

Tunnel Safety Concept Koralm Tunnel

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ABSTRACT

The 32.8-km-long Koralm tunnel requires additional measures to guarantee a sufficient safety level. The methodology applied to define safety measures for this very long tunnel is on the one hand based on a set of guidelines and on the other hand based on the specific boundary conditions of this tunnel. These tunnel-specific conditions are considered by establishing customized safety targets. All aspects of safety are summarized in a specific tunnel safety concept.

As a result of an investigation into the construction and operating phase, the tunnel system was determined to consist of two single-tube tunnels, an emergency station, cross-passages every 500 m and no crossover. The emergency station in the centre of the tunnel, which incorporates various considerations, was designed to accommodate staggered platforms and a combined refuge room with a length of 800 m. The physical structures of the emergency station (distance of escape tunnels, door configurations, etc.) were checked by application of an evacuation simulation.

With a view to the incident management strategy to be adopted, characteristic operating scenarios were analysed to realistically reflect the sequence of events in case of an emergency.

Keywords: tunnel safety, railway safety, emergency station

INTRODUCTION

The Koralm railway line is part of the so-called Pontebbana corridor, which represents the easternmost crossing of the Alps and links several Eastern European countries and Vienna with southern Austria and northern Italy (see figure 1). This new stretch will have a total length of approximately 130km, and will connect the provincial capitals of Graz and Klagenfurt. With this new railway line the travel time between Graz and Klagenfurt will be reduced from the present three hours to less than one hour.

The Koralmbahn route planning is characterised by large radii and minimum gradients which makes it possible to run both fast passenger trains and heavy freight trains.

The design speed amounts to $V_{max} = 250$ km/h, the maximum gradient is reduced to 10‰.

The most prominent tunnel along this stretch will be the Koralm tunnel. It will underpass the Koralpe, a mountain range between the provinces of Carinthia and Styria. The maximum overburden will reach almost 1.200 m. This double tube tunnel will have a length of approximately 32.8 km. The separated tubes are connected by cross-passages approximately every 500 m.



Figure 1: Overview map

Depending on the results of the detailed investigation construction works for the Koralm tunnel could start in the year 2008/2009 and should be finished in 2016.

TUNNEL SYSTEM

Starting with the design process for the environmental impact assessment, a system analysis was launched to examine the essential elements of the Koralm tunnel. This analysis considered construction and operating phase criteria. For the operating phase, the effects regarding passenger safety, maintenance, power consumption, aerodynamics and operating safety were taken into consideration.

Based upon this analysis, the following system was chosen (see Figure 2):

- Two single-track tubes
- Cross-passages connecting the tubes at a 500 m distance
- One emergency station in the centre of the tunnel with no direct link to the surface
- No crossover inside the tunnel

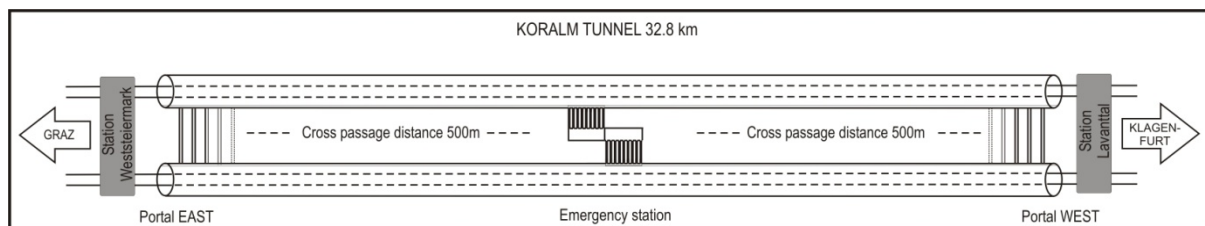


Figure 2: Tunnel system Koralm tunnel

Necessity of an emergency station

In case a fire occurs in a running train inside a tunnel, the train should leave the tunnel as fast as possible, since the chances of people being rescued are considerably lower inside the tunnel than outside the tunnel.

The TSI (Technical Specification for Interoperability) [2] states that, in case of a fire, the running capability of a train is to be ensured for a period of 15 minutes, permitting the train to proceed at a speed of 80 km/h.

