Disposal of Emergency Telephones in Swedish Railway Tunnels: Practical application of the CSM RA-regulation

Karl Fridolf[a] & Johan Lundin[b]
[a]The Swedish Transport Administration
Box 366, SE-201 23 Malmö, Sweden,
E-mail: karl.fridolf@trafikverket.se
[b]Brandskyddslaget AB, Stockholm, Sweden

ABSTRACT
In this paper, the safety implications of removing emergency telephones from railway tunnels owned by the Swedish Transport Administration is assessed. Employing the European common safety method for risk evaluation and assessment (CSM RA), it involves risk and expert analysis of various tunnel designs and communication equipment. The study finds that emergency telephones mainly serve as a redundant system, with other wireless options like GSM-R providing similar functions. The conclusion is that telephones can be safely removed, provided that for tunnels longer than 1 km, adequate radio communication and fixed connections are established in safe areas. This approach offers a balanced solution for maintaining safety while managing costs and infrastructure efficiency.

KEYWORDS: emergency telephones, common safety methods, CSM RA, removal, disposing, tunnel safety

INTRODUCTION
In order to prevent and/or mitigate railway tunnel-incident scenarios, such as collisions, derailments, and fires, technical and administrative measures are typically introduced as part of a tunnel safety concept. Providing means for emergency communication in general, and emergency telephones in particular, is an example of a technical measure, which historically has been used to allow people in a tunnel to communicate with the control center of a tunnel infrastructure manager. Consequently, emergency telephones are today installed in approximately 70 of the Swedish Transport Administration's (Trafikverket's) railway tunnels. Facing large costs related to maintenance and reinvestments as part of the life cycle management of these emergency telephones, the question was raised whether or not they could be removed. As such action is a change to the railway system in Sweden, regulation (EU) no 402/2013 shall be applied. The regulation establishes a common safety method (CSM) for risk evaluation and assessment (RA), and in this paper, the practical application of the so called CSM RA-regulation to assess the impact of the proposed change on safety levels is presented. This paper gives a brief overview of the work conducted that is presented in a project report (TRV 2022/102615).

Purpose and objectives
The primary purpose of the work presented in this paper was to conduct a comprehensive analysis of the safety implications associated with the decommissioning of emergency telephone systems within railway tunnels owned by Trafikverket. The objective was to evaluate the impact of removing these systems on overall safety measures and communication protocols within these tunnels. Through meticulous examination and risk assessment, this research aimed to identify potential challenges, risks, and alternative communication measures post the removal of emergency telephone systems. By understanding the consequences of this action, the study sought to propose viable strategies and guidelines to ensure the maintenance or enhancement of safety standards within railway tunnels, aligning with EU directives while accommodating the evolving technological landscape and safety protocols.

Scope

The proposed change was expected to primarily impact on-board staff and passenger safety. This is because emergency telephones in tunnels are unlikely to be utilized by rescue personnel during an emergency response. Additionally, operations and maintenance staff are not expected to use emergency telephones as they rely on other communication systems both during regular operation and in emergency situations, primarily GSM-R. However, the safety of maintenance staff needs assessment based on the facility's status and the nature of their work.

The risk identification was mainly focused on how on-board staff and passengers are affected, while the consequences of removing emergency telephones for operation and maintenance personnel's communication with Trafikverket’s traffic control center (TTCC) was not thoroughly examined. It is essential to note that although the focus was limited to the implications for on-board staff and passengers, the risk analysis encompassed the entire sequence of events from cause to effect, including alarm chains and the TTCC’s actions.

An emergency telephone itself is not expected to increase the risk of an initial accident. Its primary purpose is to mitigate damages and consequences after an accident has occurred. Therefore, the activities to identify risk sources, especially during the below-mentioned risk workshop, focused on describing how various accident scenarios in tunnels unfold and how on-board staff and passengers are expected to act during these events.

Special attention was given to the use of different communication systems (regardless of type) and the anticipated severity of damage based on various actors' actions during an accident. The method resembles a combination of 'what-if' scenarios and sensitivity analysis, where accident scenarios were developed, focusing on one communication system at a time.

A collision between trains in a single-track tunnel without derailment was assessed as highly unlikely and not specific to tunnels. Such an event could occur anywhere in the railway system with severe consequences, but several safety systems are already in place to minimize the risk, such as signaling systems and traffic control. Therefore, this event was not further explored in the subsequent work.

DEFINING THE SYSTEM UNDER ASSESSMENT

As a first step, the system under assessment was defined and described in a so called system definition. The system was defined to include Trafikverket’s railway tunnels (belonging to subsystem infrastructure) and all measures that has been taken to enable emergency communication with TTCC. A distinction was made between the following types of tunnels equipped with emergency telephones:

A. Single-track tunnels with safe areas[1] (such as service tunnels and service shafts)
B. Single-track tunnels without safe areas
C. Double-track tunnels with safe areas
D. Double-track tunnel without safe areas
E. One of two (or more) fire-separated single-track tunnels with cross-passages
F. One of two (or more) single-track tunnels that are not fire-separated

The tunnels were categorized based on length and system design, impacting the requisite communication infrastructure. Tunnels shorter than 1 km exhibited relatively simpler communication needs compared to longer counterparts.

