# KORALM TUNNEL –
# DEVELOPMENT OF TUNNEL SYSTEM DESIGN AND SAFETY CONCEPT

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## 1 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.

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, no crossover and cross-passages every 500 m. The emergency station in the centre of the tunnel, which incorporates various considerations, was designed to accommodate staggered platforms and a refuge room with a length of 800 m.

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.

## 2 THE KORALM TUNNEL PROJECT

The Koralm tunnel is one of the key elements of the Koralm high-capacity railway line, which connects the cities of Graz and Klagenfurt in the south of Austria. The Koralm railway line is part of the Baltic-Adriatic Axis, which represents the easternmost crossing of the Alps and links several Eastern European countries and Vienna with southern Austria and northern Italy. The Koralm line is a 130-km-long high-capacity railway line engineered for a design speed of 200 km/h.


**Figure 1: Overview map**

In the centre section of the Koralm line lies the Koralm tunnel, which underpasses the Koralpe mountain range at a depth of up to 1,200 m. Its length of 32.8 km makes the Koralm tunnel the longest railway tunnel located entirely within Austrian territory.

Following the route selection procedure and the environmental impact assessment, the first construction permit in compliance with railway law was issued in 2006. At the moment, exploratory measures involving pilot tunnels and deep drillings are being implemented in the tunnel area. The construction works are scheduled to start in 2008.

## 3 DECISION ON 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 was to consider both construction phase and operating phase criteria. With a view to 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:

- Two single-track tubes each with a cross-section of 52 m²
- Cross-passages connecting the tubes at a 500 m spacing
- One emergency station in the centre of the tunnel with no direct link to the surface
- No crossover inside the tunnel

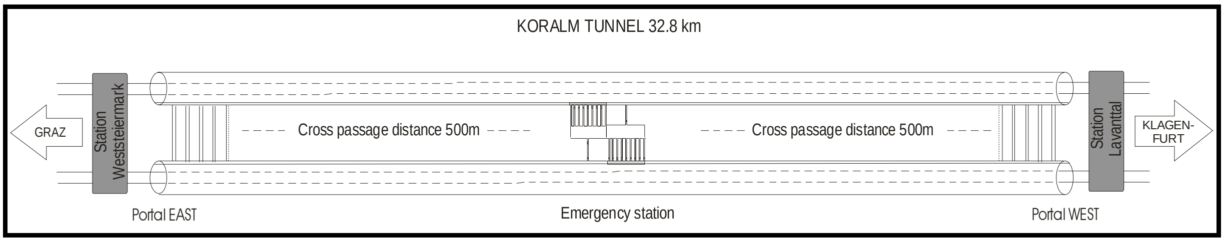


**Figure 2: Tunnel system Koralm tunnel**

The twin-tube system, which has in the meantime been included in the UIC Guideline [1], is recommended for very long railway tunnels and represents state-of-the-art technology for such tunnel structures.

Emergency exits in new railway tunnels are – in analogy to the Guideline issued by the Austrian Fire Fighters Association [2] – currently constructed with a standard spacing of 500 m, regardless whether they lead to a second tube or to the surface. This standard spacing has also been adopted for the Koralm tunnel.

A train operation simulation was performed to decide whether a crossover would be needed in the Koralm tunnel. This crossover would primarily be used for maintenance works, since 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 even if maintenance works are to be performed, a sufficient train operation quality can still be ensured. Safety considerations (switches, strict separation of tunnel tubes) as well as the need for additional maintenance activities were facts speaking against a crossover.

