 “…let us say that there are two passengers on a ship going across the Atlantic Ocean. One man, A, is very wealthy and enjoys a lifestyle few will ever experience. The other man, B, is a poor man who struggles to make ends meet. Halfway across the ocean, the ship is hijacked by pirates and taken to a strange, unknown island which functions as a communist utopia. The outcome of this event is clear but the result is less so. For A, it is easy to see (after events have unfolded) that he faced a risk when he got onboard the ship because he was about to lose the privileged lifestyle he had enjoyed. However, for B, it is not so easy since we can imagine that he might be relieved to find himself with a better standard of living and without the constant stress of meeting his needs to survive. He might also experience the kind of camaraderie and acceptance he lacked when he was a poor man. In this case, would we say that A and B faced the same risk given that the outcome for both is the same? I think we would probably answer in the negative because it is the evaluation of the outcome (Rescher’s result) that matters in terms of what kind of risk was faced. This illustrates the importance of evaluating outcomes. It is possible then to have one outcome that is a risk for one person and not for another person, which suggests that risks are not really objective matters in the world, but very much depend on agent evaluations…”

This example shows that focusing on the subjective side of values and risk shifts attention away from the context-dependent nature of the choice and the alternatives. The evaluation of the outcome might not differ significantly between A and B, but the comparative evaluation of the alternatives completely changes the perspective.

* 1. Conclusions

Relevant general principles on risk are straightforward: avoidable risks should be minimized, alternatives should be considered, and the incremental risk associated with the system should not be significant compared to everyday life risks. Tolerable risks should balance with the benefits. However, creating a coherent policy that adheres to these principles for land-use planning, including the siting of hazardous installations and developments around them, is more complex.

The above is not an argument to approach every practical decision regarding risk as a unique decision problem without using standards and criteria. To provide transparency, comparability, and predictability, a standardized approach is sometimes the best. It might be sensible to use the same risk criterion for all companies handling large quantities of hazardous substances, rather than making individual decisions based on the benefits a specific company brings. Speed limits in car traffic, which also serve to control the risk of casualties, are also not based on the individual driving skills of the car driver, so that a professional racing driver and a less capable driver would receive a fine at the same speed. The argument is to critically examine whether the framework being used is appropriate and to avoid inadvertently comparing apples to oranges. Especially when reusing criteria from a specific technology or setting for a different application, it is crucial to make this consideration thoroughly. At such a moment, it is useful to take a step back from the practicalities and view the issue within a broader context.

Often, it is poor policy to disregard common sense simply because it does not align with artificial standards or theoretical rationality at first glance. It is more likely that the theory has been misapplied in defining the decision problem than that common sense is systematically flawed.

*“There is only a perspectivist seeing, only a perspectivist ‘knowing’; and the more affects we allow to speak about a matter, the more eyes, different eyes, we know how to use for the same matter, the more complete will be our ‘understanding’ of this matter, our ‘objectivity’. But the elimination of all will, the sidelining of all affects, assuming we could do that: what now? Would that not mean a castration of the intellect?”* Friedrich Nietzsche: On the Genealogy of Morality

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