DECIDING THE SIGNIFICANCE OF THE PROPOSED CHANGE

It was early established that the proposed change had an impact on safety. Hence, the significance of

[1] a safe area is defined as a temporary survivable space for passengers and staff to find refuge after they have evacuated from a train.

the change had to be assessed by expert judgement. A group of experts representing individuals with knowledge and experience within of tunnel safety, CSM RA, radio and telecommunications systems, facility monitoring and work as a train driver assessed the significance based on the following criteria: failure consequence; novelty used in implementing the change; complexity of the change; monitoring; reversibility; additionality. It was unanimously decided to consider the proposed change as significant. Consequently, the risk management process described in the CSM RA-regulation had to be applied (TRV 2022/102615).

IDENTIFICATION OF RISK SOURCES AND SCENARIO REPRESENTATION

The risk analysis work included examining and analyzing how the risk in existing tunnels where emergency telephones are part of the safety concept is affected if they are disposed, and assessing whether the remaining risk is acceptable. Prior to the risk assessment, the system design for the facility inventory was categorized and specified. This constituted an important starting point for structuring the risk analysis. The risk assessment, in broad terms, involved the following activities:

1. Identifying sources of risk and risk scenarios, including a pre-study, during a risk workshop and in subsequent meetings with individuals with knowledge about experience from train driving.
2. Estimating relevant sources of risk and risk scenarios using a semi-quantitative risk estimation method.
3. Evaluating risks and applying code of practices as a principle for risk acceptance.

Since all risk sources are controlled through code of practice, the risk management process was limited to the following:

a) Identification of risk sources
b) Recording the use of code of practice in the hazard record
c) Documentation of the application of the risk management process
d) Independent assessment

The risk analysis method initially involved the identification and analysis of accident scenarios using a functional communication system to determine the importance of contacting TTCC in various types of accidents, facilitated by the emergency telephone. The following step in the assessment was to consider the emergency telephone in comparison to other communication methods.

The risk assessment commenced with a workshop involving the same participants as the significance assessment. Efforts were made to contact the chairperson of the Railway Companies' Safety Focus Group, but despite an initial response, there was no further reply regarding invitations to coordination meetings. Therefore, the initial risk workshop was followed up with a meeting involving the Swedish Traffic Administration employees previously working as train drivers to ensure the accurate documentation of identified risks, accident scenarios, and actions.

Types of Accidents

The process of identifying sources of risk was based on studying the types of accidents that can occur in a tunnel and that are specific to tunnel environments according to regulation (EU) no. 1303/2014 concerning the technical specification of interoperability relating to safety in railway tunnels (TSI SRT). These include:

- Fire (combination of heat, flames, and smoke)
    - Fire occurring on board trains
    - Fire occurring in traffic or ancillary spaces (such as the tunnel or a utility space in a service tunnel)
    - Explosion followed by fire

- Release of toxic smoke or gas
- Collision
- Derailment
- Spontaneous evacuation

During the risk workshop and the subsequent meeting conducted with former train drivers, participants were given the opportunity to supplement this list. However, no such addition was deemed necessary at that time.

Identification of Relevant Risk Sources and Scenarios

In the risk assessment, the railway tunnel was viewed as a complex facility with numerous interdependencies among its various components and systems, especially during emergencies and different types of accidents and their consequences. An accident might result from multiple interacting hazards, leading to several similar consequences. Due to the lack of a practical method to identify relevant risk sources in this complexity, a customized risk identification method was devised. The objective was to pinpoint which accident scenarios needed closer examination to assess the risk associated with the proposed change, particularly where an emergency telephone reduces risk. A traditional risk model (Figure 1) was adapted and adjusted (Figure 2) to analyze the effect of emergency telephones during tunnel-specific accidents.

According to the CSM RA-regulation, the identification of risk sources only needs to be detailed enough to determine when safety measures can control the risks. In addition, selecting the risk acceptance principle is challenging before an initial risk identification has been made, making the work iterative. The assessment was that a structured accident development according to the adapted model meets the requirements. Code of practice was deemed applicable as the risk assessment principle for all identified risks within the scope of this work.