## 4 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:

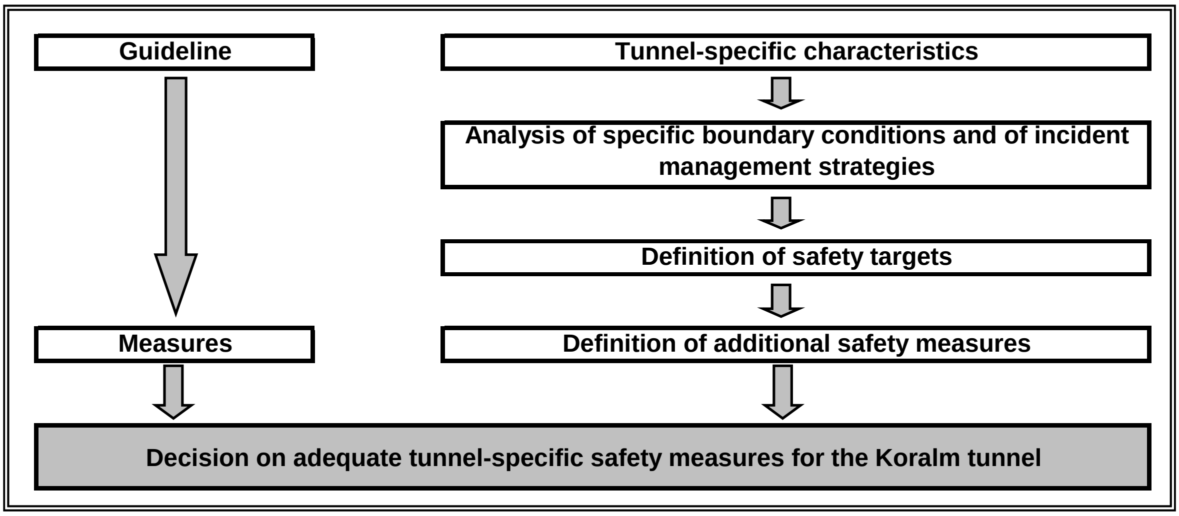


**Table 1: Procedure adopted for the definition of safety measures**

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

As Table 1 illustrates, several analyses were performed to reflect the special boundary conditions of the Koralm tunnel. One of these analyses will be described in Item 7 - Analysis of incident management based on traffic scenarios.

## 5 NECESSITY, LAYOUT AND INSTALLATIONS OF EMERGENCY STATION

<u>Necessity</u>

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) [3] states that, in case of a fire, the running capability of a train set 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 reaching a safe area decreases. It is in response to these findings that the guidelines [1] [2] [3] call for special measures in tunnels exceeding a length of 20 km.

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, which is no longer capable of leaving the tunnel, as its running capability has reached its limits, is brought to a halt in the emergency station, which provides a favourable environment for the train to be evacuated.

