Building "common knowledge" when responding to major road tunnel incidents: an inter-organisational focus group study

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Abstract

Purpose – Major incidents in tunnel environment will pose several challenges for the emergency service organisations in terms of heat, visibility and lack of experiences from working in confined environments. These aspects, in turn, could pose challenges to establish collaboration. This study aims to contribute to the field of collaborative tunnel responses by exploring how "common knowledge" (Edwards, 2011) is built by the emergency services organisations, that is, what the organisations consider important while working on a potentially common problem, and their motives for the interpretations and actions if a major tunnel incident occurs.

Design/methodology/approach – Participants from the road traffic control centre, emergency dispatch centre, emergency medical service, rescue service and police were included in the study. Data from four focus group sessions was analysed using thematic analysis.

Findings – The study revealed that the tunnel environment presents specific aspects of how common knowledge was produced related to lifesaving and safety. The themes *structuring mechanisms to reduce uncertainty, managing information for initial priorities, aligning responsibilities without hampering each other's work and adjusting actions to manage distance,* illustrated how common knowledge was produced as crucial aspects to a collaborative response. Organising management sites, grasping and communicating risks, accessing the injury victims, was challenged by the confined environment, physical distances and imbalance in access to information and preparedness activities in tunnel environments.

Originality/value – This study offers new insights of common knowledge, by illustrating a motive perspective on collaborative responses in tunnel incidents. Creating interoperability calls not just for readiness for action and tunnel safety, but also training activities acknowledging different interpretations and motives to further develop tunnel responses.

Keywords Collaboration, Common knowledge, Emergency organisations, Major incident, Road tunnel

Paper type Research paper

Introduction and aim

If a major incident occurs in a road tunnel, the emergency services professionals will enter a challenging work environment (Holgersson *et al.*, 2020; Njå and Svela, 2018). The key operational challenges include difficulties reaching the injured, a lack of and contradictory information, hazardous goods and darkness (Lockey *et al.*, 2005; Tokuda *et al.*, 2006). In addition, smoke and extreme heat can quickly generate a fatal environment for the tunnel users and responders (Li and Ingason, 2018). Incidents around the turn of the millennium revealed shortcomings in tunnel-specific preparedness and response, such as command and communication problems due to multiple scenes and a lack of experience regarding tunnel environments (Holgersson *et al.*, 2020; Njå and Svela, 2018). As tunnels become more complex infrastructure systems, the need to increase preparedness and learn from experiences to ensure effective tunnel responses is evident (Bjelland *et al.*, 2021; Casse and Caroly, 2019).

If a major incident occurs in a road tunnel in Sweden, the rescue service, emergency medical services (EMS), and police will be informed and dispatched to the incident site. In addition, organisations such as the emergency dispatch centre (EDC; in Sweden "SOS Alarm") and road traffic control centre (RTCC; a part of the Swedish Transport Administration), will be involved in the response. In Sweden, these organisations are governed by different organisational domains and management systems (Berlin and Carlström, 2011). Organising crisis management with autonomous organisations, each being responsible for its own tasks, management and initiation of collaboration, makes Sweden an interesting case to study with respect to how collaborative responses are established.

During a major incident, responding organisations work towards shared superordinate goals such as "saving life" and "reducing risk", but with overlaps, interdependencies and differences in sub-goals (Waring *et al.*, 2020). This means that responses bring together professionals with different expectations and motives for their actions (Edwards, 2011). For example, when working on life saving endeavours, a fire fighter might be oriented towards extinguishing a fire or conducting risk assessments, while ambulance personnel focus on providing care. Using expertise in a response is therefore tightly connected with what matters to people in their specialist practice and how motives guide them in the actions they take. In this context, learning how to align each other's complementary skills (Moynihan, 2008) and interpret each other's needs and requirements for collaboration is regarded significant for successful collaborative responses (Wolbers and Boersma, 2013). Nevertheless, collaboration is often challenged by the lack of knowledge and understanding of each other's work processes (Sederholm *et al.*, 2021). Vagueness regarding roles, procedures and information sharing can have a negative impact on the parts of a response that require collaboration (Waring *et al.*, 2020; Hylander *et al.*, 2022).

Professionals from a single organisation cannot solve complex problems such as major road tunnel incidents alone, and this requires collaborative interpretations (Edwards, 2012; Wolbers and Boersma, 2013). This is a process that relies not only on technical and safety issues but also how emergency services coordinate their response and manage to establish their roles and procedures (Holgersson *et al.*, 2020; Hylander *et al.*, 2019). It has been pointed out that current approaches focus on tunnel design and risk analysis, implying a lack of focus on tunnel management and actual response (Alvear *et al.*, 2013; Bjelland *et al.*, 2021). Forums for clarifying terminology and procedures (Hylander *et al.*, 2022) and inter-professional discussions (Casse and Caroly, 2019), has been suggested as a key for improving safety and quality of tunnel responses. There is, however, limited research on how such knowledge is organised and negotiated across organisations. To contribute to this field, the present study will use the concept of "common knowledge", that is, the knowledge built at the boundaries where professionals work together (Edwards, 2011). Common knowledge involves *what* they consider important, namely what facilitates and hinders their work, as well as understanding

the others' perspectives and aligning *motives* for actions (Edwards, 2011). More specifically, this study aims to explore the research question: how is common knowledge built by emergency services organisations in major tunnel incidents?