These requirements regarding the running capability of trains indicate that, with tunnels featuring a length in excess of 20 km, the probability of leaving the tunnel decreases. It is in response to these findings that the guidelines call for special measures in tunnels exceeding a length of 20 km [2]. For the Koralm tunnel, the construction of an emergency station in the centre of the tunnel was investigated as additional safety measure. This emergency station serves the purpose of creating an area which offers exceptionally favourable self-rescue conditions in case of a fire. A train is brought to a halt in the emergency station before its running capability has reached its limits.

No crossover

A train operation simulation was performed to decide whether a crossover would be needed in the Koralm tunnel. This crossover would primarily be used during maintenance works, since a section of the tube, which is to be worked on, would then be closed. The simulation also covered an increase in train traffic induced by a possible upgrade of the feeder lines. The studies confirmed that, even if no crossover is provided inside the tunnel and if one tube is completely closed due to maintenance works, a sufficient train operation quality can still be ensured.

Safety considerations (accidents caused by switches are reduced, strict separation of tunnel tubes) as well as the need for additional maintenance work (inspection of switches and connecting tunnel tubes with doors and installations) were facts speaking against a crossover.

METHOD ADOPTED FOR DEFINITION OF SAFETY MEASURES

For the definition of safety measures in railway tunnels, in Austria reference is generally made to the existing guidelines [1, 2, 3]. But in view of the different operating conditions and in light of the considerable tunnel length, additional measures are to be taken at the Koralm tunnel.

As in Austria there are no acceptance limits regarding passenger risks in railway tunnels, the approach of a quantitative risk analysis was discarded and instead the following procedure was employed for the definition of safety measures:

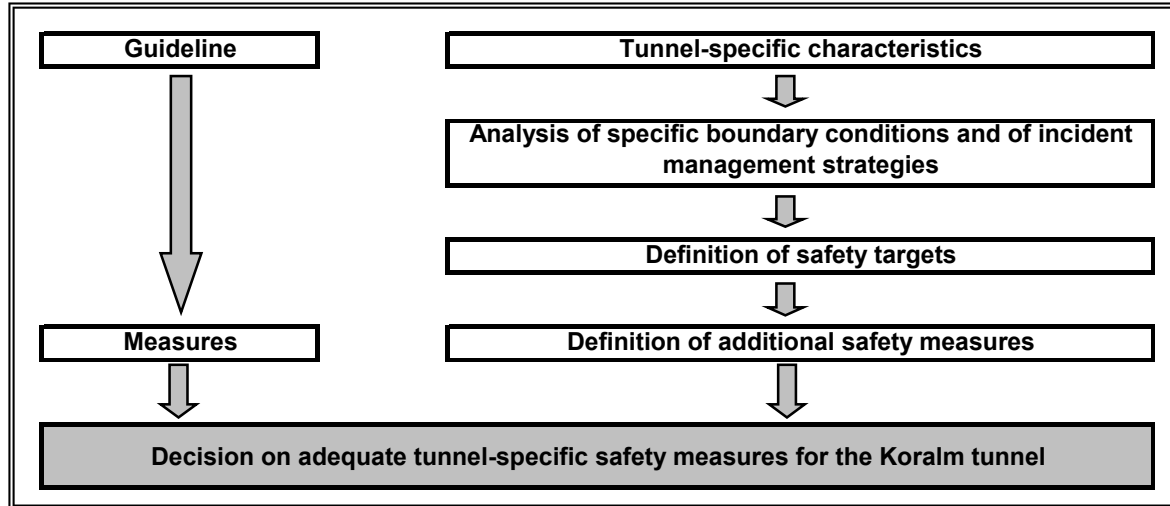


Table 1: Procedure adopted for the definition of safety measures

The measures defined in these guidelines are applicable to standard tunnels. In order to ensure an equally effective safety level for the Koralm tunnel, adequate safety targets were defined in a first step. In the course of this process, tunnel-specific characteristics were analysed regarding their impact on safety, the results were compared to the postulated safety targets and conclusions were drawn regarding the need for special/additional safety measures

RESCUE CONCEPT

When developing the rescue concept for the Koralm tunnel, a special effort was made to assure maximum uniformity with the sequences determined for other tunnels of the Koralm railway line and with the Austrian railway network as a whole.