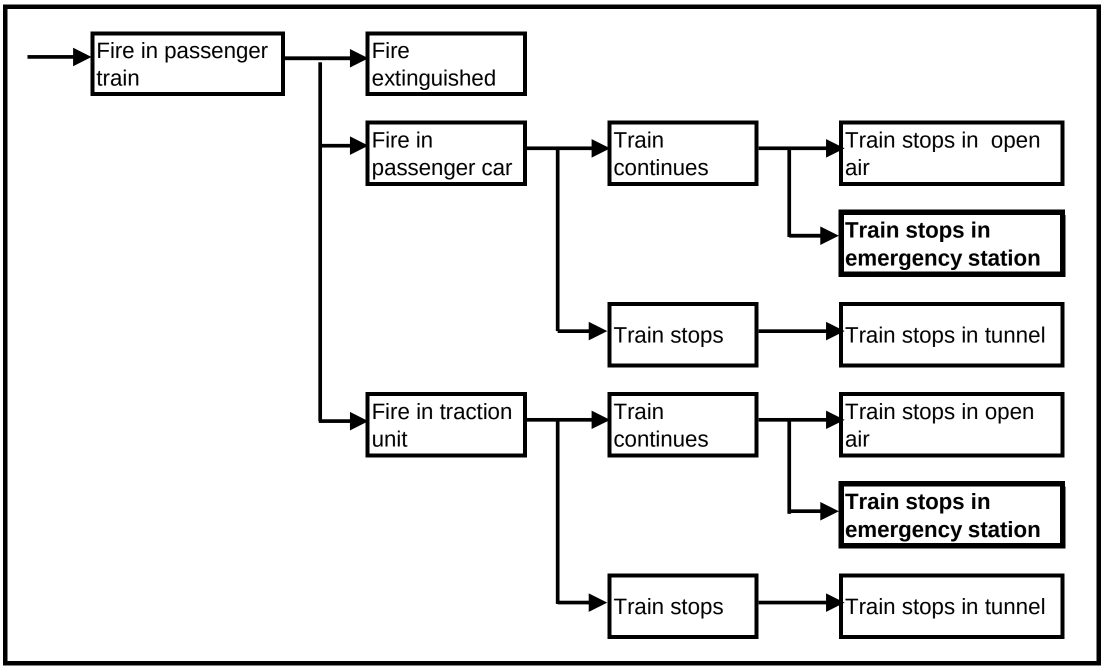


**Figure 3: Simplified event tree for fire in passenger train**

As the event tree in Figure 3 illustrates, a burning passenger train may either come to a stop outside the tunnel, in the emergency station or at any other location inside the tunnel, whereas a burning traction unit has a higher probability of losing its driving force and coming to a halt in the tunnel.

The analysis performed for the Koralm tunnel produced the following probability ranking. The probability of the train leaving the tunnel received a higher ranking than that of the train stopping in the emergency station and this in turn received a higher ranking than that of the train stopping at any location inside the tunnel.

In the course of a sensitivity analysis, a reduction of the cross-passage spacing was investigated as alternative to the provision of an emergency station. This study indicates that an emergency station is still the preferable solution.

Layout and Installations

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

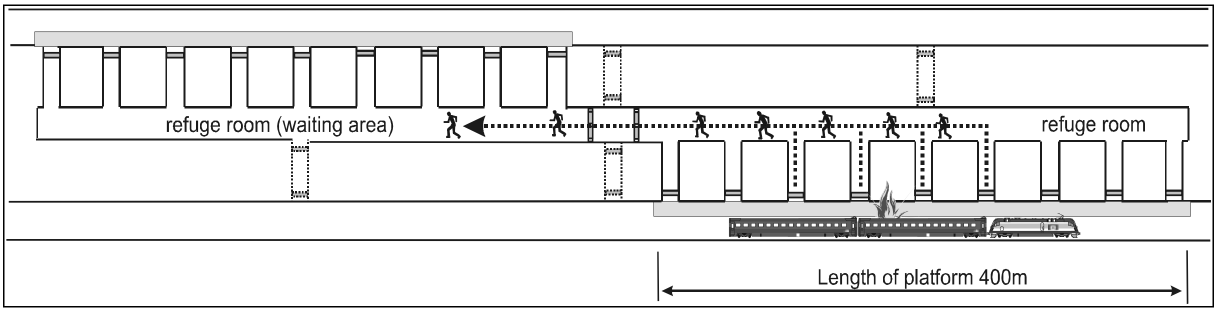


**Figure 4: Layout of emergency station**

Between the two tunnel tubes, a refuge room is located in the emergency station area, which is connected to the platforms via cross-passages provided at a 50 m spacing. As Figure 4 shows, a staggered platform arrangement is chosen, which results in an approx. 800-m-long refuge room.

A lock is used to divide the refuge room into two equally large parts. At the emergency exits leading from the platform to the cross-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.

The evacuation to a safe area outside the tunnel will predominantly be accomplished by passenger trains.

This emergency station arrangement offers the following advantages:

- From a fire protection perspective, the waiting area is clearly separated from the platform area.
- People leaving the train cover a distance of approx. 400 m (see Figure 4), in other words they definitely 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 cross-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 has been made 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 5).