Conceptual framework: common knowledge

The concept of common knowledge is rooted in socio-cultural learning theories and has been used to explore how collaborative capacity can be developed in inter-professional work (Edwards, 2012), as well as in professional-client relationships (Hopwood and Edwards, 2017). Common knowledge has been pointed out as valuable in work where established solutions are insufficient (Edwards, 2011). Developing common knowledge requires a process of first recognising "*what matters*" to one's own and other organisations when interpreting and responding to a shared problem, and then explicates their own priorities and understands the others', as well as identifying the motives (i.e. why they act and prioritise as they do to reach an outcome) and how differing motives can be aligned. Knowledge of what matters to those with whom one can work helps in understanding their reasons for acting and responding in particular ways (Edwards, 2012). In addition, understanding how motives differ does not imply that differences can be resolved but rather explore what it means for unfolding collaborative work. To this end, Edwards (2012) suggests that "building common knowledge which enables quick transfer or makes translation easy, is an important prerequisite to quick and responsive relational work" (p. 25).

Collaboration is here understood as an emergent process in which different interdependent forms of knowledge, actions and decisions are aligned (Wolbers *et al.*, 2017). However, collaborative capacity does not arise by itself; it is built up by common knowledge which requires effort to align motives, including making one's own expertise explicit and engaging with others' interpretations (Hopwood and Edwards, 2017). For example, information incorporates different professional languages and is often incomplete as a situation is constantly changing (Wolbers and Boersma, 2013). In addition, information must be negotiated and made actionable for its different users to support the collaborative efforts in a response. Here, tensions can also arise when motives are difficult to align due to the knowledge and values embedded in the organisations, which can impact the task at hand (Edwards, 2011). An important note here is that common knowledge does not imply that the motives and what matters must be (come) one and the same to the professionals (Hopwood and Edwards, 2017). Rather, it "involves gaining sufficient insight into purposes and practices of others to enable collaboration" (Edwards, 2011, p. 34).

Methods

Study design, context and participants

For this study, four focus group sessions of 4–4.5 h were carried out online (using Zoom), at four-week intervals, during spring 2021. The rationale for using Zoom was the possibility to gather the participants (safely and effectively) during the Covid-19 pandemic (Oliffe *et al.*, 2021).

Capturing common knowledge is not just a question of knowledge transfer between organisations; it involves a more complex problem-understanding that emerges from the work done together (Hopwood and Edwards, 2017). Focus groups were used as they provide access to participants' own understandings about work, concepts and concerns regarding a tunnel response, as well as how these are elaborated and negotiated in discussion with others (Wilkinson, 2021). The research team initially set out the focus groups to commence discerning participants' experiences and challenges in collaborative road tunnel responses and held a closing session using practical case work. The content and questions for each

session were, however, subsequently built from knowledge and questions from prior sessions. We aimed to alternate experiences and conceptual and practical elements, *in situ* to capture the research questions concerning "what matters" and the participants' motives, from different perspectives and knowledge sources. The research group had two meetings prior to each session to plan the theme, structure and any specific questions. One week in advance, the overarching theme, goal, discussion questions for the session and a summary of bullet points from the previous session were sent out to the participants.

The study was conducted in a region in Sweden with a population of approximately 580,000 and several twin tube tunnels. The organisations included (see Table 1) are typically involved in road tunnel responses. Managers in the organisations were contacted to acquire the names of presumptive participants. Subsequently, the potential participants in each organisation received an e-mail containing information regarding the purpose and overall design of the study. The study participants have extensive work experience within their organisations and are expected to have an on-site operational or tactical management function in a major response. The police department had two different representatives, whereas the rescue service had three. The participants solved these issues internally; hence all representatives are expected to have the same function in a tunnel response. Unfortunately, the police service was unable to participate in session I and IV due to urgent duties.

Data collection

Each session was led by one moderator and one administrator from the research team. The moderator's role was to actively encourage participants to interact with each other (Wilkinson, 2021). Annika Eklund (AE) moderated session I and III; Lina Gyllencreutz (LG)

Session	Subject	Activity	Participants
I	Challenges and prerequisites for effective response in major incidents in tunnel responses	Sharing and creating knowledge, priorities and actions, based on open questions	2 EMS personnel 1 RTCC-operator 2 EDC-operators 1 rescue service personnel
II	Time-effectiveness in tunnel responses: identifying most important tasks and critical moments	Case-based discussion and best-practice during the first 20 min of a response	2 EMS personnel 1 RTCC-operator 2 EDC-operators 1 rescue service personnel 1 police officer
III	Situational awareness in tunnel responses	Identifying practical use of concepts in "Busby Theory of Situational Awareness in MCI"	2 EMS personnel 1 RTCC-operator 2 EDC-operators 1 rescue service personnel 1 police officer
IV	Information management	Practical case: scenario work, collecting, managing and sharing information during the first 20 min of a response	2 EMS personnel 1 RTCC-operator 1 EDC-operator 1 rescue service personnel

Table 1.
Sessions, themes, activities and participants*

Note(s): * EMS (emergency medical services), RTCC (road traffic control center), EDC (emergency dispatch center)

moderated session IV, where also Sofia Karlsson (SK) participated; and session II was moderated by a tunnel expert on the team.