Railway operation

The first operational steps to be taken when a fire occurs inside the tunnel may be summarised as follows:

- All trains shall leave the tunnel; passenger trains which have not passed the emergency station yet shall stop upon arrival at this point.
- All trains, running ahead of the accident train, shall drive out of the tunnel.
- All trains following the accident train shall – by moving backwards – secure the greatest possible distance to the hazard zone, or they shall be evacuated.
- All trains in the second (safe) tube shall either come to a halt or continue their journey at reduced speed.

Self-rescue, evacuation

A self-rescue becomes necessary when an emergency occurs, that brings a train to a halt inside the tunnel, that keeps a train from driving on and that puts a person's life at risk. When a train stops at a random location inside the tunnel, the self-rescue is performed via cross-passages leading into the second tube. When a train stops in the emergency station, the self-rescue is accomplished by evacuees proceeding to the rescue room.

People waiting inside the tunnel are predominantly evacuated by passenger trains running on the Koralm line. Problems may occur at night when fewer trains are in operation. In these cases, alternative solutions like “bringing in trains parked at stations along the Koralm line” or “increasing the capacity of the rescue train by adding passenger cars” would be conceivable. An optimized solution will be developed in connection with the operating programme at a later stage, shortly before the tunnel will be opened to traffic.

Assisted rescue, rescue train

An assisted rescue from the Koralm tunnel shall be performed by a rescue team, supported by members of the voluntary fire brigade. For the rescue crew to be transported to the site of the accident, rescue trains shall be positioned at the nearest stations. Rescue operations are planned to be carried out from both sides.

LAYOUT OF THE EMERGENCY STATION

The emergency station in the centre of the tunnel consists of 400-m-long platforms in both tunnel tubes. Inside the emergency station, the walkway, which extends over the entire length of the tunnel, is widened (2.0 m) and raised to the commonly level of platforms (55 cm above rail) in Austria. The walkway and the emergency exits may thus be kept on the side facing the second tube.

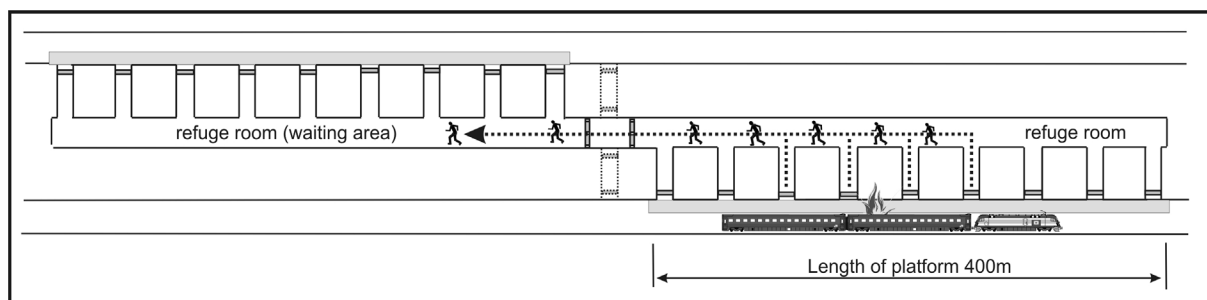


Figure 3: Layout of emergency station / self-rescue under way

In the emergency station a refuge room is located between the two tunnel tubes. This refuge area is connected to the platforms via escape-passages provided at a distance of 50 m. As Figure 3 shows, a staggered platform arrangement is chosen, which results in an approx. 800-m-long refuge room. A lock divides the refuge room into two equally large parts. At the emergency exits leading from the platform to the escape-passages, 2-m-wide doors are installed. It is envisaged that in case of an incident, all evacuees will proceed to the more distant part of the refuge room (waiting area), where they will be waiting to be evacuated by passenger trains.

Due to the great overburden in the middle of the tunnel, no rescue tunnels or ventilation shafts to the surface were realised.

