Competence constraints for fire and rescue personnel involved in tunnel fire safety as part of the tunnels' risk acceptability

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The Commission Directive 2004/54/EC provides minimum safety requirements for tunnels in the trans-European road network and has been implemented in the Norwegian regulatory framework. The Directive states that the tunnel owner shall ensure a sufficient emergency response performance. This is a goal oriented and functional requirement, but its contents and interpretation is uncertain. In order to ensure an adequate emergency response it is expected that administrative authorities shall put in place organizational and operational schemes for the training and equipping of emergency services. The tunnel fire safety systems are complex systems that need to be understood by its safety constraints controlled by personnel that is supposed to interact in order to ensure a holistic and robust system. Currently, we cannot find any recommendations or outlines of risk acceptance criteria to road tunnels. This means that risk acceptance must be revealed from risk analyses and their associated system designs. The emergency response arrangements and related competence of the involved organizations and personnel contribute to specific risk levels. However, these connections are rarely seen in the safety documents. This article challenges the relationships between the risk analyses and the established competence constraints set by the fire and rescue departments. We scrutinize the fire and rescue personnels' governing curricula in order to identify its contribution to risk acceptance. The major goal is to clarify how safety and performance requirements are developed and specified for fire and rescue personnel involved in tunnel fire safety.

Keywords: tunnel fire safety, emergency response services, risk analyses, fire and rescue personnel, competence constraints.

1. Introduction

Norway is one of the countries that erects most road tunnels on a worldwide basis. Some of the main purposes with tunnels is to facilitate new routes through mountainous areas, replace ferry transport, avoid environmental difficulties especially in urban areas, and improve transportation flow.

The severity of the incidents that occurred in the Mont Blank tunnel in 1999, the Tauern tunnel in 1999 and the St. Gotthard tunnel in 2001 triggered the European authorities and the policy-makers to be more concerned with tunnel safety (PIARC, 2007; Gandit, et al., 2009). As a result, the European Commission launched the Directive 2004/54/EC that sets the minimum safety requirements for tunnels in the trans-European road network (EC, 2004). The Directive has established a common platform to evaluate tunnels' safety and introduced the use of risk assessments in order to evaluate the tunnels' risk acceptability (PIARC, 2012; Borg et al., 2014; Ntzeremes & Kirytopoulos, 2019). It is expected in the Directive to ensure an adequate emergency response, and that the administrative authorities shall put in place organizational and operational schemes for the training of the emergency services.

The tunnel fire safety systems consist of a variety of actors and organizations, ranging from the road owners and authorities to emergency responders and road users. The diversity of involved parties and the interactions between them contributes to the system's complexity (Leveson, 2011). In order to ensure a holistic and robust system, the personnel that is supposed to interact needs to identify and enforce safety constraints within the entire socio-technical system. We explored the system safety theory and address our major issue: *Which connections are established between competence constraints amongst fire and rescue personnel and the tunnels' risk acceptance criterion*?

We know that the Norwegian Public Roads Administration (NPRA) has not developed general risk acceptance criteria for tunnels, thus we needed to assess current risk analyses to reveal levels of risk acceptance. Furthermore, it was the arguments behind we sought out in order to identify connections between risk acceptance and competence constraints. We used the Ryfast tunnel as a specific case for our analysis. Ryfast is a subsea tunnel of 14.4 km, 292 m below sea level,

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max slope 7.85, twin tube, speed limit 80 km/h, AADT 8000, HGV proportion 8%, Design fire - HRR 100MW.

We collected data by contents analysis of the following documents: the Directive 2004/54/EC, the Tunnel Safety Regulation, the Handbook for Tunnels - N500, and Guidance for Risk Analysis of Road Tunnels. The first author observed the Ryfast tunnel system's emergency response preparations prior to opening of the tunnel. In this context, we have examined how the emergency response capabilities are assessed and followed up. It seems that the emergency response services' capabilities to cope with major incidents in tunnels is not recognized by the tunnel owner as a criterion used to assess the tunnels' accepted level of risk.