Session I was set out to be an open discussion to discern the participants' understandings of specific challenges and needs for responses in tunnels, as well as illuminate the impact of intra-organisational decisions and actions for saving lives. Based on the data from session I, the first 20 min were found to be crucial for establishing the response (see the Results section), which is why this phase was focused on during session II and IV. Session II was a case discussion based on a full-scale tunnel exercise, in which several of the study participants had taken part. During session II, the response, decisions and actions in the exercise illustrated an example, which allowed the participants to discuss time-critical moments, and organisational needs for effectivity, focussing on the injured victims. Because the participants during session I and II recurrently discussed challenges regarding information management and sharing, session III was set up for the participants to reflect on situational awareness during a tunnel response. This was based on an established model of situational awareness (Busby and Witucki-Brown, 2011), which participants received in advance. Session III started with the moderator introducing the concepts of the model, followed by the participants discussing their reflections on the concepts and how the model can be understood in their work. Session IV was a "digital exercise", where the participants acted in their real functions and focused on collecting, managing and sharing information during the initial response phase. The session started with the research team showing pictures from a tunnel incident and making the emergency calls. After the participants had received and acted on this information, the exercise was interrupted and the participants reflected on the initial information by considering how it was shared and with whom, and how decisions affected their continued work. The exercise then proceeded with a scenario of increased severity. A final round of reflections about information sharing and decisions concluded the session.

Data analysis
Thematic analysis of the interactions was performed inductively, following Braun and Clarke's (2006) framework. Each transcription (overview presented in Table 2) was read through independently by all authors to gain an overall understanding of the material. Secondly, sections pertaining to the aim were marked in colour, guided by a search for where participants articulated or discussed "what matters", i.e. what is important, hinders or facilitates the organisations when interpreting and establishing a collaborative tunnel response; or the motives, i.e. why these aspects matter and arguments supporting their interpretations and actions. This means that both individual and interactive segments of the data were relevant for analysis. These selected segments were extracted and initially coded by the first author. Summaries of overall impressions and initial codes were shared across the team, whereby different perspectives of the data and potential relations between the codes were explored. The data were then sorted into potentially recurring sub-themes and themes covering aspects of common knowledge. All authors then met to review and modify the suggested themes, as well as refine and name the themes and sub-themes and identify a main

Focus group session	Number of transcribed pages
I	43
II	44
III	36
IV	36
In total	159

Table 2.
Overview of data

theme. Quotations are presented in the results section to illustrate the findings and increase trustworthiness.

Ethical considerations

This study was conducted in accordance with the Helsinki Declaration (World Medical Association, 2013) but is exempt from the Swedish Act concerning the Ethical Review of Research involving Humans (SFS 2003:460). The participants received written and oral information regarding the aim of the study; how the data would be handled, analysed and presented; and their right to withdraw from the study at any time without specifying a reason. Written informed consent was obtained from the participants.

Results

The results present the participants' perspectives on how common knowledge is built for interpreting and establishing collaborative responses in road tunnels. The main theme "Striving to ensure safety and save lives while managing interdependencies and distances in tunnels", illustrates a continuous process based on the organisations' different preparedness, access to information sources and experiences from tunnel environments. These aspects were interpreted to matter when attempting to timely save lives, while managing distances and scene safety issues brought by the tunnel environment. The themes s*tructuring mechanisms to reduce uncertainty, managing information for initial priorities, aligning responsibilities without hampering each other's work* and *adjusting actions to manage distance* were aspects found crucial to a collaborative response. These will be further elaborated in Table 3.

Structuring mechanisms to reduce uncertainty

With the motive of striving to reduce uncertainty and increase the predictability of actions during a tunnel incident, the participants discussed structuring mechanisms, such as common tools for organising work. The rescue services and RTCC were understood to have a prominent role in a response with the motive of having tunnel-specific plans, work experience and usually taking the lead.

