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Time-efficiency factors in road tunnel rescue as perceived by Swedish operative personnel – an interview study

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Abstract

Purpose – Major incidents in road tunnels remain a collaborative challenge for the emergency services (fire and rescue service, police and ambulance), emergency dispatch centres (EDCs) and infrastructure owners. The aim of this paper is to investigate how collaborative partners to the ambulance services perceive the rescue effort and to identify factors that may influence its efficiency.

Design/methodology/approach – Focus group and individual interviews were conducted with 19 participants who were infrastructure owners or had operational or tactical responsibilities with the emergency

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services or EDCs in two regions in Sweden with multiple road tunnels. The collected data were analysed using qualitative content analysis.
Findings – Three main categories described efficiency factors during and after an incident: (1) coordinating the initial information (using a shared terminology), (2) achieving situational awareness (identifying those persons in need) and (3) lessons (not) learnt (lack of joint tactical plans and exercises). The emerging theme was access, assess and evaluate.
Practical implications – The findings suggest that establishing national policies and collaborative forums might yield more efficiently managed rescue efforts in road tunnel incidents in Sweden and other countries with similar organisational structures.
Originality/value – This study offers new insights on interoperability during responses to complex underground incidents.

Keywords Collaboration, Major incident, Incident management, Disaster medicine, Road tunnels
Paper type Research paper

Introduction

According to the World Health Organization (WHO), road traffic incidents are the ninth leading cause of death, with 1.35 million fatalities and 50 million injured each year. This staggering death toll can be attributed to preventable causes emanating from poor safety standards and urbanisation (WHO, 2018). One effect of urbanisation is that an increasing proportion of road traffic may be steered below ground, into road tunnels, to reduce travel time and traffic congestion (Ayalon *et al.*, 2016; O'Kane, 2020). Following the construction of longer and more complex road tunnels such as; the world's longest road tunnel, Norway's Lærdal Tunnel which is 24 km (14.9 mi) long, questions have been raised regarding their safety (Li and Ingason, 2018; Ntzeremes and Kirytopoulos, 2019; Njå *et al.*, 2021).

The tunnel wall may worsen the mechanical impact of a collision, affecting injury patterns and complicating victim extraction, as evidenced by the coach crashes in Måbø Tunnel in Norway and Sierre Tunnel in Switzerland (Björnstig, 2011; Lyon and Sanders, 2012; PIARC, 2020). Those crashes occurred near the tunnels' entrances, congruent with current studies suggesting a higher crash frequency in the areas surrounding the tunnel portals (Amundsen, 2009; Sun *et al.*, 2019; Yeung and Wong, 2013). Given the confined nature of a tunnel, a crash may result in complex and time-sensitive injuries (e.g. poisoning from toxic fumes, projectile injuries secondary to explosions or blunt force trauma) which will require swift medical care (Amundsen, 2017; Chen *et al.*, 2019; European Parliament, 2004; Li, 2019; Ouyang *et al.*, 2020; Qu *et al.*, 2013; Sun *et al.*, 2020).

However, crashes resulting in the release of toxic fumes (including fires) may impair the emergency service's response (Bassan, 2016; Tseng *et al.*, 2018). Studies from underground mines indicate that ambulance personnel may be impaired for other reasons, e.g. feeling unprepared, remaining passive and becoming reliant on rescue services (RS) or the mining company; all factors which may affect time to care and collaboration (Aléx *et al.*, 2017; Karlsson *et al.*, 2019).

In Norway, which has more than a thousand road tunnels, emergency services have developed specific tunnel-incident rescue strategies (Hylander *et al.*, 2019). Hylander *et al.* (2019, 2020) found that the most critical factor in their success was collaboration, beginning with on-scene commanders' decision-making, tactical support and prehospital care. Other studies have confirmed the importance of collaboration among various organisations, such as RS, police, emergency dispatch centres (EDCs) and infrastructure owners (Alvear *et al.*, 2013; Björnstig and Näsman, 2017; Njå and Svela, 2018). Björnstig and Näsman (2017) found that optimised tactics, collaboration and repeated training can reduce evacuation time by 80% in major bus crash exercises. However, to our knowledge, there have been no studies focused on opinions from RS, police, EDC and infrastructure owners on how to maximise efficiency in road tunnel-incident response.