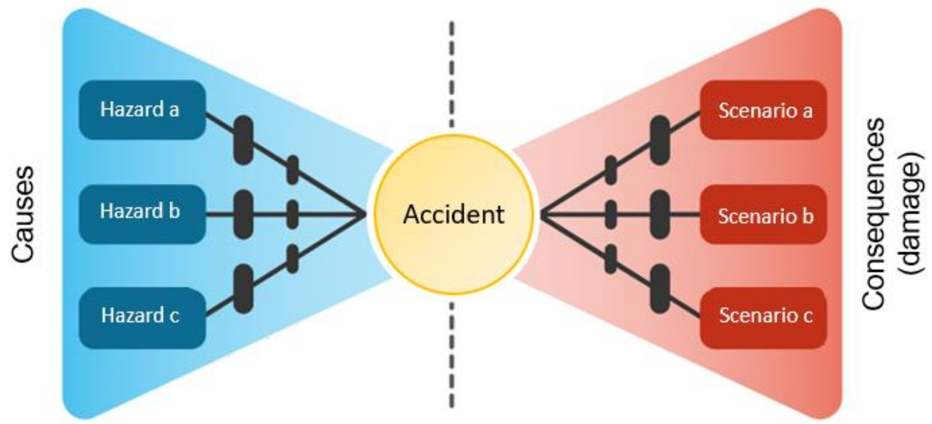

Figure 1. Traditional model for dividing and describing risk.

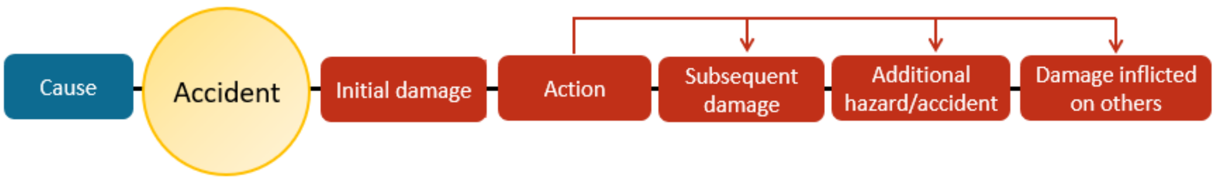

Figure 2. Adapted model for risk in the current application.

Below is a concise description of the different components in the adapted model:

- Cause: The causes of accidents in a tunnel can be diverse.
- Accident: Represented by tunnel-specific accidents.

- Initial damage: Harm to passengers and on-board staff during the initial phase of the accident.
- Actions: Expected actions of on-board staff and passengers during the accident.
- Subsequent damage: Harm occurring later during the accident sequence due to the initial incident, for instance, the spread of smoke in the tunnel as a fire develops.
- Additional hazard/accident: Beyond the initial incident, various additional accidents can affect individuals on the train or during evacuation, such as fallen power lines, traffic in the tunnel on other tracks, etc.
- Damage inflicted on others: Initially affecting individuals on-board the affected train, the consequences can extend to other individuals, including people on other trains or maintenance staff.

Scenarios specific to tunnel events are described using an adapted model (see *Figure 2*). Participants in the risk workshop and train driver representatives contributed to describing various actors' actions after the initial damage.

Based on the accident sequence in *Figure 2*, each communication system was analyzed separately (GSM-R, public mobile phones, and emergency telephones), in an assessment of how on-board staff and passengers can be expected to react depending on the available communication systems in a given accident scenario. During the risk workshop, the model followed a repetition of the following points:

1. What could be the cause this tunnel-specific accident?
2. What can be expected to be the initial damage?
3. How would on-board staff and passengers act if they only had access to this communication system (GSM-R, public mobile phones, or emergency telephones)?
4. What consequences and additional dangers/accidents can be identified and how does this impact other individuals?

The following uncertainties in the accident sequence have been identified and considered in the risk analysis:

- Actors' actions and regulatory compliance
- Functionality of communication systems
- Factors influencing the scale of the accident, such as fire and smoke spread
- Location of the accident in the tunnel
- Tunnel design

These uncertainties were important input values in the construction and structuring of the risk analysis, from risk identification, division of the accident sequences into different parts, to the presentation of results. During the risk workshop, it was observed that behaviour can be expected to be influenced by several factors, which is expected to be similar under different conditions. This information constitutes input values for the risk estimation.

Causes
Causes of accidents, i.e. hazards, encompass both the reasons for the original incident and additional hazards and accidents that can threaten individuals in a tunnel. These causes were mapped during the risk workshop.

Type of Damage in Different Stages of the Accident Sequence
A hazard record for various tunnel accidents and their impact due to delayed alarm to TTCC was documented and constituted input to risk index calculations. In summary:

1. Additional accidents may occur after the evacuation starts, except in track incidents in a double-track tunnel when a passing train collides with a still standing. This assumes a lack of alarm to TTCC.
2. Alarms to TTCC reduce the dangers for evacuating individuals, especially in the case of electrical accidents involving fallen power lines or train collisions with individuals.
3. Individuals within the tunnel can evade the effects of the accident through alerts from GSM-R or TTCC via public GSM.
4. Alarms to TTCC can reduce subsequent injuries for passengers and facilitate faster emergency services response. The effect is considered to be small because the time it takes for the emergency services to reach the accident site is expected to be long in relation to the progression of the accident. The tunnel safety concept relies on the self-evacuation principle, meaning individuals in the tunnel should be able to rescue themselves without assistance from emergency services, which has been the standard even before the introduction of the TSI SRT.