Using (joint) plans to prepare for actions. The organisations used different tools for initiating their responses. RTCC, the rescue services and the police all used plans and tactics specifically developed and used for tunnel incidents, while the EDC used interview guides,

Main theme	Themes	Sub-themes
Striving to ensure safety and save lives while managing interdependencies and distances in tunnels	Structuring mechanisms to reduce uncertainty	Using (joint) plans to prepare for actions
		Managing the imbalance of tunnel-specific preparedness
	Managing information for initial priorities	Need to know vs need to share
		Establishing communication channels
	Aligning responsibilities without hampering each other's work	Being responsive to current vulnerabilities and needs
		Diverging priorities for effectivity and safety
	Adjusting actions to manage distance	Creating visualisation
		Leading from a distance

Table 3.
Overview of main theme, themes and sub-themes

whereas the EMS had no tunnel specific plans or tactics. Based on experiences from major incidents in other environments, and the tunnel exercise discussed in session II, plans were understood as a support for what matters to the organisations in terms of how to initiate a response, initial prioritisations, mental preparedness and not losing time. As an example, the motives to evacuate tunnel users from the affected tube were clearly aligned across the emergency service organisations. However, there were no clear tactics or agreements for how to manage the unaffected tube or choose an emergency response route.

Having specific plans for tunnel objects was also interpreted by the EMS and EDC as a potentially useful tool for organising initial work. The motive was that plans could help reduce uncertainty in terms of stipulating the type of resources needed and reducing the amount of information to consider in the initial phase of a response. This argument was motivated by their impressions of the other emergency services' structured work in tunnels. For example, the EDC agreed that plans would contribute to efficiency in, e.g. ambulance routing. Another example was that specific plans helped the RTCC to automatically activate measures in the tunnel, such as signs and lowered barriers. These actions, in turn, required knowledge about what matters to the organisations and tunnel users to create a safe environment:

> Plans are activated depending on how I assess the situation . . . it helps me, I do not have to remember to put it on these signs, oh, I must get these crosses . . . it is built-in to some extent. There are of course restrictions where we must solve it manually. (RTCC, FG I)

The plans needed, however, to be combined with professionals' assessments due to the specific tunnel (e.g. construction, systems), situation (e.g. what time of the day), continuous assessments of changes and tunnel user behaviour (e.g. if they chose to stay in their car instead of evacuating). Further, the participants asked for joint plans, terminology and management structures for tunnel responses. The motive was to clarify what to expect from the collaborating organisations in terms of initially establishing their work and decisions. However, an ambiguity emerged here about the construction and use of joint plans, which was related both to the uniqueness of each tunnel, as well as the intra-organisational structures:

> It would be brilliant if we could reach all the way to common tactics and action planning and everything. I think it is difficult to get all the way because we think very differently, especially the police, and we think very differently when it comes to tactics and plans. But at least create a common picture of how a tunnel event like this could be implemented and organised. (Rescue service, FG I)

Managing the imbalance of tunnel-specific preparedness. Another structuring mechanism was the organisations' established ways of organising responses. The Swedish crisis management system stipulates that emergency services organisations are equal actors, and that management should be organised in collaboration (Berlin and Carlström, 2011). Hence, the rescue service interpreted their function as prominent in a tunnel incident, namely to initiate collaboration, prevent the incident from escalating and create a safe environment. The participants from the EMS and police also expressed that how they established their response was largely dependent on the rescue service taking the lead for initial decisions and assessments. The motive was that the rescue service usually arrived first at the incident site, and they were usually more experienced in managing tunnel responses. However, the EMS found it difficult to establish a safe workspace if they arrived first at a tunnel incident or the rescue services were not dispatched. This could cause hesitation for the EMS in terms of their decision of whether to enter the tunnel:

> My thoughts are partly on my own work environment, if we arrive first to the scene. When we get to the tunnel entrance, the first decision you need to make is probably whether to go into the tunnel or not. (EMS, FG IV)

The police services interpreted their role to work at the disposal of the rescue services' interpretations and needs:

> If you don't have the information yourself, you ask those who know, and I assume that the rescue service knows in these situations . . . in these events, the police work quite a lot on behalf of the rescue service (Police, FG III)

The rescue service and RTCC were also understood to have the mandate and best knowledge about the tunnel as an object. They are both central actors during the initial phases of a tunnel projection and construction, as well as any evaluations after major incidents. In addition, the high frequency of daily collaboration during and following road incidents motivated them more generally for further development of joint work. Their plans and decisions were also clearly interdependent, which was motivated by their distributed responsibilities. For example, the RTCC performed many tasks based on specific plans, such as activating signs and ventilation. However, the strength of the ventilation was decided by the rescue service incident commander.

Managing information for initial priorities
To gather, examine and share information was discussed as particularly important by all involved participants. However, information that mattered also diverged based on responsibilities and expectations in the organisations in tunnel responses. With the motive of creating a timely response, the initial information management was to gather and share relevant content and establish communication channels. The latter mattered specifically in tunnel environments where much information was shared on the radio due to distances and different attack routes.