This paper is organized as follows: Firstly, we depict the Norwegian safety management regime for road tunnels. Secondly, we argue for systems engineering as a more adequate approach to the tunnel safety management. Thirdly, we present the results from the risk analysis of Ryfast and the current competence requirements amongst fire and rescue personnel. As a conclusion, we recommend enforcement of competence constraints for fire and rescue personnel involved in tunnel fire safety.

2. NPRA's Safety Management Regime

2.1. Guiding safety principles

Since 1999, the Zero Vision philosophy underlies all the Norwegian road traffic safety work (Langeland, 2009). The Zero Vision is a vision of a road traffic system that does not lead to loss of lives or permanent injuries amongst the road users. To achieve this vision, the road authorities have demanded the NPRA to provide a systematic control over all various risk factors that may affect safety. This has generated various safety assessments, risk analyses, inspections, revisions and accident investigations within the road traffic system.

The NPRA has the administrative authority for road tunnels and is responsible to ensure that all aspects related to tunnel safety are followed up in accordance with the requirements in the Directive (DPR, 2019).

2.2. Risk analysis for road tunnels

According to the Directive, a risk analysis is *an analysis of risk for a given tunnel, taking into account all design factors and traffic conditions that affect safety*… (EC, 2004, p. 54). Safety in tunnels is determined by *the geometry of the tunnel and its design, safety equipment, including road signs, traffic management, training of the emergency services, incident management, the provision of information to users on how to behave in tunnels, and better communication between the authorities in charge and emergency services*… (p. 41). Thus, we expect evaluations associated with the emergency response services' preparations and their related competence levels as part of the risk picture.

An examination of the guidance for risk analyses of road tunnels (Wiencke et al., 2007) reveals that there is no consensus as to what the analyses should involve or which methods are best suited.

3. Systems Engineering Approach and the Tunnel Fire Safety Systems

3.1. Control and safety constraints

According to Leveson (2004; 2011), complex systems necessitate a better understanding of all factors involved, and may be treated adequately only in their entirety by taking into consideration all aspects related to the social and technical aspects.

Accidents occur in the interaction between the system's components as a result of inadequate control mechanisms (Leveson, 2011). Thus, safety becomes a matter of creating a control structure that enables the system to operate safely. Leveson suggests the imposition of constraints to regulate risk related activities and ensure safety. Constraints represent acceptable ways the system or organization can achieve the mission goals. This places demands upon the tunnel owner and how the emergency response needs to be designed. Safety arises when constraints are imposed upon the degree of freedom of one level from the level above.

However, designing and enforcing appropriate safety constraints is a demanding task. There is a need for communication and feedback mechanisms about the state of the tunnel system to identify critical safety constraints for the system's operation and design. This knowledge must be conveyed to the decision makers responsible to ensure tunnel fire safety. Such information is valuable and helps determine whether the existing corrective actions are acceptable or if additional safety measures must be taken. Moreover, the notion of control requires monitoring in order to detect the hazardous event or condition, measurement of specific variables, interpretation of the measurement and response.

We have adopted Leveson's (2011) control structure, Figure 1, to identify unsafe control actions from the perspective of the emergency response services' capabilities and competencies in tunnels.