Actions of Train Drivers, On-board Staff, and Passengers
An overview of how on-board staff and passengers can be expected to act given their access to (only) a specific communication system (GSM-R, public mobile phones, or emergency telephones) is presented briefly in Table 1. The presentation also outlines actions in the absence of communication systems.

Significance of System Design
The tunnel design outlined in the introduction of the paper impacts the development of an accident, extent of damage, and the effectiveness of emergency communication. Below is an overview of the differences in types and sizes of damage at different stages:

1. The cause of the accident influences the extent of the initial damage. A fire onboard a train can spread at different rates, influenced by where in the train it starts.
2. Initial damage is usually similar, except in double tracks involving multiple train sets. In such cases, more individuals may be affected, potentially increasing the damage's size.
3. Subsequent damages vary depending on the tunnel's design. Some designs allow protection against fire or toxic gas through evacuation spaces, while double tracks may involve more trains and larger damage.
4. Tunnel design impacts the risk of injuries during evacuation, such as falls or electric shocks, especially during train evacuation.
5. In single-track tunnels, the extent of damage partly depends on the distance to eemergency exits, varying based on the accident's location within the tunnel.
6. In double-track tunnels, damages are similar to single-track tunnels but pose risks of additional injuries such as train collisions or being struck by trains.
7. In facilities with multiple tunnel tubes, there's still a risk of being struck by trains or sustaining injuries during evacuation due to traffic, fire, or abrupt braking during evacuation.

Table 1. Description of Expected Actions Following an Accident by Train drivers/On-board staff and Passengers Based on Analysis in the Risk Workshop and Subsequent Meeting with Former Train drivers.

Communication system	**Subsequent activities train driver/on-board staff**	**Subsequent activities passengers**
Only GSM-R (MobiSIR)	Train driver: "Ordinary alarm chain in case of apparent threat": Emergency call to TTCC and all trains in nearby area. Supplementary alarm call to TTCC. The alarm receiver forwards the alarm to, among others, the emergency services according to an alarm receiver checklist. Communication with other on-board staff occurs via the train's internal communication system. Extensive additional activities are outlined in the National Railway Traffic Regulations, e.g., emergency signs should be displayed. On-board staff: If they have GSM-R, they receive emergency calls. Railway companies have safety regulations. The staff is expected to inform that leaving the train is dangerous. Typically, the onboard supervisor does not have their own GSM-R, but has been trained to send emergency calls via a GSM-R device. Initiates possible evacuation. The decision on this is made by the driver in consultation with the train dispatcher and electrical engineer at TTCC. A GSM-R phone is typically available in both driver cabs of the train. Whether the unit is fixed or mobile varies between train types.	Instruction: Move from danger to the next carriage. Presumed spontaneous evacuation (quite common). Lower risk during spontaneous evacuation as long as there is no apparent danger. Good information from the driver reduces the risk of this.
Only public GSM	Train driver: Alarm number is available in the route book. The GSM-R phone can be used via the public network through roaming, with normal functionality. Some time delay due to delayed alarm and more to handle. The alarm receiver at TTCC has more tasks because the emergency call has not been made. Otherwise, the same conditions. Possible initiation of evacuation. The train driver decides this in consultation with the train controller and the electrical engineer at TTCC.	The risk of spontaneous evacuation increases as the time elapses. Several are expected to call relatives, friends, or emergency services. Risk of overload on the GSM network used by train drivers in case of non-functioning GSM-R. It is not possible to rule out overload on the GSM system. 112 may have reserved channels, but whether operators have implemented this is uncertain.
Only emergency telephone	Train Driver: Contacts TTCC via the nearest emergency telephone, but there is no guarantee for this. Should be signposted and emergency lit. Dependent on the person. On-board staff: Unclear if they sound the alarm. Probably stay on board. May initiate evacuation. The train driver decides on this in consultation with the train dispatcher and the electrical operation engineer at TTCC. The route book indicates the presence of an emergency telephone, but not its exact location.	Depends on the circumstances. May vary in different parts of the train. Emergency telephone might be used.
No communication system	Evacuation. Possibly faster in the absence of dialogue with TTCC. Uncertain. Organized evacuation and/or spontaneous evacuation. Lack of possibility for consultation with the train controller and electrical engineer.	Evacuation. Organized evacuation and/or spontaneous evacuation.