Need to know vs need to share. The initial report from the first arriving emergency service at the incident site was deemed crucial and mattered for all involved organisations. Much effort was put into identifying who had the most updated and relevant information – and could manage an intense information flow with the motive of establishing a timely response. This was a process of identifying what and how information could contribute to the intra-organisational response and safety assessments, as well as how to adjust the information to be relevant to the other organisations. The latter process required knowledge about what matters across organisations:

> I think that is a very important thing in this first initial report. That it contains information that is . . . not only for our own organisation but that we can provide information for decision-making to the other organisations as well so that they can make decisions about their own resource structure. (EMS, FG III)

However, what mattered here diverged in part due to the organisation's different primary responsibilities in a tunnel response. The type of incident, and whether dangerous goods were involved, mattered to the RTCC and rescue services, with the motives of safety and decisions regarding whether the tunnel users should evacuate or stay. On the other hand, the number of injured and type of injuries mattered for the EDC and EMS, with the motives of dispatching the right type and number of resources.

Managing information was discussed as an on-going process throughout a response, yet the initial approximately 20 min was particularly important and challenging for establishing the response. The RTCC and EDC were central actors for gathering and disseminating information about the incident and tunnel user behaviours in the initial phase, since they were "the eyes" on site via the tunnel cameras and the callers in the tunnel. What matters to the EDC is to obtain correct information from the callers and to share that information as quickly as possible, with the motive of dispatching the right type and number of resources to the right place. This process required, in turn, an informed understanding of what mattered for each of the organisations that would be dispatched to work in the tunnel:

> Our most important task is to create an operating picture as early as possible based on the calls that come in. Then to communicate this operating picture to all collaboration partners in the response as soon as possible, and above all to inform all participating organisations so that you can rescue the third party in the best possible way . . . our part is probably mainly the initial stage. To establish an organisation to relieve, then it ends up with each organisation doing what they are there to do (EDC, FG I)

Establishing communication channels. The sheer number of involved organisations in major tunnel incidents makes the process of managing information complex. The emergency service organisations used different procedures for communication during the initial phase of a response: the rescue services used a shared information channel, whereas the EMS and the police used intra-organisational channels. The rescue service was here interpreted as "being in charge" and taking the lead to collect, interpret and disseminate information. The motive was primarily historical traditions of how initial communication was established. However, this routine brought challenges for the rescue services to manage simultaneously intra-organisational communication in tunnel responses where communication channels were expected to be overloaded, but also for the other organisations to share information in the joint systems:

> For many years we were never on RAPS [joint communication channel] even though we have had the joint system for a very long time. And when we were going to start using it, it was like "you can listen, but you must not disturb them" . . . so we got no clear routine for how we should behave (RTCC, FG I)

Although this way of establishing information channels was not tunnel specific, it could have specific implications in a tunnel, since information about the position of the incident and directions mattered for the organisations to access the tunnel most effectively. For example, information about positioning and traffic flow mattered for the EDC when dispatching the ambulances, with the motive of being able to choose the optimal response route and allocate resources.

Aligning responsibilities without hampering each other's work
This theme illustrated that the overall tunnel response was influenced by how each organisation interpreted their tasks, based on what mattered for them to be able to pursue their responsibilities. However, these interpretations also illustrated the interdependencies for life-saving actions and providing a safe environment for tunnel-users and on-site staff, where aligning resources and decision making mattered.

Being responsive to current vulnerabilities and needs. The EMS expressed that a major tunnel incident would exceed their capacity in terms of the ability to provide care and transport for the injured. This vulnerability meant that support from other organisations mattered for the EMS response, with the motive of lifesaving measures and evacuation from the affected tunnel tube:

> The emergency medical services will have a rather extreme lack of resources. The investigations, and simulations have demonstrated . . . that the first half hour, at least the first 20 minutes, there will be an extreme lack of resources for healthcare and for us to be able to . . . for these patients to receive treatment, we must work together (EMS, FG I)

What matters here was for the organisations to be responsive to the current needs, namely the EMS asking for support and the other organisations taking initiatives to actively contribute to lifesaving. The rescue service typically had resources on site to support EMS, but their health care measures were dependent on the medical assessments.

The rescue services capacity to make initial risk assessments on site (i.e. spread of fire and smoke, impact on the construction) mattered for the other organisations further actions in a tunnel response. However, it mattered that each organisation made its own risk assessment and communicated such internal decisions further. The motive was that such intra-

organisational decisions could impact the overall response as well as the tunnel users' behaviours and safety. For example, the request for and cancellation of traffic stop in a tunnel could come from different organisations with different motives and timelines for work:

> Rescue services: If we have requested a traffic stop, the police and emergency medical services may have done the same. Each actor must take back their own traffic stop and do this in dialogue at the management site. The rescue service says that "we are done with ours, we can break our traffic stop", but the police may still need theirs, the RTCC may need theirs . . . so collaboration is important, so you have a clear picture of what is going on, continuing and what to interrupt.

