

On the interpretation of risk acceptance of major tunnel fires

Ove Njå
 SEROS
 University of Stavanger
 Stavanger, Norway
 Ove.njaa@uis.no

Geir Sverre Braut
 SEROS
 University of Stavanger
 Stavanger, Norway
 gsb@sus.no

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ABSTRACT

The traditional approach to risk management is that risk acceptance criteria are developed by the tunnel owner prior to risk analysis. Risk analysis results are thereafter evaluated against these criteria in order to document a sufficient safety level. In this paper we introduce risk acceptance as a process after analyses have been carried out, rather than using risk acceptance criteria as a part of result assessment.

This is a new way to work with risk management, which departs from the strong influence of compliance approaches. We propose to transfer the engineering based thinking of risk into a field of systems theory [1] with use of resilience approaches. We claim that our approach will make the transition from traditional safety management into modern resilience based management much easier, especially for traditionally managed critical infrastructures, such as the road traffic that includes tunnels.

BACKGROUND

During the recent decade Norway has experienced several tunnel fires, some of them exposing many road users for heavy smoke. Even though major tunnel fires are frequently observed, assessing the risk of major fires in a specific road tunnel is a difficult task. Norway has more than 1100 road tunnels and they vary substantially in designs (length, cross-section area, equipment, curves, slopes, intersections, traffic, etc). How can tunnel owners, public and the society as a whole express what is safe enough? Risk analysis of major tunnel fires (> 30 MW) involves uncertainties, in which modelling, data gathering, assumptions and use of expert opinions play major roles.

The Norwegian public roads administration (NPRA) has not yet developed risk acceptance criteria for their tunnels. The NPRA has many roles, such as; the road authority providing regulations; tunnel owner responsible for the tunnel standard; tunnel operator managing the daily traffic works; tunnel maintenance planner; and tunnel contingency provider. The NPRA acknowledges difficulties with providing strict criteria encompassing all tunnels as well as the lacking precision of risk analysis tools. Risk results are difficult to interpret in

absolute terms. The NPRA's technical specification, which has also status as regulation - N500 [2], describes minimum standards to technical solutions, but do not give insights into related safety levels. Looking into the background material of regulations has not yielded considerations of what are seen as risk acceptance criteria.

In this paper we introduce risk acceptance criteria as a process, rather than result assessment. This is a new way to work with risk management. It departs from the strong influence of engineering based compliance approaches, into a field of systems theory [1]. Our approach follows up Stephen Watson's [3] concern that probabilistic safety analyses are nothing else than dialectical arguments over safety that needs to be debated amongst stakeholders in order to provide good basis for decision making. This view on risk analyses has not obtained much attention amongst stakeholders and the safety management domain as a scientific discipline. Fire safety is seen as an expert oriented discipline in which risk is considered a quantity that could be analysed by objective, true models and data. We oppose this view.

Our approach to risk acceptance criteria contains the process from when the hazard and risk analysis is presented, further on to the process of learning and reflection activities amongst stakeholders, until it is integrated into system constraints [1]. Thus, the process is an integral part of engineering safety using systems theory. Fire safety engineering as traditionally seen in construction projects may have difficulties to adopt this approach to risk management, communicative planning has not become a strong characteristic of construction projects. However, we claim that the NPRA, after nearly twenty years of experiences with the Zero Vision philosophy would be a mature risk informed actor.

The risk images regarding major fires in the considered tunnel system, will then be open for debate and criteria chosen as part of the process. Currently, risk models predicting major fires in tunnels are lacking. The NPRA has been criticized from many agencies:

- The Office of the Auditor General of Norway documents that the NPRA does not assess specific risks related to the tunnel studied [4], and they further claim that the NPRA lacks control in their safety work.

- The Road Supervisory Authority put forward similar critics and emphasizes that the NPRA has not sufficiently implemented the Tunnel Safety Directive nor is the tunnel safety work based on clear cut concepts and activities [5].
- We also mention that the NPRA is lagging severely behind in their tunnel upgrading project. The tunnel upgrading project's aim is to ensure compliance with the Tunnel Safety Directive and the project is meant to be finalised in 2019.
- The Accident Investigation Board Norway (AIBN) points at serious malfunctions of the NPRA's safety work after the many fires occurred in Norwegian tunnels recent years [6-8].

However, on the other hand the NPRA can document that traffic safety in Norway has significantly improved since 2000. The Norwegian records on fatalities and seriously injured people in traffic is amongst the lowest in the world taken all comparative approaches and concepts into consideration. No one has died from intoxication after major fires in Norwegian tunnels.