This study aims to investigate how collaborative partners to the ambulance services perceive the rescue effort and to identify factors that may influence its efficiency, in order to create a basis for future reduction of time to definitive treatment and form a basis for future training programmes.

Method

Study design and context

This study used a qualitative, inductive design (Thomas, 2006), ideal for capturing the participants' views and experiences with road tunnel rescue efforts. Two regions in Sweden with several road tunnels and a total population of approximately 2.9 million people (Statistics Sweden, 2020) were included. The Road Traffic Control Centre (RTCC) monitors the traffic flow in Swedish road tunnels (Swedish Transport Administration, 2018). When an incident occurs in a road tunnel, the first report generally comes from someone calling the emergency number 112 or the RTCC. They contact the appropriate EDC, which receives and triages emergency calls, dispatches emergency vehicles and personnel and relays information to the police and RS control centres (SOS Alarm, 2020).

Participants and data collection

The inclusion criteria for participation were personnel from the RS, police, infrastructure owner and EDC with operational or tactical responsibility, i.e. having a coordinating or managing role in road tunnel incidents. Potential participants were contacted via email and received written information regarding the study.

We collected the data using both focus group and individual interviews. Staljmeijer *et al.* (2014) suggested that the optimum number of participants in a focus group was 3–13. We planned to include five participants from each organisation in each focus group. However, this proved unfeasible due to the lack of available personnel. To accommodate the participants' availability, we replaced our planned focus groups with the police with individual interviews, making minor changes to the interview guide. Further, one of the EDCs declined to participate in the study. Ultimately, we conducted five focus group interviews and two individual interviews with 19 participants (five female and 14 male) and achieved theoretical saturation (Morgan *et al.*, 1998). Table 1 shows the participants' work experience and role.

We completed all the interviews from March to November 2020, with the first author as moderator, conducting half the interviews in person and the rest online using an encrypted

Meaning unit	Code	Subcategory	Category
For instance, when a tire explodes, how will this be perceived in our own organisation [Police] or collaborating organisations? How secure is the tunnel if something explodes? What kind of fuels is involved? A lot is involved in the risk assessment	A lot is involved in the risk assessment. Risk for explosions and fuels	Risk assessment	Achieving situational awareness
When positing an incident in a tunnel, there are numbers in the tunnel system to be used for guidance. It should be easy to position the incident correctly, but sometimes the incident can be positioned incorrectly by 400 meters	The tunnel incident can be positioned incorrectly be 400 meters	The location of a tunnel incident	Coordinating the initial information

Table 1. Participant's characteristics

videoconferencing service. We developed a semi-structured interview guide for this study consisting of open-ended questions designed to spark discussion, such as these: 'Discuss how your organisation would respond if the ambulance services asked for assistance' and 'Describe your way of communicating with the ambulance services'. We recorded all the interviews, which lasted 41–68 min and transcribed them verbatim.

Data analysis

We analysed the data (i.e. the transcribed text) using qualitative content analysis (Graneheim *et al.*, 2017; Graneheim and Lundman, 2004). First, the authors read all the text to create an overview of the content. Thereafter, the text was broken down into meaning units (i.e. words or small paragraphs) which related to the aim of the study. These meaning units were then labelled with a code. The codes, 310 in total, were grouped into 10 subcategories and three categories. In the analysis process, a theme linking the categories together was identified (Graneheim *et al.*, 2017). Table 2 shows some examples from this process.

The first author conducted the primary analysis and discussed the results with the co-authors, reaching consensus on categories, naming of categories and theme (Table 3). This paper describes the theme, categories and subcategories in the results section and provides excerpts from the transcribed text to increase internal consistency.