> EMS: I can draw the parallel with the railway, this responsibility that there are no civilians on the railway . . . it also feels like a common responsibility, just as it is in the tunnel. (FG III)

Diverging priorities for effectivity and safety. Another central aspect of this theme was the differences in what mattered to the organisations regarding the decision of whether to close the tunnel, or close one of both tubes. The initiative to close the tunnel completely could only be taken by the rescue service officer in charge. This decision, and which plan was activated by the RTCC, mattered for the subsequent work of all involved organisations. This quote illustrated the dilemma for the RTCC when navigating between the motives of rapid access for the rescue services and safety for the tunnel users:

> A difficult assessment for us is to close a tunnel tube, since it means that you prevent . . . the rescue personnel to arrive perhaps. (. . .) The challenges are that it is in a tunnel, it is more difficult . . . if I close this tube, will I disturb the rescue services that are on the way? Should I wait until they are on site and then close? It has to do with not making it difficult for them to get there . . . and then that if there is a traffic stop, people are not so very inclined to respect that either. (RTCC, FG I)

Whether to close the tunnel was not only a question of what to do, but also when to do it. These decisions could also delay the EMS work. The EMS wanted to close both tubes to use the "unaffected" tube, not only in case of fire, but regardless of the type of event. The motives were an expected lack of resources for transporting injured, rapid access to the seriously injured and the provision of care on site. The issue of closing the tunnel difficulties in aligning the organisations' diverging motives regarding safety and providing care, which was illustrated in this dialogue:

> EMS: Our needs look the same, even as in the type of event that occurred at the Marieholm tunnel, as if it was a fire. The question is if we get there?

> RTCC: You mean that we would close the tunnel also without fire?

> EMS: Exactly, if we have a major tunnel incident.

> RTCC: A major incident would lead to closing as well. The thing is that there may be a delay, and in the beginning you may just close the affected tube. (. . .) We may need your help in assessing that . . . that you say 'close the other tube as well'. Otherwise, the effect will be that we close the unaffected tube as well, when people start moving and when they sense that now they will evacuate the tunnel, they will go out into the unaffected tube, which lead to us closing it as well. We always think safety, safety. (FG 1)

Another aspect that mattered for the tunnel closure was that some of the tunnels are not easy to close quickly or have outdated plans of action. Sometimes the rescue services arrived at the incident site before the RTCC effectuated the tunnel closure. Here, the response organisations motive of time effectiveness to quickly reach the injured could constitute a safety issue (e.g. not knowing the fire's direction).

Adjusting actions to manage distance

The tunnel environment meant that the organisations had to find strategies to adjust their response to distances. Not being able to visualise the site was also complicated as every

tunnel had a unique construction, which meant that object-specific knowledge and capacity to adjust their actions mattered.

Creating visualisation. The organisations had access to different sources of information about the type of incident and positioning. For example, only the RTCC and rescue services had access to pictures from inside the tunnel, while the EDC had information from tunnel users or actual injured persons (via the callers). These sources were interpreted as providing the best possible information for establishing the initial shared operating picture. This, in turn, made the on-site rescue organisations highly dependent on the RTCC's and EDC's initial assessments; information gathering and dissemination; positioning of the incident; and driving directions for safety assessments and resource allocation. In other words, this process relied on the capacity of the RTCC and EDC to identify what matters for the other organisations when creating a shared operating picture.

The EMS and EDC did not have access to pictures from the tunnel due to Swedish law (Camera Surveillance law, 2018:1200). However, the EMS and EDC argued that access to pictures could provide them with the most updated visual picture and reduce the need for extensive clarification (i.e. ask the caller fewer questions). The motive here was to save time to access the injured and assess safety. The participants emphasised that rather than everyone having access to the same sources, the importance should be placed on sharing the information across organisations:

> The most important tasks we have are to describe this environment, the work situation at the site, in the best way possible. If it is the road traffic control centre, emergency dispatch centre or rescue services that can give us that info . . . it is very valuable to give us access to the patient. (EMS, FG I)

> There we have a collaboration. We have a shared operational picture, we do not have to have the pictures ourselves, only someone describing the context. (Police, FG III)

Many of the challenges related to physical distance during a tunnel response were perceived to be similar to those of other types of major incidents spread over larger areas. However, not being able to see the incident site in tunnel environments could limit their access to information that matters when establishing a safe worksite:

> EMSa: It can be more difficult with the risk assessment; in particular, it can take longer to see which route to take.

> EMSb: Perhaps it is more difficult to get this initial feeling for the incident that you had when you drove towards your bus that was across the ditch. There you maybe get more visual info. (FG II)

Leading from a distance. Not being able to visualise the incident scene could also imply challenges for establishing management. One challenge was to find each other at the site, since a tunnel required collaboration at different physical sites, and the organisations used partly different systems and terminology for management functions. The distance also meant that managers could never be as updated as the staff onsite. Since conditions change every minute, continuous updates from staff arriving and working in the tunnel mattered to those in leading positions, with the motive of establishing logistics and assessing workload.