RISK MANAGEMENT IN THE ROAD SECTOR

In this chapter we present the NPRA's experiences with risk assessment and how various organisational levels in the road transport systems view risk. It is based on studies we have conducted since 2013, both regarding general risk assessments and specific tunnel fire safety assessments.

A. NPRA's experiences with risk analyses

The NPRA had undertaken approximately 200 risk assessments in 2013. Risk assessments were carried out as specified by the NPRAs Handbook 271 "Risk assessments in road traffic." In an effort to further develop and improve their risk assessment practice the NPRA decided to evaluate a selection of risk assessments. The main purpose of this activity was to develop insights regarding whether and to what extent the risk assessments provide users with good decision support, and to examine whether the risk assessments function as a good learning tool for the NPRA. The evaluation was based on an analysis of ten road projects where risk assessments were part of the project management [9]. The risk assessments were subjected to existing and planned road systems, to systems such as roundabouts, bridges, sections and tunnels, and risk assessments were also carried out in relation to traffic safety during construction phases.

The results from the comparative case studies show that risk assessments in the NPRA both provide good decision support and that participation in risk assessments imply learning.

1) In general very useful experiences

Some of the results from the study are summarized below. It was originally described as a "success story":

- In the analyses where the assessment had a clear and single purpose defined by or together with the project owner, the application of findings was more successful.
- The cases where respondents explained that risk assessments were practically institutionalized as part of the planning process, appeared to be the projects that made the best use of the risk assessment tools.
- All the respondents emphasized the multidisciplinary nature of the assessments as a key success criterion.

Here the respondents focused on the hazard meetings (meetings of experts discussing safety problems guided by a process-leader). The hazard meetings appear to have a very positive effect in terms of developing knowledge and creating a common understanding of projects.

Furthermore, the study concluded: "In relation to concrete decisions it is important that the risk assessments are done at the right time and that significant interests are represented. This is true not only for project owners, but for all actors that can affect the final result of the projects we examined" [9].

2) Challenges and opportunities for development

In order to recommend issues for further development, the study looked at a number of tasks, in which researchers gave concrete advices, reported as "we recommend":

Competence among those who order risk assessment is a critical factor. An individual who orders a risk assessment based on a careful consideration of what he or she wishes to achieve, will enhance ownership to the assessments. In addition it makes the process appear more meaningful. *We recommend* that the NPRA should establish competence requirements upon those who order risk analyses as part of decision processes.

Assessment criteria are not operationalized. Criteria for assessing risk analysis is merely an image that everyone carries. The design of the road system is meant to lead to safe behaviour. It is also meant to protect against serious consequences of mistakes. These amongst a number of other normative statements are functional demands that are established in the NPRA. These statements but have not been subjected to debate. *We recommend* that the NPRA considers how the assessment criteria should be operationalized and used in risk assessments.

Does the NPRA lack a culture for discussion of risk? Use of risk results as a discussion regarding traffic safety was not observed in the study. Reports are only evaluated to a minor extent and the risk assessments groups are not challenged regarding their assessments of the risk factors. *Our recommendation* is that the NPRA should encourage discussions regarding the contents of risk analyses. In this way knowledge will be challenged and decisions will be made in a constructive manner.

Risk assessments are power. Risk assessments are an attractive tool for individuals with strong opinions about the suitability of solutions. The use of concepts is also related to power. The risk assessment process leader and the report writer have also power. The only way to deal with active use of power is by using knowledge and strong process leaders who have professional integrity. How to secure the quality of the analyses? Traceability, credibility, transferability and validity are concepts that can be used to establish quality criteria. *We recommend* that the NPRA should create quality criteria aimed specifically at risk assessment processes, where one of the goals should be to avoid misuse of power by individual participants.

The limits for risk acceptance criteria, tolerability levels and other requirements are not documented. *We recommend* that the NPRA should develop clear guidelines with regards to how various assessment criteria should be understood and determine who is responsible for ensuring requirements and criteria are followed up.

Decision situations, uncertainty and frameworks for the risk assessment process. Handbook 271 on risk analysis emphasizes the importance of uncertainty in risk assessments. *We recommend* that the NPRA should study uncertainty in relation to how risk assessments are planned, and perhaps also develop a tool for use in the assessments that can aid participants in describing uncertainty. Such a tool can contribute to the creation of purposes and limitations of the risk assessments that are done. We are however not recommending that uncertainty should be described alongside the results of the risk analysis.

The study from 2015 emphasized the unresolved problem with risk acceptance criteria, both regarding to whether it should be developed by the NPRA and how the criteria should be expressed and interpreted.