Table 2. Examples of the analysis process

	Number of participants	Years of experience Mean (SD)
Catchment area A		
Emergency dispatch centre	N/A	N/A
Fire and rescue service	4	11 (5)
Police	1	12 (N/A)
Infrastructure owner	4	8 (7)
Catchment area B		
Emergency dispatch centre	3	8 (4)
Fire and rescue service	2	28 (3)
Police	1	30 (N/A)
Infrastructure owner	4	10 (6)
Total	*19*	*12 (9)*

Table 3. Theme, categories and subcategories

Theme	Categories	Subcategories
Access, assess and evaluate	Coordinating the initial information	The location of a tunnel incident
		Dispatching the proper resources
		Assessing the number of injured persons
	Achieving situational awareness	Setting a joint agenda
		Identifying those persons in need
		Joint command post
		Risk assessment
	Lessons (not) learnt	Lack of exercises
		No joint evaluations
		Lack of tactical plans

Ethical considerations

This study was conducted in accordance with the Helsinki Declaration (World Medical Association, 2013) and approved by the Swedish Ethical Review Authority (2019-03611).

Results

Theme: access, assess and evaluate

The theme addresses what emergency service personnel need, to reach and help victims trapped in a major tunnel incident. The emergency services need quick access to the injured persons, who need to be properly assessed by personnel with knowledge of triage and treatment. Tunnel incidents need to be evaluated in order to improve efficiency and engender a sense of preparedness.

Category 1: coordinating the initial information

This category highlights the need to collect accurate information about, for example, the location of an incident and distributes such information as quickly as possible to initiate an efficient rescue effort. Accurately locating the vehicles involved in a tunnel incident together with a tiered response and estimate of the number of injured persons were regarded as crucial factors in the initial stages of a tunnel incident.

Subcategory: the location of a tunnel incident

The location of vehicles involved in a tunnel incident can be determined in various ways: by the RTCC via an automatic alarm from a tunnel safety system or manually by RTCC operators viewing CCTV footage; members of the public via mobile phones or an automated in-vehicle system, eCall, which sends crash data to the EDC (Your Europe, 2021). The participants described the information flow between the EDC and RTCC as limited. For example, the different centres did not use the same terminology for the different tunnels: This caused delays as a result of misunderstandings regarding the location of a tunnel incident. The senior incident commanders from the RS and police needed quick access to the precise location in order to plan access routes for the emergency services and roadside assistance.

> Our RTCC has automatic fire alarms installed in tunnels and the local RS is notified immediately in the event of a fire. Other road tunnels in Sweden do not have automated fire alarms. In such cases, the RTCC will contact the RS manually. (Participant 15)

Subcategory: dispatching the proper resources

It was deemed important that an optimal number of resources were dispatched. The RS was dispatched using predetermined action plans that were tiered to the scale of the incident. For example, in an incident involving X number of vehicles, Y number of vehicles from the RS were dispatched. The police and ambulance service did not have similar plans, which the participants described as limiting. Further, the participants asked for additional information before they could determine whether or not they had sufficient resources. The participants also felt a need to keep an open mind as the information might change during the dispatch phase.

> Many people are involved in interpreting the information from the site of an incident. For example, this could be members of the public reporting a serious incident. The EDC assesses this information and relays it to the police or RS dispatch centres, which assess the information differently. (Participant 18)

Subcategory: assessing the number of injured persons

It was important to assess the anticipated number of injured persons as accurately as possible and communicate this information to superior officers and hospital crisis managers. The estimate of the number of injured persons might be conducted in different ways: from the caller or by estimating the number of vehicles in a tunnel. The amount of information from the caller could be limited as they might be in a state of distress during the phone call and lack an overview of the situation. The RTCC operators can only estimate the number of vehicles in a tunnel as the closed-circut television (CCTV) cameras do not have a zoom function that would enable the number of people to be counted.