The Importance of Notifying TTCC for the Size of the Damage
During the risk workshop, the importance of notifying TTCC to assess the extent of the damage was emphasized. Below are the summarized conclusions from the workshop:

1. Communication systems for alerts have the greatest impact on damages in additional accidents outside the affected train, such as electrical accidents involving downed overhead lines and collisions with evacuating trains or trains on adjacent tracks or in adjacent tunnel tubes.
2. Emergency telephones are part of the alert process, but their impact varies. The study focuses on stages where the alarm is relevant.
3. The difference in alert times between different systems is estimated to be a few minutes, but the system initiating the alert is less important compared to the alert reaching TTCC on time.
4. The presence of emergency telephones in a railway tunnel affects the ability to sound an alarm and possibly (under certain circumstances) the timeline until an alarm is raised, which can impact the risk. GSM-R is assumed to be quicker. The primary function of the emergency telephone is to serve as a redundant system.
5. The effect of alerts to TTCC is similar regardless of system. It has the least impact in single-track tunnels with functional ancillary spaces (technical rooms) since the risk of train-person collisions is minimal.
6. Simultaneous alerting through multiple systems is not advantageous and can overload the public mobile network. Preventing staff alerts is considered as a negative safety impact.
7. Traffic Administration staff at the traffic control take actions using the control and monitoring system, not solely based on emergency alerts. The safety concept relies on their continuous monitoring and intervention.

The Importance of Choosing Communication Systems for Notifying TTCC for the Size of the Damage
During the risk workshop, the behavior and sequence of events during accidents were examined, along with how the alerting process was affected by different communication systems. It was clarified that the impact of the alerting process was confined to damages from additional accidents and injuries to other individuals. The assessment concluded that the alerting process had minimal impact on the initial damage and subsequent injuries. GSM-R is presumed to provide faster alerts than emergency telephones, with the primary effect of the emergency telephone being an additional communication system.

RISK ESTIMATION

During the risk workshop, a thorough analysis was conducted on how different communication systems and risk identification affect the consequences of accidents in tunnel environments. Several crucial conclusions emerged, forming the basis for understanding how emergency communication impacts safety during accidents.

A key finding was that if risk sources are managed according to code of practices, the associated risks can be deemed acceptable. This implies that further analyses are not required for these specific risk sources, and the use of such practices is recorded as safety requirements for the relevant risks. Despite this conclusion, the authors of this paper chose to conduct a rough risk estimation to enhance understanding of how emergency communication affects the complex sequence of accidents in tunnel environments. Through discussions in the risk workshop and meetings with train driver representatives, combined with experiences and literature reviews, an assessment was made of the magnitude of damage in various scenarios.

The method of risk estimation involved a semi-quantitative approach, assessing the likelihood of different types of accidents and system designs, represented by indices from 1 to 3. This index aimed to reflect the relative likelihood of each type of accident, considering that tunnel accidents occur with very low frequency.

The consequence for each type of accident and system design was also assessed with an index ranging from 1 to 3 for different stages of the sequence of events. Furthermore, a risk index for each type of accident and system design was calculated by multiplying the probability and consequence indices. Subsequently, the significance of having at least one functioning communication system during an accident was evaluated by assessing the difference in risk indices between the scenario with and without a functioning communication system.

This approach provided a deeper understanding of the expected effect of emergency communication at various stages of an accident. The reporting of results primarily aimed to enhance understanding of the effects of proposed measures from a risk and safety perspective.

The Impact of Alarming on the Risk Profile

Detailed results of the risk indices for the types of accidents are presented in the project report and are summarized in Table 2. In the table, the difference in risk indices between functioning and non-functioning alarms to TTCC is presented for various tunnel configurations, with a particular focus on scenarios with the most impact on the risk index. The difference in RI values is calculated by subtracting the RI for scenarios with functioning alarms from those without functioning alarms, reflecting the added safety value of operational alarm systems. As an example, a train fire in a double-track tunnel without functioning alarms to the TTCC can escalate risks due to delayed responses. Key hazards include potential collisions with oncoming trains or electric shocks during evacuation if power is not promptly cut. With an operational alarm system, these risks are significantly reduced by enabling quick actions such as halting train operations and alerting evacuation personnel. In the project report detailed risk index comparisons under these scenarios are provided. The summary table aided the identification of situations where functional communication systems have the greatest influence. The data serves as the basis for subsequent risk assessment and review of safety requirements to mitigate these risks in new constructions and renovations.

Findings

The risk analysis indicates that emergency communication with TTCC is significant for the risk profile, particularly in later stages of an accident, especially in double-track tunnels and tunnels with parallel tubes. In the absence of this communication, the risk of damage in additional accidents increases, especially through electrical accidents involving downed overhead lines and collisions with evacuating trains or trains in adjacent tunnel tubes. Deficiencies in communication also affect warnings to maintenance personnel and increase the risk of another train entering the affected tunnel tube. However, the significance of this is less in single-track tunnel with side space featuring emergency functions compared to other tunnel designs.

RISK ASSESSMENT AND RISK ACCEPTANCE

The risk analysis evaluates the acceptance of one or multiple risk sources within the assessed system according to the CSM RA-regulation. Principles for risk acceptance include the use of code of practices, comparison with similar systems, and an explicit risk estimation. This assessment, subject to review by an independent assessment body (AsBo), is crucial for documenting safety requirements and maintaining an acceptable level of risk.