B. Two levels within the road tunnel system with different interpretation of risk

The tunnel system comprises a hierarchical level of actors both involved in the planning processes as well as in operations. The Norwegian Public Roads Administration serves many levels and purposes, from issuing regulations to plan and administer the tunnel as well as managing the traffic. Two important levels is the Directorate, situated in Oslo that is responsible for regulations, guidelines and project approvals. The Regional Office is the tunnel owner and responsible for the risk assessments related to design and operations. Since the Zero-Vision philosophy became part of the premises on traffic safety in Norway in 2000, risk assessments have developed incrementally.

However, the two levels within the NPRA have also developed in different directions, in which some regions have a pragmatic view on risk assessment. These regions see risk as an image of the analysts involved and they relate the risk assessment very strongly to choice of solutions. For them risk is connected with safety concerns and they associate events and consequences with subjective statements on probabilities and uncertainties. They are pragmatic and use hazard-meetings as their risk assessment tools.

On the other hand the Directorate is data driven and sees risk as relative frequencies of fatal accidents or seriously injured people, often normalised on traffic work, population or similar quantities. Their positivistic view on risk is classical, and often uncertainties are neglected. They see risk as a context free concept.

Generally we can relate persons working in the areas to the various characteristics of risk interpretation, but it will be fair to say that the various interpretations are consequences of the different needs for decision support that exist in the two tunnel system levels. The Directorate has a national overall view, while regions are context specific single tunnel oriented.

RISK ACCEPTANCE - A DISCUSSION AMONGST STAKEHOLDERS

Acknowledging risk as a dynamic phenomenon with specific characteristics related to the unique conditions in each tunnel calls for a situated approach. Applying highly standardized techniques may not reveal the real challenges connected with risk governance under the given conditions.

We therefore propose a modified approach to analysis of risks focusing on the involvement of different stakeholders. In designing this type of an analysis, we may draw on experiences from the hazard-technique, both with enhanced

requirements to the procedural elements of the process. Instead of focusing the risk as a dependable variable or as an output-measure, the risk image may be developed on basis of what emerge as concerns during the process of analysis.

For such a process to become transparent, testable and able to validate it has to document facts and concerns related to a set of factors:

- Underlying knowledge on which the following risk discussions are based.
- Experiences from relevant or comparable projects.
- Values and norms at stake, including legal requirements and economic considerations.
- Framing conditions related to nature, culture and other structural elements, including expectations related to transportation volumes, patterns and types.
- Expectations from different stakeholders.

On basis of these factors there will be a need to develop criteria for evaluation of the tunnel system functions. To ensure validity of the findings, there must be a plan for continuous follow up, taking up-coming events into account and bringing them, new knowledge or new experiences and expectations into an iteration of the process.

In this way the "risk analyses" never will be finalized, but it may be used as basis for discussions and decisions at different times during both the planning, building and management of the tunnel.

A common risk picture/image developed/designed/negotiated among the different stakeholders cannot be regarded as the ultimate truth, but it may be claimed that it mirrors the basis of explicit and implicit knowledge on which risk related decisions are made at different stages in the life of a tunnel. Thus, a well-designed hazard process will have risk acceptance criteria as the superior goal, both related to underlying knowledge, technical, operational and organisational solutions. Presentation of this process is not part of the scope of this paper. However, by introducing risk analyses, systems and underlying knowledge in this way to stakeholders it will increase the understanding and position of safety in general and fire safety specifically. We have conducted several studies, which shows that decision makers have minor knowledge of safety and risks [10, 11].

DISCUSSION / CONCLUSIONS

In this article we propose that the traditional approach by establishing risk acceptance criteria as a basis for formalized risk assessment methods can be substituted by a process involving stakeholders in position to have some kind of impact on the safety level and the safety constraints of the specific system.

This may be done through a hazard-inspired procedure in which the specific conditions related to the tunnel to be analyzed are taken as a basis for initiating a managed dialogue among persons and institutions that have interests in maintaining a high safety level in the transportation system.

The result will not be a visualized picture of the accepted risk, as we find in FN-plots and ALARP-diagrams. But the discussions may establish a risk image to be shared amongst those in position to have impact on the safety constraints and

safety level in the tunnel (or any other road traffic system) studied.

The result cannot be perceived as the ultimate truth about the risk in the system. Regrettably results of traditional approaches seem to be apprehended as showing the truth to a higher degree than defensible from a scientific point of view. Still it may show to constitute a platform for continuous collection of experiences and an iterative process related to improving safety in the system. This need to be further explored through prospective, empirical studies of real cases.

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