This emergency station arrangement offers the following advantages:

- From a fire protection perspective, the waiting area is clearly separated from the affected platform.
- The distance between two escape passages of only 50 m leads to short escape routes
- People leaving the train cover a distance of approx. 400 m (see Figure 3), move out of the immediate danger zone. If they were forced to stay in the rescue room directly adjacent to the platform, they would only be shielded by the short escape-passage between the fire scene and the safe area, which would give them the feeling of being very close to the zone of danger. This scenario was considered to be problematic in case of an extended stay in the emergency station – as a period of up to 90 minutes may be required for the evacuation to get underway.
- More space is available for people waiting to be evacuated, a provision which shall help to prevent uncontrolled attempts to leave the waiting room.
- The evacuation and the assisted rescue campaign will be made easier, as unwanted interactions will be prevented (see Figure 4).

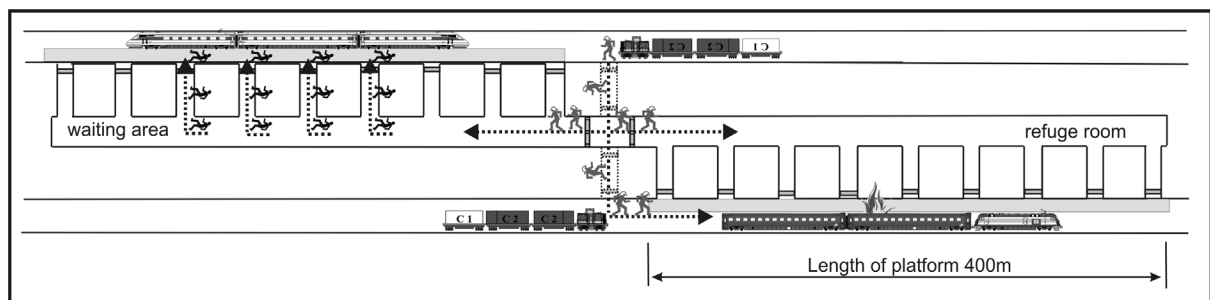


Figure 4: Evacuation train and rescue train in emergency station

EVACUATION SIMULATION OF EMERGENCY STATION

Evacuation simulation model

An evacuation simulation of a passenger train that stopped in the emergency station was carried out to support the assessment of the evacuation options and to serve as a supplement to the design which was performed in compliance with state-of-the-art know-how and all pertinent guidelines and regulations.

In the evacuation simulation model, the position of the affected train in the emergency station, the location of the train fire, the site of the emergency exits, the propagation of smoke, and last but not least the reaction and behaviour of the people during the evacuation to the refuge room via the emergency exits and the escape passages were taken into account. This approach made it possible to determine the main factors influencing the time needed by passengers and train personnel to reach a safe area.

Questions addressed

The evacuation simulation was performed to find answers to the following questions:

- How long will it take for all evacuees to leave the incident train?
- How long will it take for all passengers to reach a safe area (escape passages)?
- Will the platform be wide enough to prevent possible congestions on the way to the emergency exits?
- Will the spacing between the emergency exits be adequate?
- Will the emergency exit doors be wide enough?
- Will the door width between the rescue area and the waiting area of the refuge room be wide enough to prevent possible congestions on the way to the waiting room?

Scenarios investigated

For the person model, a train with 14 carriages and a maximum number of 1,000 occupants was used. The different scenarios were examined with and without smoke propagation along the platform. It was assumed that, as a result of the smoke propagation, the walking speed is reduced by half.

Miscellaneous simulations were made with varying positions of burning carriages in the train.

- Burning carriage between two of the escape passages (all emergency exits can be used)
- Burning carriage in front of one of the escape passages (one emergency exit cannot be used); even the doors of the train are blocked by fire
- Two carriages affected by the fire with people fleeing inside the train to the adjacent carriages (the concerning doors of the train are blocked by fire); two escape passages cannot be used on the way to a safe area (worst case scenario)

Within the framework of this sensitivity analysis, other scenarios, like obstacles on the platform (e.g. scattered luggage) or different door widths (e.g. only one open door wing) were also checked.