> We can only estimate the number of vehicles in a tunnel. . . From our perspective, it's difficult to assess the number of people in each vehicle. (Participant 16)

Category 2: achieving situational awareness

This category highlights the need to share objectives and use joint tactics for the rescue effort. In order to achieve this level of mutual understanding, a list of priorities needs to be created, taking into account the location of potential victims, as well as safety concerns.

Subcategory: setting a joint agenda

The participants highlighted the need to create a shared understanding of the situation by initially identifying the priorities and then formulating tactics for the rescue effort. For example, what is most important right now, what could wait and what will have to wait. The RS incident commander was considered the natural leader in major road tunnel incidents, which could hamper the joint agenda. Consequently, the other incident commanders were expected to take a subordinate role, for example, retrieving information that could help the RS incident commander in decision-making. Further, the RS used predetermined tactical plans developed for rescue efforts in road tunnels. The police or ambulance services have no access to such plans prior to an incident. The lack of access to joint action plans was regarded as something that decreased the effectiveness of the rescue effort.

> Since it's a case for the RS, our incident commander will take the initiative. He should also take the initiative and tell the collaborative partners what is needed of them. This could be closing a road, more ambulances, etc. It's our job to take and keep the initiative as long as it's a case for the RS. (Participant 3)

Subcategory: identifying those persons in need

The participants emphasised that it was critical to quickly identify persons in need of medical treatment. They also stated that it was sometimes necessary to go beyond the primary tasks of their own organisation. For example, roadside assistance personnel could act as first responders if they were first to arrive at the incident site. If they had been dispatched to an incident as a first (and only) responder and then discovered there was a need for medical attention, medical assistance could be delayed because the ambulance service had not been contacted. The participants also stated that an understanding of each other's organisational tasks could improve the willingness to provide mutual assistance. For example, a firefighter would care for a patient if there were not enough ambulance personnel. However, no common method of triage, i.e. the prioritisation of injured persons, was used. This was regarded as causing confusion and delay in rescuing the victims, which is particularly important for seriously injured persons.

> All kinds of triage systems are used. It could be a coding system using colours such as red, yellow and green. It could be stated plainly [who should be prioritised first]. Or it could be a combination of both. (Participant 8)

Subcategory: joint command post

The incident commanders for the emergency services generally assemble at a predetermined location close to a tunnel, such as a petrol station or similar location. However, in one of the regions, in the event of a road tunnel incident, a specially designated building is used as a meeting point. This building has access to CCTV footage from the tunnel system, whiteboards, maps and a direct link to the RTCC to enable more effective coordination. If a petrol station or other building was used as a command post, the incident commanders did not have access to CCTV footage and had to ask the dispatch centres for information. This could take time and impact efficiency. Further, the RTCC operator would not be able to communicate directly with incident command as communication would have to go via the organisation's dispatch centres or roadside assistance personnel.

> I think it works very well. They [the RS] are quite clear about what they need help with. I think we use the same cameras in the tunnel system. They do not usually want to view any other cameras. (Participant 19)

Subcategory: risk assessment

Identifying potential risks was described as being important for potential victims and personnel. For example, the EDC asked for vehicle licence plate numbers to assess risks such as cargo, type of fuel, etc. The RTCC tried to identify any leakage (fuel or other kind of leakage) or the presence of smoke that could indicate a fire by using tunnel cameras to determine whether it would be safe to enter the tunnel. The RTCC could limit risks, such as dense traffic, by closing a tunnel or redirecting traffic at an early stage of an incident. The participants all regarded risk assessment as being essential to the safety of their own personnel, as well as for injured persons. Every organisation was responsible for conducting its own risk assessment, which resulted in inefficiency. For example, the police might set up a command post far away from the incident, while the RS wanted the command post to be closer to the actual incident. Further, there was no consensus regarding when ambulance personnel should be allowed to access to the incident site, resulting in a loss of time for persons trapped and injured in a tunnel.