Code of practices, applied as a principle for risk acceptance for all risks, involve a set of written rules used to control one or multiple risk sources. These rules are widely accepted within the railway sector and include TSIs, national regulations, and EN standards. To be considered code of practice, these rules must be recognized within the railway domain, relevant for managing the risk sources within the assessed system, and available for review by assessing bodies.

If the risk sources are controlled according to such code of practices, the associated risks are considered acceptable, and thus do not require further analysis. Registering the use of code of practices serves as safety requirements for relevant risk sources in the hazard record. The use of code of practices in this context were justified by the existing emergency communication practices during tunnel accidents, the relevance of this practice in controlling the identified risk sources, the absence of other applicable national or international standards, and the lack of additional requirements from the Swedish Transport Agency regarding communication in railway tunnels.

Table 2. Difference in risk index between functioning and non-functioning alarms to TTCC for various tunnel configurations.

Tunnel specific accidents	**Initial damage**	**Subsequent damage**	**Damage du to additional hazard/accident**						**Damage inflicted on others**					
			Single-track tunnel - safe areas		Double-track tunnel - safe areas		Parallell tubes - fire separated		Single-track tunnel - safe areas		Double-track tunnel - safe areas		Parallell tubes - fire separated	
System design			YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO
			A	*B*	*C*	*D*	*E*	*F*	*A*	*B*	*C*	*D*	*E*	*F*
Fire in a train stopping in the tunnel	0	0	0	0	4	4	4	4	2	2	2	2	2	2
Fire in a train on the adjacent track causing trains to stop in the tunnel	0	0	N.A.	N.A.	4	4	N.A.	N.A.	N.A.	N.A.	2	2	N.A.	N.A.
Fire in infrastructure or side space causes trains to stop in the tunnel	0	0	0	0	4	4	4	4	2	2	2	2	2	2
Explosion followed by fire affecting a train stopped in the tunnel or causing a passenger train to stop in the tunnel	0	0	1	1	2	2	2	2	1	1	1	1	1	1
Gas leak affecting a train stopped in the tunnel or causing a passenger train to stop in the tunnel	0	0	1	1	2	2	2	2	1	1	2	2	2	2
Collision	0	0	0	0	4	4	4	4	0	0	0	0	0	0
Collision leading to derailment	0	0	0	0	4	4	4	4	0	0	0	0	0	0
Collision with subsequent fire	0	0	0	0	4	4	4	4	2	2	2	2	2	2
Derailment	0	0	0	0	4	4	4	4	0	0	0	0	0	0
Derailment causing a fire	0	0	0	0	4	4	4	4	2	2	2	2	2	2
Derailment leading to collision	0	0	0	0	4	4	4	4	0	0	0	0	0	0
Spontaneous evacuation	0	0	3	3	6	6	6	6	0	0	0	0	0	0

(red)	Medium or high impact of functioning alarm
1-3	low
4-6	medium
7-9	high

Note: The values in each column represent the difference in Risk Index (RI) calculated as RI_non-functioning_alarm – RI_functioning_alarm for each tunnel configuration and stage in the accident sequence. Absolute RI values for functioning and non-functioning alarm systems are presented in the project report.

Code of practices
Tunnels in the rail system of the European Union are critical facilitites that demand hig safety standards. To ensure this safety, the TSI SRT prescribe specifications guiding the design, construction, and assessment of new or modified tunnels. This encompasses a range of measures aimed at minimizing specific risks to on-board staff and passengers within tunnels.

Technical specifications for interoperability are considered as codes of practice within the framework of the Railway Safety Directive (2016/798/EC) and are guiding in assessments according to the CSM RA-regulation. Therefore, these principles were applied and assessed as relevant and compliant with the requirements of the CSM RA-regulation for the current system.

Within the TSI SRT, there are detailed requirements and clarifications regarding emergency communication in tunnels. Specific sections apply to tunnels longer than one kilometer, while shorter tunnels do not explicitly demand emergency communication. Clarifications also encompass the definition of a 'mobile phone' and emphasize the necessity of communication between on-board staff and the TTCC in emergency situations.

It's crucial to note that the overall safety of the tunnel is not solely reliant on passengers' or on-board staff members' ability to make emergency calls. There is, for example, no direct link between requirements for safe areas and those for emergency communication, even concerning general radio coverage.

Furthermore, the requirements for radio coverage for emergency services during crises are not linked to or reliant upon communication between traffic and side areas. The principle that mobile communication via GSM-R reduces the need for fixed connections, such as emergency telephones or radio coverage for general mobile communication, has been consistent since the initial versions of the TSI SRT.

There's a history where emergency telephones have been used in Swedish railway tunnels due to the absence of other communication solutions. When GSM-R was implemented, signal telephones along the track vanished but were retained in the Swedish Transport Administration's tunnels, renamed emergency telephones following guidelines like BVS 545.22200 and later TDOK 2015:0287. This example highlights the evolutionary development of communication systems in these environments.