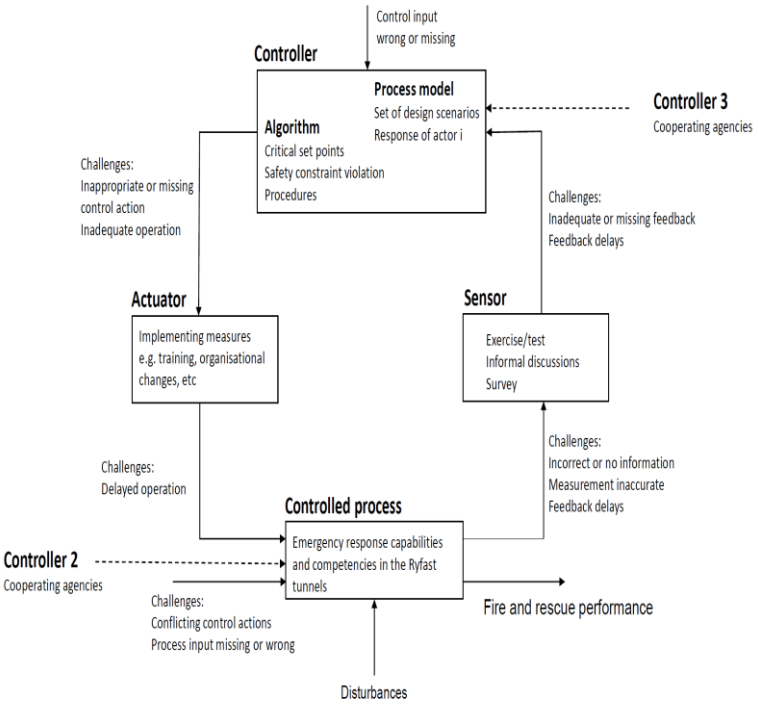

Figure 1. Causal factors to identify competence constraints amongst emergency response personnel adapted from Leveson (2011)

Since unwanted events, in our case insufficient capabilities and competencies in tunnels, are results from inadequate control and implementation of safety constraints, the process leading to this may be seen as expressions of flaws in the emergency response systems' design and operation. The model shows the causal factors that may lead the tunnel systems into a hazardous state. The main purpose is to identify competence constraints, so that the scenarios that may lead to insufficient capabilities in tunnels may be eliminated or controlled. The model assumes that each element in the control structure may have its contributions that can lead to inadequate control.

The emergency response capabilities in tunnels is an assembly of the competencies of various actors, spanning from the municipalities (fire and rescue services) to various regional services (NPRA, health and Police). In order to control the emergency response capabilities and competencies some type of sensors are required. The sensors are directly linked to the controlled process (emergency response capabilities and competencies) and represent a rich source of information to the controller, in our case the fire and rescue chief or the person responsible for training activities. Additionally, the safety of the controlled process is strongly influenced by inputs from other system controllers. For this study, we have examined how results from risk analyses are used to provide decision support in order to establish competence constraints for fire and rescue personnel. The NPRA expresses acceptable levels of risk in tunnels through risk acceptance criteria predetermined by independent actors. We presume that the information generated in this process influences the fire and rescue services when establishing their performance requirements; thus when developing the set of scenarios used for the training of the personnel. Consequently, this process will yield assessment of the fire and rescue services' capabilities, and critical points for the emergency response performance may be identified.

A major concern and challenge is that the information conveyed may prove to be insufficient or incorrect. In these cases, the controller may issue inappropriate control actions, including creating inadequate training activities indicating that sufficient capabilities are obtained, when this is actually not true. Consequently, control actions (implementation of measures) may be inadequately executed and hazardous conditions may arise in the system.

We claim that in order to reveal potentially unsafe decisions, it is necessary to evaluate the context from which the defining scenarios and the training activities are developed. Based on this critical information, the controller may be able to make appropriate decisions, and respectively design appropriate competence constraints to ensure an adequate emergency response in tunnels.

3.2. The Ryfast control structure

In the context of approaching the opening date of the Ryfast tunnel system, representatives from the tunnel owner and the emergency services met to discuss the tunnel's risk level. The parties' goal was to deliberate the tunnel emergency response system's capability to cope with potential incidents. The tunnel system itself encompasses a large number of highly technical safety standards. Some of these are; evacuation crossovers every 250 m, a robust ventilation system, surveillance system, safety equipment for the emergency services, etc. It has been discussed that insufficient capabilities amongst emergency response personnel may contribute to fatal consequences in the event of major tunnel fires, even though the tunnel's equipment is facilitated so that the personnel may be able to perform an adequate response. Since the emergency services have limited experiences with rescue and extinguishing operations in long subsea tunnels, the need to increase competence amongst the personnel has been addressed as a crucial issue. Through close cooperation between the tunnel

manager and the emergency services, several scenarios have been developed to serve this purpose. Introductory visits, skills training and function exercises for both the individual agencies and in cooperation have been regarded as essential training activities to achieve the overall goal of sufficient emergency response capability. In order to effectively carry out the training activities, the tunnel manager has provided access to the tunnel, and allocated a certain number of days to conduct the practical training. However, due to delaying factors prior to the opening phase, the time allocated to the emergency response preparations has been reduced.