> The CCTV system in the tunnel is fixed so we can't zoom in or rotate the cameras, which is pretty useless... Sometimes we have tried to guess whether there are any orange plates on trucks [indicating dangerous cargo], so zoom is a feature that we need. (Participant 11)

Category 3: lessons (not) learnt

This category is about preparedness and training. This forms the basis of effective and timely rescue. It addresses learning factors after incidents and how to improve efficiency and reduce time to care. Clearer legislation, more mandatory exercises, as well as structured feedback and evaluations are warranted.

Subcategory: lack of exercises

The participants asked for short, case-based exercises so different tactics could be evaluated within their own organisation. More frequent and larger training exercises together with other involved organisations were also requested. However, the participants experienced a lack of interest from the police and ambulance service in participating in more extensive tunnel exercises. The current legislation was described as being a potential reason for the lack of participation, as it only covers the infrastructure owners and RS. There are no legal requirements for all organisations to attend. A review of the current legislation was requested by the participants.

> If participation [in tunnel incident exercises] were required by the legislation, the organisations would not just be expected to participate, they would have to participate. This would send a clear signal to tunnel owners and organisations that they were required to participate in both the planning and execution of exercises. (Participant 7)

Subcategory: no joint evaluations

The ambition of the respective RS incident commanders was to have short evaluation meetings directly after each rescue effort. However, this was not common practice and was not prioritised by the police or ambulance service due to their heavy workloads. The focus of these meetings was to summarise what the RS had done well, what they should continue doing and what could be improved. The EDC and RTCC operators stated that they needed to be included in these meetings so they could receive feedback on their performance. They described the lack of a joint evaluation as frustrating.

> We would like to be included more in the debriefings than we are at present. We would like a more active role so that we can receive feedback. For example, what happened after the incident, what could be improved, what could we have done differently? We are not involved in the aftermath but play a key role during the incident. (Participant 14)

Subcategory: lack of tactical plans

The participants stated that access to educational material such as e-learning courses and documents were important in order to be prepared for the next incident. For example, in one of the regions, the RS had access to e-learning courses. These courses presented the structure of the road tunnel, the available safety features and the planned access/egress routes and were described as being vital to understanding how to manage tunnel incidents. The participants requested a national e-learning course provided by the infrastructure owner with up-to-date and easily accessible material. An e-learning course could lead to better preparedness for future road tunnel incidents.

> There's a complexity in the different factors presented in a tunnel incident that we are required to handle, sometimes by ourselves. I think that some shorter form of education that covers tunnel incident management and the tunnel environment itself would be beneficial, so we could make informed decisions that could limit consequential incidents or injuries. (Participant 18)

Discussion

The main finding of this study is that the participants from the RS, police, infrastructure owner and EDC, all having operational or tactical responsibility in road tunnel incidents, describe a need to develop a shared terminology for these types of incidents to avoid time-consuming misunderstandings. This is in line with findings of Tovey *et al.* (2018) and of Joint Emergency Services Interoperability Programme (2016) who found that accurate communication and using a shared terminology is paramount for a successful joint response. The participants also described a need to set mutual objectives for the rescue effort. This is similar to findings in several previous studies, describing that the incident commanders need to share and achieve their objectives to save lives (Mishra *et al.*, 2015; Tovey *et al.*, 2018). Lastly, the participants described the need to evaluate and reflect on the rescue effort. This is linked to the findings of McBrien (2007) and Alvear *et al.* (2013) who described reflection as important in gaining new insights and that prevention is a key factor in tunnel safety.

The most important contribution of this study is its indication of issues concerning interorganisational communication during a rescue effort in a complex, underground

environment. This can be linked to theories of non-technical skills (Flin *et al.*, 2008). Skills which are important for an efficient incident response consist of *decision making, situational awareness, leadership, teamwork, communication and personal resilience*. These have been adapted for use by incident commanders (Butler *et al.*, 2020). The identified lack of a simple and common nomenclature can affect the efficiency of the rescue effort, i.e. the incident commanders cannot utilise their non-technical skills. In a broader sense, misunderstandings can result in valuable time being wasted and by extension, delaying the prehospital care.