Findings
According to code of practices, communication via GSM-R constitutes a necessary safety requirement to achieve an acceptable level of safety for the identified risks. A prerequisite is the ability to communicate from a mobile phone or fixed connection both from the tunnel's traffic area and from a safe area. As per code of practices, GSM-R provides sufficient reliability for alarm signaling without additional redundancy. This implies that the residual risk due to the absence of alarm signaling with GSM-R or malfunctioning GSM-R is acceptable.

SAFETY REQUIREMENTS
The risk assessment suggests that the existing emergency telephones in the Swedish Transport Administration’s tunnels can be phased out, but before this occurs, safety measures must be verified to achieve an acceptable risk level in accordance with code of practices. The technical requirements vary depending on the tunnel's system design and length. For tunnels longer than 1 km, specific communication capabilities are required as per practice, with different requirements for different system designs.

System designs A, C, and E must enable radio communication between trains and the TTCC, either via GSM-R, public GSM, or fixed connections in the side spaces. Systems B and D do not require more than GSM-R between trains and the traffic center, as they lack safe areas for emergency communication.

Emergency communication requirements vary for tunnels over 1 km depending on the system, and some options are more complicated to implement than others. Relying solely on public GSM in emergencies may lead to overload, preventing contact with the TTCC in severe events. The recommendation is to use fixed connections in safe areas together with GSM-R in the tunnel to ensure robust communication and adequate safety. However, this alternative requires train companies to provide GSM-R terminals, while relying solely on GSM requires prediction of the expected number of users to avoid overload.

ACTIONS REQUIRED IN DISPOSAL PROJECTS

To ensure emergency communication between traffic and side spaces in the Swedish Transport Administration's railway tunnels, each disposal project should adhere to the following requirements:

1. In tunnels ≤1 km, no additional safety requirements need to be fulfilled after disposal

2. In tunnels >1 km with safe areas, radio communication between the train and TTCC shall be provided in the tunnel, as well as one of the the following in the safe area(s):
    a. communication by GSM-R, or
    b. communication by GSM, or
    c. communication by fixed connection.

In tunnels >1 km (systems A, C, and E), alt. c) is the recommended option, thus providing fixed connections in safe areas. Additionally, the following must be done regardless of the tunnel's length:

- The basis for the Route book (section L) should be updated according to TDOK 2013:0240 and TDOK 2014:0553.

- Train companies on the route must be informed about the change and its consequences.

- Trafikverket's facility registry in BIS should be updated in accordance with TDOK 2016:0407, TMALL 0594, and TMALL 0588.

Technical documentation, such as fire protection information and safety concepts, should be revised or removed for decommissioned facilities according to tunnel personnel safety.

These steps are part of Trafikverket's process for implementing measures on roads and railways and are managed by the responsible project manager. According to TDOK 2018:0193, the project manager leads the project and ensures compliance with the requirements by following the Swedish Transport Administration's documents. This mainly involves managing facility requirements and handing over new or modified infrastructure according to various regulatory documents (such as TDOK 2018:0099 and TDOK 2012:139).

The person responsible for IT and telecommunication infrastructure, especially the emergency telephone system, must include safety requirements in the planning and implementation of each change project. This is part of their responsibility for the technical management, operation, and maintenance of these facility components.

DISCUSSION

Balancing Safety and Technological Advancements

The disposal of emergency telephone systems from railway tunnels marks a significant shift toward modernizing communication infrastructure. However, this transition necessitates a delicate equilibrium between safety imperatives and technological upgrades. The evaluation revealed the critical importance of maintaining robust communication links within tunnels, especially during emergencies, to ensure passenger safety and expedite response times.

Challenges in Implementing Alternative Systems
While advocating for the integration of GSM-R-based systems supplemented by public GSM networks or fixed communication lines, challenges surface in ensuring seamless implementation. Foremost among these challenges is guaranteeing consistent coverage across tunnels, avoiding overloads on public mobile networks, and estimating the potential number of simultaneous users during emergencies.

Transition Strategy for Optimal Safety
The study's recommendations propose a phased compliance roadmap, advocating for a strategic transition plan. This approach aims to minimize potential disruptions while ensuring uninterrupted communication capabilities during emergencies. Implementing such a transition necessitates collaboration among various stakeholders, including railway authorities, technology providers, and regulatory bodies, to ensure a harmonized and systematic adoption process.

Challenges during the practical application of the CSM RA-regulation
The CSM RA-regulation specifies a method for capturing, assessing, controlling and accepting risks arising from changes that can affect adversely the safety on the European Railways, tunnels included. Thus, it has a broad scope and is formulated to be applicable with regard to changes of technical, operational and organisational nature. As such, a large responsibility is put on the risk assessment leader to adapt and adopt the method to fit the scope of the proposed change. In the study presented in this paper these are some of the observations were made by the authors of this paper:

1. The decision or rather interpretation of whether a proposed change has an impact on safety varies between individuals. Although presented with the same information about the proposed change, different experts initially judged the impact on safety differently. Discussion during the work shop eventually led to consensus.