To ensure a thorough execution of the training and to achieve the overall goal, the emergency response services have assigned several dedicated persons to conduct the training activities. Experiences from the training activities, evaluations, informal discussions and self-evaluations amongst the personnel have provided feedback information indicating that the overall learning goal is far from being achieved. Subsequently, the representatives from the emergency services have demanded the tunnel owner to allocate additional days with access to the tunnel system to implement corrective measures. After several meetings, the tunnel owner agreed to allocate the emergency services increased access to the tunnels. Nevertheless, due to resource challenges, the Road Traffic Center (RTC), health and Police have not had the possibility to participate in the supplementary training activities. We claim that as a consequence, there is a great deal of uncertainty regarding the emergency response's capabilities to cooperate in order to ensure adequate response actions.

We have in our previous work pointed out that the frame conditions for developing optimal learning systems within the emergency response systems are not in place (Bjørnsen and Njå, 2019). Moreover, concerns have been expressed regarding the tools used to assess the effect of the learning activities. We argue that in order to ensure safety in tunnels, the emergency response services must identify and enforce relevant competence constraints that can be monitored by the responsible personnel.

4. Review of the Ryfast Risk Analysis

4.1. Risk acceptance and risk results

In the Ryfast tunnel case, the tunnel owner has commissioned an independent consultant to carry out the required risk analysis (Hoj Consulting, 2014). The purpose of the analysis was to provide rational decision support and to optimize safety in a cost-effective perspective. The risk analysis approach has been to develop previous risk analyses for the Ryfast tunnel, and utilize the TRANSIT-model to provide quantitative risk assessments (Schubert et al., 2011). A reference tunnel has been used to evaluate the quantified effects of the Ryfast tunnels' distinctive characteristics.

The TRANSIT-model is a Bayesian belief network model, which is based on data and expert judgements gathered from the Norwegian road authorities, based on a study from approximately ten years ago (Schubert et al., 2011).Validation of data and models has, as far as we know never been carried out. The model has limitations, see discussions in Borg et al. (2014).

The consultant provided a specific section on risk acceptance criteria, based on a comparison criteria; *safety against human injuries shall be as good per km road section in a tunnel as the road in the open* (p.16). By far, this is a criterion which is always met, taking expected values into consideration. Furthermore, the consultant has defined the absolute criterion of 10.4 fatalities per billion vehicle km. This criterion is developed from the last ten years average number of fatalities in Norway (Statistics Norway). The risk acceptance criterion was set to 70% above the average (6.1 fatalities per billion vehicle km). We question the NPRA's approval of these arguments.

The current risk analysis rejects specific attention towards major accidents, such as HGV-fires. The consultant argues that public attention and risk aversion of major accidents creates conservatism. This might, according to the consultant, imply economically biased investments and ethical problems. The consultant advocates that consequential damages from major events, direct and indirect, need to be thoroughly assessed.

Tables 1 and 2 present the results of the risk calculations.

Table 1. Individuals' risk for the Ryfast tunnel system

	Fatalities/ year	Injuries/ year	Incidents/ year
Accidents	0.1860	3.461	2.293
Vehicle fires	0.0013	0.020	1.616
HGV fires	0.0040	0.061	1.507
Dangerous goods	0.0007	0.002	0.000
Total	0.1919	3.544	5.417

Table 2. Expected number of incidents for the Ryfast tunnel system

Traffic	45.66	10^6 vehicle-km/year
Accident rate	0.050	Per 10^6 vehicle -km
Fire rate	0.068	Per 10^6 vehicle -km
Fatality rate	4.20	Per 10^9 vehicle -km

The reported results show that the fatality risk is dominated by accidents. The analysis show a fatality rate of 4.20 per billion vehicle kilometers, which is far below the limit of 10.4 fatalities per billion vehicle kilometers. The analysis does not reflect uncertainties and model assumptions.