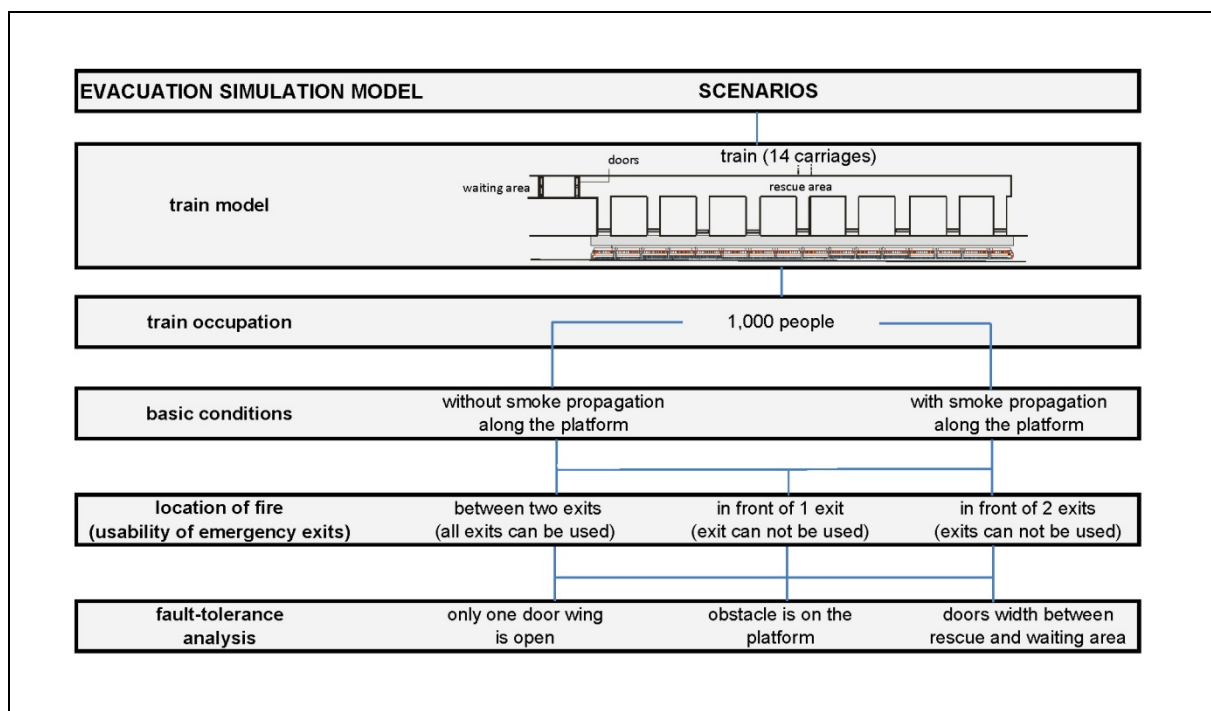


Figure 5: Overview of scenarios

Results and Conclusions

The results of the evacuation simulation show how many persons manage to reach a “safe area” depending on the time elapsed and the conditions encountered (length of escape routes, atmospheric conditions, etc.) – see evaluation diagram in Figure 6.