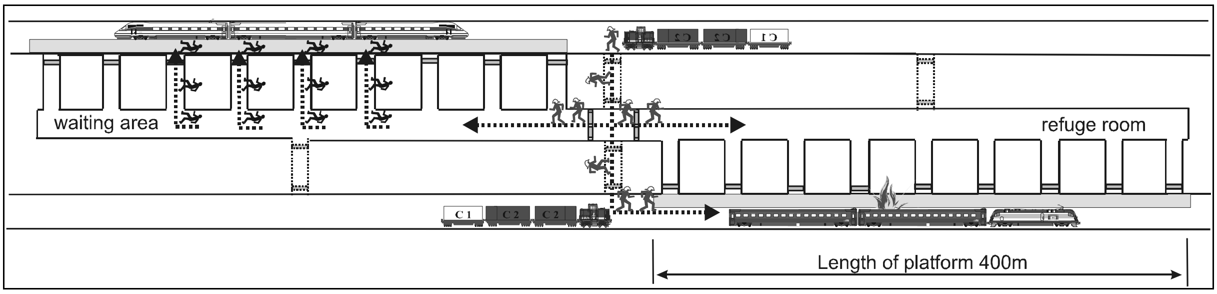


**Figure 5: Evacuation train and rescue train in emergency station**

The ventilation system of the Koralm tunnel creates an air flow at the emergency exit doors, which is designed to keep smoke from entering the refuge room. This also allows a controlled air exchange in the waiting room.

The emergency station shall be equipped with the following facilities:

- Emergency telephone
- Video surveillance and loudspeaker system for announcements
- Lighting system comparable to that of a station
- Seating accommodation
- The provision of separate areas for the treatment of injured persons and for toilets is still being discussed

## 6 DEVELOPMENT OF 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.

<u>Railway operation</u>

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, which have passed the scene of the accident, 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.

A highly critical scenario as regards operational measures is created, when during a fast stoppage of a passenger train, people are trying to escape into the second tube, where another train is approaching the accident scene. It is generally assumed that even under these conditions, a fast communication between the incident train and the control centre and an immediate implementation of emergency measures will eliminate the risk caused by train traffic in the second tube. No final decision has as yet been made on the way how these operating instructions shall be communicated to the trains and on the question which emergency measures shall be taken immediately. A controlled locking of the cross-passage doors to keep tunnel users from entering the second tube, shall however be prevented under all circumstances, as a malfunctioning or a faulty operation of these doors could create additional risks and would further increase the complexity of the system.

<u>Self-rescue, evacuation</u>

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 and 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 can only be developed in connection with the operating programme at a later stage, shortly before the tunnel will be opened to traffic.

<u>Assisted rescue, rescue train</u>

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 designed to be carried out from both sides.

In Austria, a rescue concept has been developed for several new high-capacity railway tunnels, which literally paves fire brigades the way into the tunnel by providing a permanent way, which is accessible to road vehicles. Analyses have been made to check whether this system could also be implemented at the Koralm tunnel. These studies revealed a significant lack of experience with tunnels of this length. Even the longest Austrian road tunnel is less than half as long as the Koralm tunnel. Another argument supporting the rescue train concept consists in the organisational structure of the fire brigades positioned in the vicinity of the portals. The voluntary fire brigades are not trained to assume the sole responsibility for an assisted rescue operation.

## 7 ANALYSIS OF INCIDENT MANAGEMENT BASED ON TRAFFIC SCENARIOS

Due to the extensive length of the Koralm tunnel, there is a high 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.

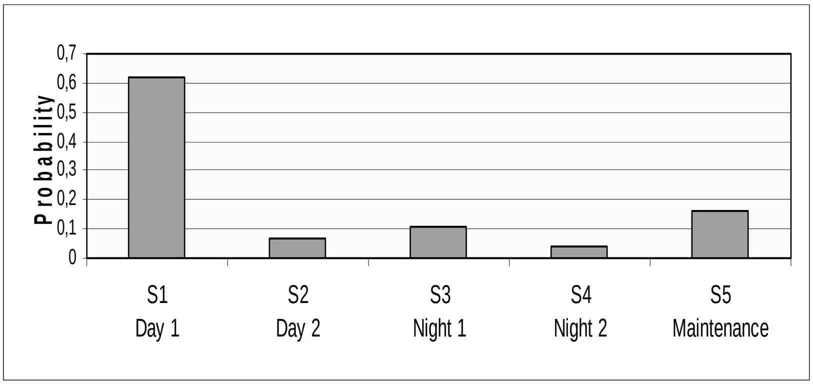


**Figure 6: Probability of train schedule scenarios S1-S5**

As can be seen from Figure 6, Train Schedule Scenario 1 (Day 1) reflects the most common operating scenario. This is the reason why this train schedule scenario has been used as a basis to analyse operating sequences and to define simple emergency response sequences.