4.2. Design fires

The tunnel system description reads that the ventilation system is designed for a 100 MW fire, and the tunnel is equipped with firewater with tapping possibilities along the pipeline in the tunnel. This includes both water and foam. The consultant estimates the response time for the fire departments in the Ryfylke tunnel to 20-25 minutes, either coming from Stavanger or Jørpeland (Strand municipality). The qualitative analysis does not reveal any information about fire risk, but refers to previous risk analyses defining scenarios;

- Scenario 4. Fire in heavy goods vehicle
- Scenario13. Dangerous goods
- Scenario 14. Dangerous fluid into the drain system
- Scenario 15. Explosion

None of the scenarios are further assessed. For the description of distinctive characteristics, the tunnel gradient (7.85%) is said to increase the fire frequency. Estimated HGV portion is 8%, which is below average.

The risk estimates of fires and dangerous goods events are presented in Tables 1 and 2. However, the characteristics of fires that are included and their severity is not known. The analysis does not provide any information about the scenarios, the performance of safety barriers etc. It does only present number of expected fatalities. There are no descriptions from the fire event occurs to the consequences as fatalities are reached. Thus, the risk assessment is not a presentation of events, only an overview of consequences and related frequencies. The consultant uses the PIARC Technical Committee C.3.3, to base the probability distribution of fires based on HRR (1 MW, 5 MW, 25 MW, 50 MW, 100 MW and 200 MW).

Our conclusion is that the existing risk analysis for the Ryfast tunnel system does not contain any information that relates to the performance of emergency response systems. The fire and rescue service's role as a fire safety measure is neglected by the NPRA. A positive interpretation is that the fire and rescue services provide an additional risk reduction to the Ryfast tunnel's fire safety.

How shall we then understand constraints developed for the tunnel fire safety competences? What are the relationships between risk acceptance criteria and performance requirements for the emergency services? The current risk analysis does not bring anything to this discussion. On this basis, we question the analysis' trustworthiness as a tool to depict design scenarios, as well as the analyst's ability to propose essential safety measures and the assumptions that underlie the risk calculations. The TRANSIT model is a black box, and the consultant has not revealed its contents.

4.3. Experiences from tunnel fires

Our starting point was that the emergency response capabilities and their related competence levels contribute to specific risk levels. This view is consistent with investigations that have been conducted in the aftermath of major incidents in Norwegian tunnels. The Accident Investigation Board of Norway (AIBN) has multiple times pointed out concerns related to the emergency response systems' competencies in order to cope adequately with major tunnel fires.

We argue that there is a need to replace the current risk analysis approach with a more comprehensive one. It should assess the tunnel system from a more holistic perspective, where both the technical and social aspects are considered. Hence, we claim that in order to determine a tunnel's risk acceptance, the analysis must reflect all safety measures including the fire and rescue services. This will yield assessment of insufficient competencies amongst emergency response services.

5. Competence Requirements

5.1. General competence requirements

The *Regulation concerning the organization and dimensioning of the fire and rescue services* provides the legal framework for the formal education and expected competence outcomes amongst fire and rescue personnel (DCP, 2003). According to the Norwegian Official Report (NOR), the concept of competence is defined as the assembling of an individual's knowledge, skills and attitudes. More specific, competence refers to *…individuals not only mastering a professional field, they must also be able to apply their professional knowledge in situations that are*

uncertain and unpredictable (NOR, 2012:8, p. 20).