2. Deciding the significance of the change, particularly in the current study, was difficult as one of the six criteria to be judged was failure consequence: credible worst-case scenario in the event of failure of the system under assessment. Given the proposed change, failure of the system under assessment was irrelevant to judge (the system would no longer be there to eventually fail). This was solved by instead judging not the possible failure of the system, but rather the consequence of actually removing the system, taking into account the existence of other safety barriers (communication systems).

3. Initially, there seemed to be a reluctancy among some experts to classify the proposed change to be significant. Discussion during the workshop eventually led to consensus, after having described that such a decision would facilitate both communication with internal and external bodies, and also – to some degree – facilitate, for example, the selection of principle for risk acceptance.

4. The eventual involvement of the AsBo was not friction free. The AsBo was contracted based on an individual call-off from a pre-defined business framework agreement in which they were to be given priority. The initial offer to review and assess the risk assessment was roughly 500 % higher than what they eventually were compensated for, despite pre-meetings and explanations of the scope of the study. In addition, it by far exceeded the actual effort to execute the actual risk evaluation and assessment. From a practitioner point of view, it is difficult not to view a large part of the work to be related to unnecessary documentation.

CONCLUSIONS
The investigation into the removal of emergency telephone systems within railway tunnels has revealed multifaceted insights into the intricate balance between safety, communication infrastructure, and risk management. This comprehensive study aimed to address the implications of decommissioning these systems while proposing viable alternatives in accordance with European Union safety directives.

The risk assessment framework employed in this study was designed to holistically evaluate the safety implications associated with the removal of emergency telephones, emphasizing the diverse parameters inherent in railway tunnel configurations. It became evident through meticulous analysis that the safety requirements vary significantly based on tunnel length, tunnel system design, and communication infrastructure compatibility.

The identified risk factors encompassed potential disruptions in communication between trains and traffic control centers, particularly in tunnels longer than 1 kilometer, highlighting the critical need for reliable communication systems. The scenario-based analysis vividly portrayed the vulnerability of passengers and railway staff during emergency situations, accentuating the significance of effective and resilient communication protocols.

In conclusion, the removal of emergency telephone systems in railway tunnels demands a careful approach considering the multifaceted challenges posed by varying tunnel configurations and safety requirements. The findings highlight the criticality of robust communication infrastructure to mitigate risks, safeguard passenger safety, and enable efficient emergency response protocols. By adhering to the proposed recommendations and compliance roadmap, stakeholders can effectively navigate this transition, ensuring enhanced safety standards and seamless communication within railway tunnel environments.

REFERENCES

Banverket, 2006. Telesystem: Telefoni längs spår (BVS 545.22200).

Commission Regulation (EU) No 402/2013 of 30 April 2013 on the common safety method for risk evaluation and assessment

Commission Regulation (EU) No 1303/2014 of 18 November 2014 concerning the technical specification for interoperability relating to safety in railway tunnels of the rail system of the European Union

Commission Implementing Regulation (EU) No 2015/1136 of 13 July 2015 amending Implementing Regulation (EU) No 402/2013 on the common safety method for risk evaluation and assessment

Commission Implementing Regulation (EU) 2019/773 of 16 May 2019 on the technical specification for interoperability relating to the operation and traffic management subsystem of the rail system within the European Union

Decommissioning of emergency telephone systems in the Swedish Transport Administration's railway tunnels: System definition and assessment of safety impact (TRV 2022/102615)

Directive (EU) 2016/798 of the European Parliament and of the Council of 11 May 2016 on railway safety

Trafikverket, 2015. Telesystem. Telefoni längs spår (TDOK 2015:0287).

Trafikverket, 2020. Metod för riskhantering vid ändringar gällande trafiksäkerhet järnväg (CSM RA; TDOK 2020:0236).

Trafikverket, 2022. Riskbedömning: Skrotning av nödtelefonisystem i Trafikverkets järnvägstunnlar (TRV 2022/102615).

Trafikverket, 2022. Väsentlighetsbedömning – Skrotning av nödtelefon i befintliga tunnlar (TRV 2022/102615).

Trafikverket, 2022. Upprättande av underlag till linjeboken (TDOK 2013:0240).

Trafikverket, 2023. Data och dokumentation till förvaltande system – Järnväg (TDOK 2016:0407).

Trafikverket, 2023. Hantering av anläggningsspecifika krav (TDOK 2018:0099).

Trafikverket, 2023. Linjeboken – underlag till linjeboken, uppdatering och publicering (TDOK 2014:0553).

Trafikverket, 2023. Projektledare Genomföra åtgärder (TDOK 2018:0193).

Trafikverket, 2023. Överlämnande av ny eller förändrad infrastruktur (TDOK 2012:0139).