Coordinating the initial information

The participants described the importance of having access to accurate information such as the location of a tunnel incident and the number of involved persons in the initial phase of an incident. These results are in line with findings of Mishra *et al.* (2015) and of Eklund *et al.* (2021) who described that the senior commanders need up-to-date information, especially in underground environments. A partial solution may be the use of automated systems. As described by Li *et al.* (2018) and Alvear *et al.* (2013) automated systems could pin-point the correct position and estimate the number of injured in each vehicle. Other researchers describe that a lack of accurate information could impact the effectiveness of response (Hugelius *et al.*, 2020; Norri-Sederholm *et al.*, 2014). To counteract this, we propose the following: usage of a joint command post with access to CCTV footage and radio equipment, a predesignated meeting point, as well as a shared terminology to positively impact the collaborative decision-making process.

Achieving situational awareness

The participants described how an understanding of each other's organisations could improve efficiency. This is consistent with findings of Smith-Jentsch *et al.* (2009) who described "teammate familiarity" as important when asking for help. Similarly, Hylander *et al.* (2019) identified trust and familiarity among the responding emergency services as essential when collaborating at a tunnel incident. The participants in the present study also described that no common method of triage was used. This finding is in line with others who described that a lack of a common method of triage could create confusion among emergency service personnel and delay essential treatment (Lampi, 2017; Advanced Life Support Group, 2012). A potential countermeasure is described by Nilsson *et al.* (2015), an education in basic triage training for firefighters showed improved triage skills both immediately and after six months. In summary, an education in each organisation's responsibilities and training in how to triage injured persons could improve the speed and efficiency of locating seriously injured persons in road tunnel incidents.

Lessons (not) learnt

As our results show, the RS incident commanders tried to have a short evaluation after each tunnel incident to briefly discuss the rescue effort. This relates to findings of others (Villado and Arthur, 2013; Little *et al.*, 2018) who identified a method for structured evaluations, that shows promise in learning from errors and enhances performance when dealing with complex tasks. Participants from other organisations than RS in the present study requested mutual evaluations. This finding is consistent with The Pollock Review (2013) who reported that a common cause of failure in major incident management is to not learn from previous mistakes. Thus, a mutual post-incident evaluation is warranted in order to achieve learning as a group of organisations and not as individual organisations. Alvear *et al.* (2013) stipulated that tunnel safety is dependent on three principal factors: 1) tunnel design, 2) tunnel management and 3) emergency response. This study has uncovered collaborative factors that

can affect the efficiency of the emergency response and tunnel management. The individual organisations need to improve planning and preparation for future contingencies in road tunnels.

Methodological considerations

An EDC from one region chose not to participate due to lack of available personnel, which may have affected the result as the views concerning their region is not included in this study. However, each of the organisations involved in tunnel management is represented and offered valuable insights from their organisations respectively. None of the authors have on-scene experiences from tunnel incidents even if some of the authors have worked as healthcare providers in the prehospital field. In order to limit the eventuality of bias, all authors were aware of their pre-understanding and tried to hold it back during the analyses.

A possible drawback might be the transferability of the results to countries with emergency services, EDC's and infrastructure owner organised in another way. Still, the main result of the dissimilar nomenclature between organisations may well be transferred to other contexts (e.g. countries and similar enclosed environments).

Conclusions

The lack of interorganisational communication in road tunnel incidents deserves attention. The organisations need to establish a joint approach incorporating such practical suggestions as interorganisational education and online courses to improve preparedness; establish standards for terminology and techniques; and develop joint policies, tactical plans and best practices. Any developed educational courses need to be evaluated for usability. Further studies are needed on how to achieve the optimum rescue efforts in road tunnels. Forming a joint task force (a 'tunnel group') might be beneficial to oversee the development of joint tactical plans for similar structures (e.g. railway tunnels and mines). International cooperation with other 'tunnel groups' could improve incident response through bilateral information and personnel exchanges.

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