The Norwegian Fire Academy (NFA) is the national educational institution for the fire and rescue personnel, and the main source supplying goals, contents and methods of the educational programs (NOR, 2012:8). The newly revised curricula for the education of fire and rescue personnel has introduced the topic *Efforts in tunnels* as a subject into the basic course (NFA, 2018). It is expected that after completion of the educational program, the student shall possess basic theoretical and practical knowledge related to the subjected topics. To achieve the overall goal, NFA has formulated goals and learning outcomes expressed in terms of knowledge and skills requirements. The knowledge requirements are conveyed through verbs appealing to the student's cognitive abilities (i.e. apply, understand and know), and are sought to be achieved through theoretical lectures. On the other hand, the skills requirements are conveyed through verbs appealing to the student's psychomotor and cognitive abilities (i.e. master, independently execute and under guidance). For those requirements, NFA demands both theoretical lectures and practical training activities.

The overall goal for the tunnel fire education is stated as; *The student shall know about various challenges related to incidents in tunnels* (NFA, 2018, p.14). Following two hours with theoretical lectures, it is expected to achieve these learning outcomes:

- *Shall know about dangers related to response operations*
- *Shall know about available equipment and how to use it*
- *Shall know about technical installations and how those work*

A fundamental idea related to the concept of competence is that it shall comprise requirements of knowledge, skills and attitudes. The examination of the governing curricula reveals that the formal tunnel fire education appeals only to development of knowledge requirements. Thus, the established learning goals seek to develop only the personnel's cognitive abilities. We argue that the formal educational program does not imply any competence requirements amongst fire and rescue personnel involved in tunnel fire safety.

5.2. *Specific competence requirements*

Following the formal educational program, the fire and rescue services must frequently facilitate practical and theoretical learning activities (DCP, 2003). The overall goal is to develop competence giving the fire and rescue personnel sufficient capabilities to cope with various risks that the inhabitants may be exposed to.

In the recently developed risk analysis, Rogaland Fire Department (RFD) has identified long, subsea tunnels as objects that contribute to increased level of risk in the Stavanger area (RFD, 2018). The analysis acknowledges that although the Ryfast tunnel system is equipped with a high standard of technical and organizational safety measures, there is still a great deal of uncertainty as to whether the emergency response performance is sufficient to cope with major tunnel fires.

Prior to the Ryfast's opening date, RFD, in close cooperation with the regional NPRA and the other emergency response services has established a framework for the training of the personnel. A first step has revolved around the personnel receiving a brief introduction into the tunnel system. Hence, information booklets comprising overview of the tunnel's safety equipment, maps and clarification of key concepts have been distributed to the personnel. Alongside the information booklets, introductory visits and inspections have been carried out. With the purpose to create a learning environment where the personnel may increase their knowledge and skills through active experimentation, RFD has developed two scenarios as a final step of the training program. The first scenario involved *response to vehicle fire*, while the second scenario involved *search and rescue in smoke-filled area*.

Subsequently, the following learning outcomes have been established:

- *Master collaboration between the fire-fighting crew, RTC and 110 emergency central*
- *Implement and utilize tactics and techniques*
- *Utilize and master the tunnel's distinctive features*

Considering the concept of competence, it may be argued that the three specific learning outcomes, formulated by RFD, are expressions of competence requirements. However, competence places a great emphasis on individuals being able to apply their knowledge and skills in situations characterized by uncertainties. Our observations have shown that the designed scenarios have not taken into account the uncertainties and limitations specific for the tunnel or how those may affect the emergency response operations. The set of scenarios represent more a reflection of basic skills training, where the personnel learns to utilize the tunnel's available resources. Consequently, the fire and rescue services have not acquired experiences indicating in which situations their emergency response capabilities will not be sufficient.

6. Competence Constraints

A main assumption has been that systems theory, as presented in Leveson (2011), represents a more adequate approach for the tunnel safety management. We have addressed concerns to the relationship between risk analyses and the established competence requirements set to the fire and rescue personnel involved in tunnel fire safety. In the Ryfast case, various representatives from the emergency services have discussed and agreed upon a framework to conduct the training activities. The main purpose has been to achieve the overall goal of sufficient emergency response capabilities amongst the personnel and an optimal collaboration between the emergency response services in tunnel fires. In an ideal situation, the scenarios assessed in the risk analyses should form the basis of the personnels' performance requirements. After the unwanted events have been identified, the next major step will be to specify safety requirements and establish competence constraints necessary to prevent the unwanted events from occurrence.