Subsequent to this initial step, the analysis has further been extended to all other train schedule scenarios to determine whether the selected response sequence would also be suited for these cases.

As, for several hours at night, operation will completely be limited to freight trains, no self-rescue and no evacuation analysis had to be performed for this period.

Boundary conditions, 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 following assumptions were taken into consideration.

| | |
|---|---|
| Travelling speed – evacuation train | 80 km/h |
| Travelling speed – rescue train | 80 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 |

**Table 2: Assumptions made regarding operating sequences**

In the endeavour to develop strategies suited to manage emergency incidents, the following topics are to be addressed:

- o How will other trains, which are also inside the tunnel together with the incident train, be led out of the tunnel?
- o Which train will be used to evacuate passengers and crew members and from which side shall the tunnel be entered?
- o From which side and through which tube will the rescue trains drive into the tunnel (are there several options)?

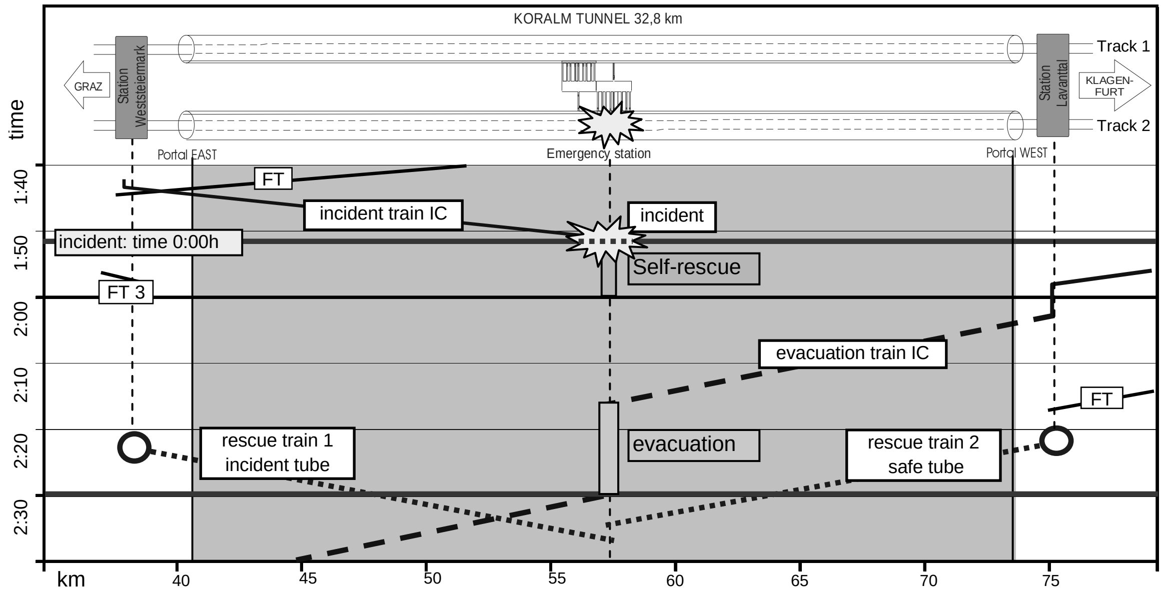


**Figure 7: Time-distance diagram illustrating the incident management of Scenario S1 (example)**

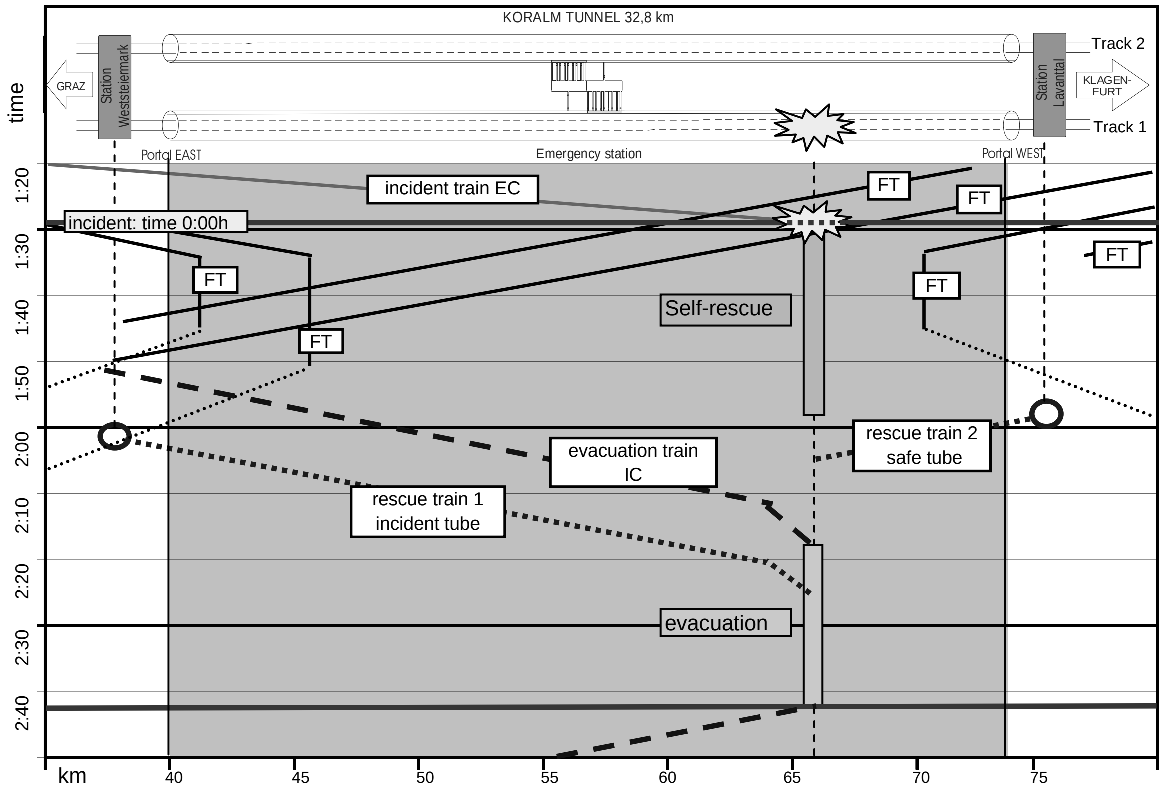


**Figure 8: Time-distance diagram illustrating the incident management of Scenario S2 (example)**

The decision to analyse possible incident management scenarios with the help of time-distance diagrams 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?

## 8 CONCLUSIONS

- When analysing the special characteristics of very long tunnels, specific safety targets required to ensure an equally effective safety level as with shorter tunnels may be identified. The definition of additional measures allows the desired safety targets to be met.
- When designing the emergency station, various aspects have to be considered. By addressing such issues as “integration of the emergency station into the walkway system”, “location of the fire source in relation to the waiting area”, and “interaction between evacuation train and rescue train”, several requirements may be met regarding the structural design of the emergency station.
- When analysing the train movements in case of an emergency in combination with the incident management strategy, the complexity of a very long tunnel is illustrated. The performance of such a detailed analysis allows rescue concept considerations, operational and organisational measures and structural safety measures to be brought into tune.

REFERENCES

[1] UIC – Codex 779-9E, Safety in Railway Tunnels, 1. Edition, August 2003

[2] 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

[3] TSI-SRT, Safety in Railway Tunnels, Draft 07/2006