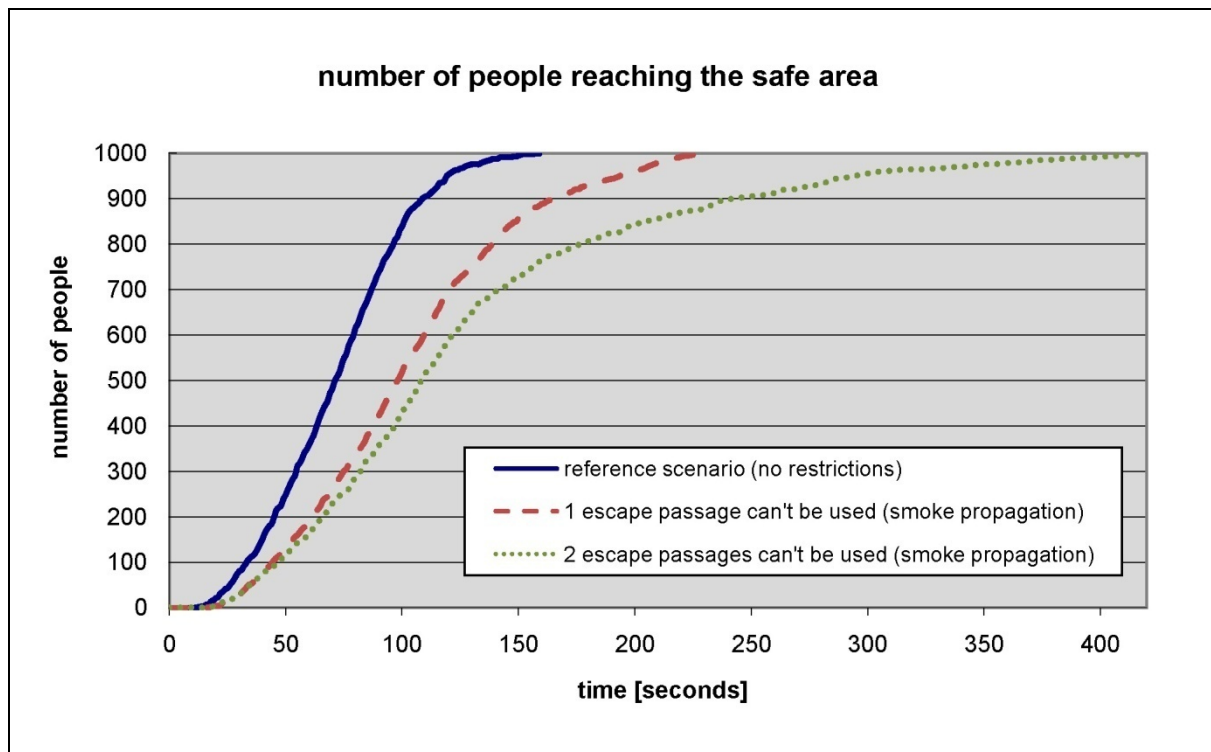


Figure 6: Number of people reaching the safe area

The narrow spacing and the sufficient width of the emergency exits enable passengers to quickly reach a safe area. The chosen platform and door widths prevent congestions on the way to the waiting room. The whole system is basically fault-tolerant (as a result of the comprehensive sensitivity analysis).

The emergency station structures of the Koralm tunnel were found to be very functional allowing large numbers of people to be evacuated in a short time (1,000 persons in 2 – 3 minutes, if no restrictions are encountered).

The analysis also revealed that with a few unfavourable scenarios, the evacuation time could be much longer (up to 7 minutes in the worst case). In these cases, the main causes for the extended evacuation time were the bottlenecks of passengers alighting the train and not the structures of the emergency station.

ANALYSIS OF INCIDENT MANAGEMENT BASED ON TRAFFIC SCENARIOS

Due to the extensive length of the Koralm tunnel, there is a non negligible probability of several trains running through the tunnel at the time, at which an emergency occurs. In response to this fact, to the necessity of having to evacuate both passengers and crew, and to the requirement of having to grant rescue vehicles access to the tunnel, special operating sequences have to be elaborated.

In view of the operating programme currently envisaged for the Koralm line, 5 different train schedule scenarios have been developed.

Boundary conditions and assumptions

It is assumed that, in case a fire is detected in a passenger train, a message is immediately dispatched to the control centre, allowing operational measures to be taken, before the train is brought to a halt. All train drivers inside the tunnel are instantly informed of an emergency by the use of GSM-R technology (voice message or SMS). A reduction of the permissible speed or a stoppage of the train will, depending on the options available, automatically be effected by the train control system, but an emergency stopping of the train shall be avoided.

To determine the operating sequences of rescue train and evacuation train, the assumptions shown in Table 2 were taken into consideration. These assumptions are based on a high number of computer simulations of the airflows induced by running trains.