Furthermore, the distance also limited possibilities to use sensory impressions to interpret the incident (such as seeing the scene, heat and smell). Such sensory input mattered for an initial understanding of an incident and provides a foundation for risk assessment. In addition, the distance means the incident commanders have a reduced opportunity to engage in face-to-face communication and instead had to work through communication systems:

> You cannot talk mouth to mouth, between four eyes, it's a difficulty to take it by radio or telephone. Now it is often facilitated in road tunnels, you have a good overview from the pictures at the tunnel management site . . . but you cannot wedge down to create your own image and feeling of the incident site as in the open air (Rescue service, FG I)

Discussion

This study illustrated how common knowledge, i.e. what matters and why, is built when collaboratively responding to major tunnel incidents. A prominent finding was that many uncertainties in major incidents might be even more challenging for collaboration in tunnel environments. Knowledge that matters, i.e. organising management sites, grasping and communicating risks, accessing the injury victims are there challenged by the confined environment, physical distances and safety issues. The challenges to align motives could be explained from an imbalance between the organisations' access to information, specific preparation tools for tunnels and expectations to provide safety. These findings support prior tunnel research that emphasises the value to articulate and question prior knowledge across organisations (Njå and Svela, 2018; Casse and Caroly, 2019). Yet, what mattered in complex tunnel responses can also be recognised from other environments. Examples include the importance of information sharing and joint terminology with the motive of tailoring a response (Waring *et al.*, 2020; Hylander *et al.*, 2022), and the challenges of leading from a distance (Hugelius *et al.*, 2021). In addition, if managers could not be present at the site, many of the impressions and complexities that matter for situational awareness and safety may be overlooked or delayed. Although there are similarities between for example evacuation from buildings and tunnels, Fridolf *et al.* (2013) argue that a major difference is often the longer distance to emergency exits. This could inhibit emergency personnel and makes rescue operations more complex. Cars and other vehicles may also obstruct the flow of people in the tunnel and the access to the incident site.

Making initial information actionable

This study demonstrates that the need to quickly grasp the position, perception of safety and resource utilisation mattered to all organisations when initially establishing their responses. This process has previously been described to require an understanding of others' needs and the adequacy of resources (Sederholm *et al.*, 2021; Edwards, 2011). Due to the distance, the surveillance camera pictures from the tunnel that were made available to the RTCC, and the information that the EDC received from the caller, were specifically important for the subsequent response. Many studies recall the difficulties of creating clarity and a shared understanding based on the disparate, uncertain and large amount of information initially available (Hugelius *et al.*, 2021; Stjerna Doohan *et al.*, 2019; Sederholm *et al.*, 2021). Consequently, the distances in tunnel responses will also reduce the possibilities for face-to-face communication and lead to an increased information flow on the radio, suggesting that the capacity to manage several channels and an intense information flow will matter the most.

The results illustrated the importance of the initial approximal 20 min of a tunnel response, highlighting the important function of the RTCC and EDC as providers of information. This, in turn, was here found to depend on their capacity to understand what matters for the on-site organisations. This process was described by Wolbers and Boersma (2013) as making knowledge actionable to "support the connection between the information itself and the way information in seen as input for action" (p. 196); that is, not only making information available, but also exchange information with the motive of creating a shared understanding. The central function of the RTCC and EDC points to the importance of including them in preparation activities to establish common knowledge as a foundation for collaborative responses.

The ambiguity of plans in dynamic settings

Further, the results illustrate that joint plans and concepts across organisations matter as tools for establishing the initial response. The motives for using joint plans and unified concepts were to reduce uncertainties related to the tunnel environment and lack of work experience in tunnels,

but also to clarify expectations of how each organisation established their response. The demand for joint concepts and structures has been highlighted as foundations for collaboration in the crisis management literature (Hylander *et al.*, 2022; Sederholm *et al.*, 2021). Hence, in a working context where these foundations are not in place, the organisations tend to arrange their work based on other knowledge sources that matter, such as personal experiences and routines. In addition, in each response, flexibility and specific knowledge mattered when creating a shared operating picture with the motive that each tunnel, incident and resource availability being unique. This ambivalence between plans and adaptability reflected what Heino *et al.* propose, namely that "what is most likely to hamper an effective response to novel situations are rigid thought patterns" (2021, p. 6). Ensuring capacity based on plans and defined responsibilities may be a first step for producing common knowledge, but stopping there could also mean the organisations ignore new solutions.