We have identified some dimensions where the fire and rescue services should consider implementation of competence constraints. Associated with those dimensions we have developed competence constraints. We believe that those constraints will contribute to a better-equipped fire department for the events that may occur in tunnels. We hope that our suggestions will generate reflections amongst the actors that hold the responsibility to ensure sufficient emergency response capabilities in tunnel fires.

6.1. Constraints amongst firefighters

In order to act promptly and adequately in tunnel fires, firefighting crews need to possess local knowledge of the tunnels located in their area of responsibility. Knowledge of the tunnels' available resources is also an essential source of information. During emergency response operations, firefighting crews must take advantage of the tunnels' available resources and use those to facilitate the self-rescue principle for the road users. Moreover, a firefighter's capability to act properly is dependent on his knowledge related to the dynamics of fire, smoke emissions and toxicity of gases. In some cases, the road users' possibility to escape the fire may be limited. Firefighters will have to assess the situation and assist the road users trapped in the smoke.

Competence constraints:

- Be capable to use the tunnels' safety equipment in the best interest of the road users/victims
- Be capable to search for road users/victims safely and quickly
- Be capable to control the fire without being exposed to high temperatures or toxic gases
- Be capable to cope with the potential of incident escalation triggered by the fire

6.2. Constraints amongst incident commanders

Incident commanders' capability to assess the situation and choose the correct firefighting strategy is crucial for the outcome of a tunnel fire. A success factor in emergency response operations is that the incident commanders are well acquainted with the tunnels' contingency plans. However, not all situations demand standardized response actions. In situations characterized by great uncertainty, the incident commanders must evaluate relevant cues, and sometimes make decisions that may deviate from the established standard procedures. Being able to adapt the firefighting strategy to the situation's characteristics demands confident incident commanders that are equipped with sufficient decision-making capacities.

Competence constraints:

- Be capable to adapt decisions of choice of actions that does not expose the road users to risk
- Be capable to adapt decisions of choice of actions that does not expose the firefighting crew to risk
- Be capable to adapt decisions of choice of actions to the situation's characteristics

6.3. Constraints amongst emergency central operators

In all types of incidents, a key factor contributing to the success of the operation is efficient communication and information sharing between all involved parties. Due to the enclosed structure, tunnel fire operations occur in demanding environments, with a substantial emphasis on collaboration. During tunnel fires, emergency central operators are responsible for resourcing of the emergency response and gathering relevant information to support the incident commander in choosing correct response actions. Thus, a significant activity is their communication with the RTC operators, the other emergency centrals and the incident commander.

Competence constraints:

- Be capable to provide and communicate key information to the incident commander rapidly and understandably
- Be capable to use available information to create situational awareness and correct risk picture

7. Conclusion

This paper argues for systems engineering theory as a new theoretical foundation to design the tunnel fire safety management regime. We recognize the emergency response services' capabilities to be tightly coupled with the tunnels' risk acceptability. Our case study has revealed that the potential of insufficient competencies amongst emergency response services is not captured or incorporated into the risk analysis. Additionally, the risk analysis shows a disposition towards assessing only the tunnels' technical aspects. So far, there is no tendency to consider the potential of the interaction between the tunnel's technical and social aspects to determine acceptable levels of risk.

The lack of general standards of risk acceptance criteria generates risk evaluations and acceptable risk decisions made by subjective judgments. Taking into account that the risk analyses are carried out by various independent agencies, without a common understanding of the tunnels' risk acceptability, we express concerns to the judgments and values that underlie the basis for the analysts' decisions. We recommend that the analysts should carefully deliberate the defining scenarios and the criteria used to support their decisions of acceptable risks.

The tunnel safety legislation requires the tunnel owner to ensure sufficient training and equipping of the emergency response services. Currently, it is left to the emergency services to determine their capabilities and competences in tunnels. We question if basic skills training is sufficient to ensure adequate emergency response in various types of situations that may occur.

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