Travelling speed – evacuation train (passenger train)	80 km/h
Travelling speed – rescue train	60 km/h
Slowdown of evacuation train and rescue train inside the tunnel	2 km ahead of the incident site, the driving speed is reduced
Reversing of freight trains (adequate operating instructions in case of an emergency are still to be elaborated)	40 km/h
Number of trains, travelling at the same time in the safe tube	One train (or travelling speed must be decreased further)

Table 2: Assumptions made regarding operating sequences

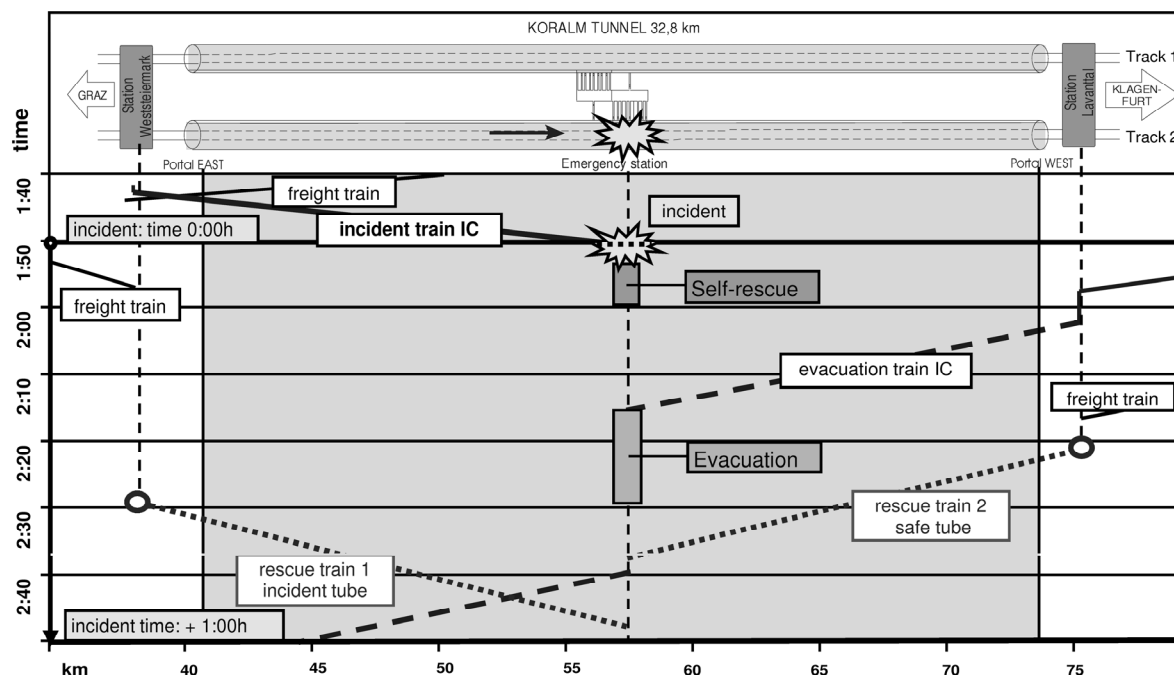


Figure 7: Time-distance diagram illustrating the incident management of a Scenario (example)

The decision to analyse possible incident management scenarios with the help of time-distance diagrams shown in Figure 7 allowed sequences to be studied in greater detail and provided answers to such questions as:

- Are there ways of moving the train(s) out of the tunnel in case of an emergency?
- Is it possible to use other passenger trains as evacuation trains within a reasonable period of time? How long will people have to wait inside the emergency station?
- For which sequences will new operating regulations have to be established?
- How long will the second tube have to be separated from the incident tube by the use of fire protection measures?
- How long will electrical installations, such as ventilation, communication and train control systems in the second tube have to remain functional?

STATUS OF TUNNEL SAFETY CONCEPT

In October 2007 the site negotiation in connection with the permit application procedure took place and the construction permit in compliance with Austrian railway law for the Koralmtunnel including the safety concept was already issued.

REFERENCE LIST

- [1] Guideline “Construction and Operation of New Railway Tunnels on Main and Branch Lines; Demands Made on Fire Protection and Emergency Management”, Austrian Fire Fighters Association, 1. Edition 2000
- [2] TSI-SRT, Safety in Railway Tunnels
- [3] UIC – Codex 779-9E, Safety in Railway Tunnels, 1. Edition, August 2003