Tensions in motives caused by an imbalance of knowledge and resources
The results of this study revealed tensions in motives regarding the decision of whether to close the tunnel. This tension illustrated the organisations' diverging interpretations of what matters the most for establishing a collaborative response. This largely originated from the organisations' different purposes and knowledge bases; knowledge about the tunnel as an object, and knowledge about providing care and evacuating injury victims. As Hedegaard (2014) points out, to understand the links of institutional demands and professional motives, it is essential to follow how informants orient themselves to the demands of their practices. The answer to the dilemma of which motive should govern the decision of whether to close the tunnel is not self-evident, yet it will have consequences for the response. Such decisions for actions should also be taken from knowledge about what it means to one's own and the collaborating organisations' (here, also the tunnel users) action and safety (Wolbers and Boersma, 2013). Here Edwards (2011) suggests an "engagement with the knowledge that underpins one's own specialist practice, as well as a capacity to recognise and respond to what others might offer" (p. 33). As pointed out in previous tunnel research, the rescue services have knowledge of and training for risk objects and facilities (such as tunnels in their catchment area), which the EMS personnel lacks and which could cause uncertainty (Stjerna Doohan *et al.*, 2019). The EMS also displayed a vulnerability regarding available resources in major incidents, which often made them dependent on the rescue services for evacuation and lifesaving measures. Importantly, rather than a lack of knowledge about each other's procedures, that research often point to (see e.g. Sederholm *et al.*, 2021), this study found an imbalance between the organisation regarding access to what matters, such as rescue services and RTCC having specific plans for tunnels and access to cameras. Such imbalance could promote engaging with what has been framed as parallel or sequential collaboration (Berlin and Carlström, 2011). This finding calls for a continuing need to discern how motives can be aligned with a timely medical approach in tunnel incidents.

Furthermore, the inherent complexity of both the tunnel environment and organisations having diverged primary responsibilities illustrated the ambiguity of common knowledge. The results indicate that the rescue services are considered to have a prominent role due to their history of establishing and leading responses, specific tunnel alarm plans, close collaboration with RTCC and being involved in tunnel planning and construction. They also provide initial information and risk assessments when establishing their tunnel responses. The significance of providing a safe scene could further cause hesitation for the other organisations to take actions in a tunnel incident without the rescue services on site. Hesitation caused by organisations having knowledge primarily about routines and not the situation has been reported elsewhere by Danielsson (2016), suggesting exercises to train the ability to "make use of other profession's knowledge and thoughts about the situation, rather

than focusing too much on how to handle and 'act' in the situation" (p. 44). Here, we would argue that working on common knowledge can support the organisations to identify potential vulnerabilities and expectations concerning organisational responsibilities embedded in traditions – not only to become familiar with each other's knowledge but to align different knowledge.

Methodological considerations

An evident limitation of the study came from the difficulties to organise physical meetings due to the Covid-19 pandemic. The focus groups were conducted using Zoom; online procedures may have influenced that the sharing of experiences and nuances might have been lost (Oliffe *et al.*, 2021).

The study includes only road tunnels, meaning the results might not be transferrable to, e.g. rail tunnels, which might pose other challenges. Another possible drawback might be the transferability of the results to countries where crisis management systems and infrastructure ownership is organised in another way. Still, the results illustrate how common knowledge is built for sharing information for the interpretation and establishment of a collaborative response, thus adjusting management and actions may well be transferred to countries and similarly enclosed environments. Studies often only include the on-site response organisations, but here RTCC and the EDC also participated, which provides a more inclusive understanding of common knowledge from alarm to completion. However, the police failed to participate in two sessions, which means the data presented limited views of their perspectives in the analysis.

A limitation regarding validity could, however, be that the same participants were gathered for the four focus groups, using different designs and approaches, which allowed them to some extent to adjust to what they found important. Still, the aim to explore common knowledge from diverging perspectives guided the choices of questions, materials and design for each focus group. Including both discussions and practical exercises could strengthen the internal validity of the findings (e.g. reduce possible discrepancies between what they say they do and what they actually do).

Conclusions

This study illustrated how common knowledge is built to adjust responses due to distances and aligned motives, where primary responsibilities and access to plans and information diverge in road tunnel incidents. The distances and possible difficulties to enter the incident site in the tunnel pointed to the important role of the RTCC and EDC to initially share information and create visualisation, based on their knowledge about what matters to the organisations working on-site. In addition, the study further illustrated differences in preparedness activities and expectations across the organisations, especially regarding safety issues, where the rescue service was given a prominent role. This was reflected in, for example, decisions to close the tunnel or not in case of an incident, which challenged the organisations in aligning motives while navigating around different responsibilities and interpretations to save lives.

The findings contribute with a motive orientation to the continuous discussion of developing collaboration while sharing and aligning knowledge in practice. Moreover, by exploring the concept of common knowledge in a different context than where it has been used previously, this study indicated a time-dimension of the concept, since the initial response phase was found to be particularly important in joint tunnel responses. However, rather than a final statement, this study was intended as a starting point for illuminating common knowledge as a learning perspective on collaborative responses. It is here argued that working on common knowledge can contribute to a refined understanding of collaboration for timely and collaborative responses in tunnel incidents. This study was based on joint forums supporting participants to share and discuss such as

procedures, priorities and experiences, which has been suggested in previous tunnel research. Still, as it takes effort and time to develop common knowledge, further studies are needed to explore methods that support this development and the possible impact on organisational actions.

The future will require knowledge to support the ability to act in even more complex tunnels, and various vehicles and fuel systems. As this calls for more than just readiness for action and tunnel safety issues, we also suggest a further development of providing possibilities to question established ways of responding and to make use of other professionals' knowledge as key areas of knowledge development.

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