ALARP and cost-benefit of safety measures for the evacuation concept of a long Norwegian railway tunnel

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Overview

- The problem
- The system
- Probable fire scenarios
- CFD studies
- Risk assessments
- Evaluating risk-reducing measures
- Conclusions

The problem

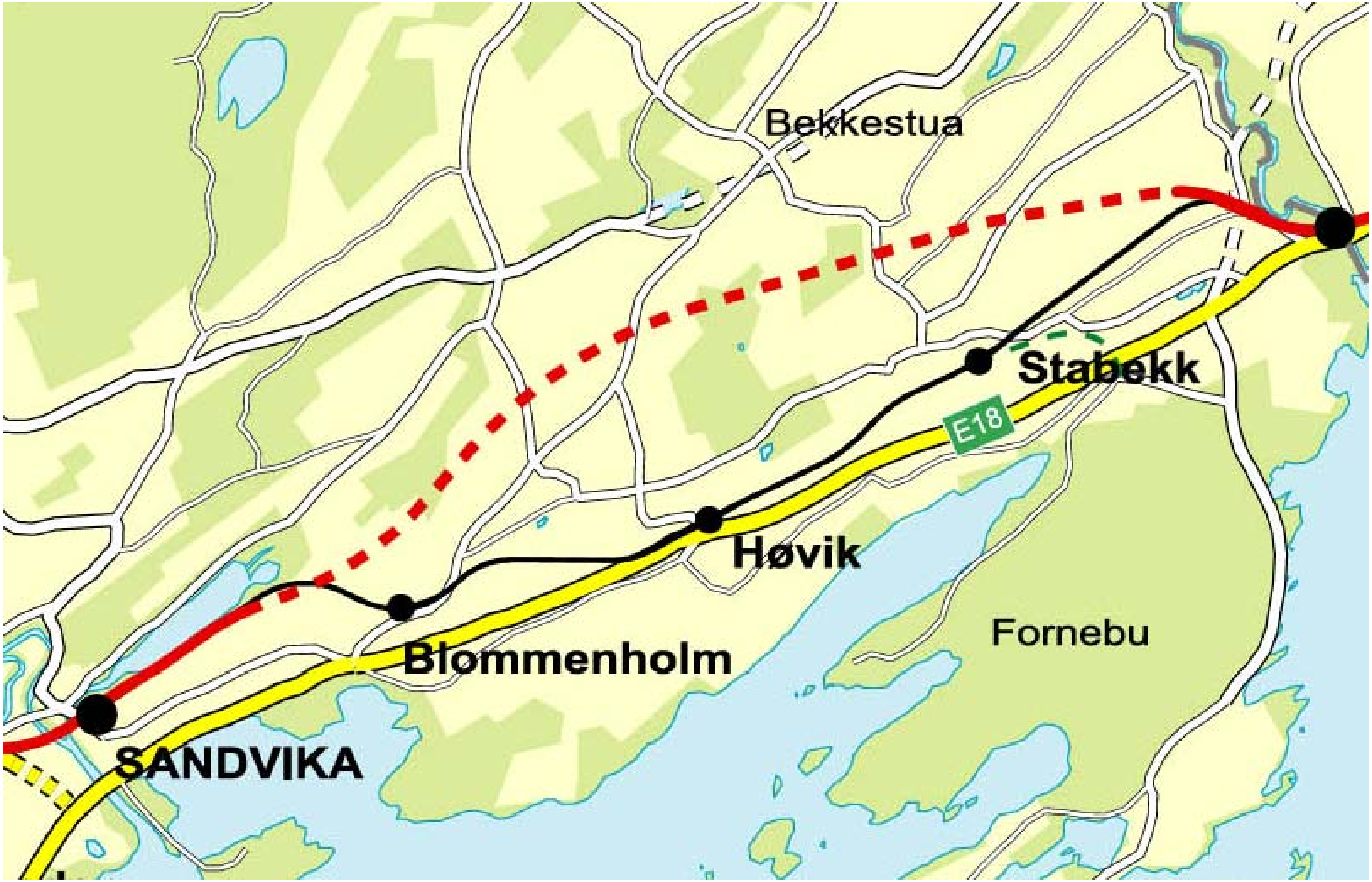
ALARP based acceptance criteria and new safety regulation requiring EN 50126

Copy of previous concept not feasible

Numerous costly measures proposed

Which measures may be justified?

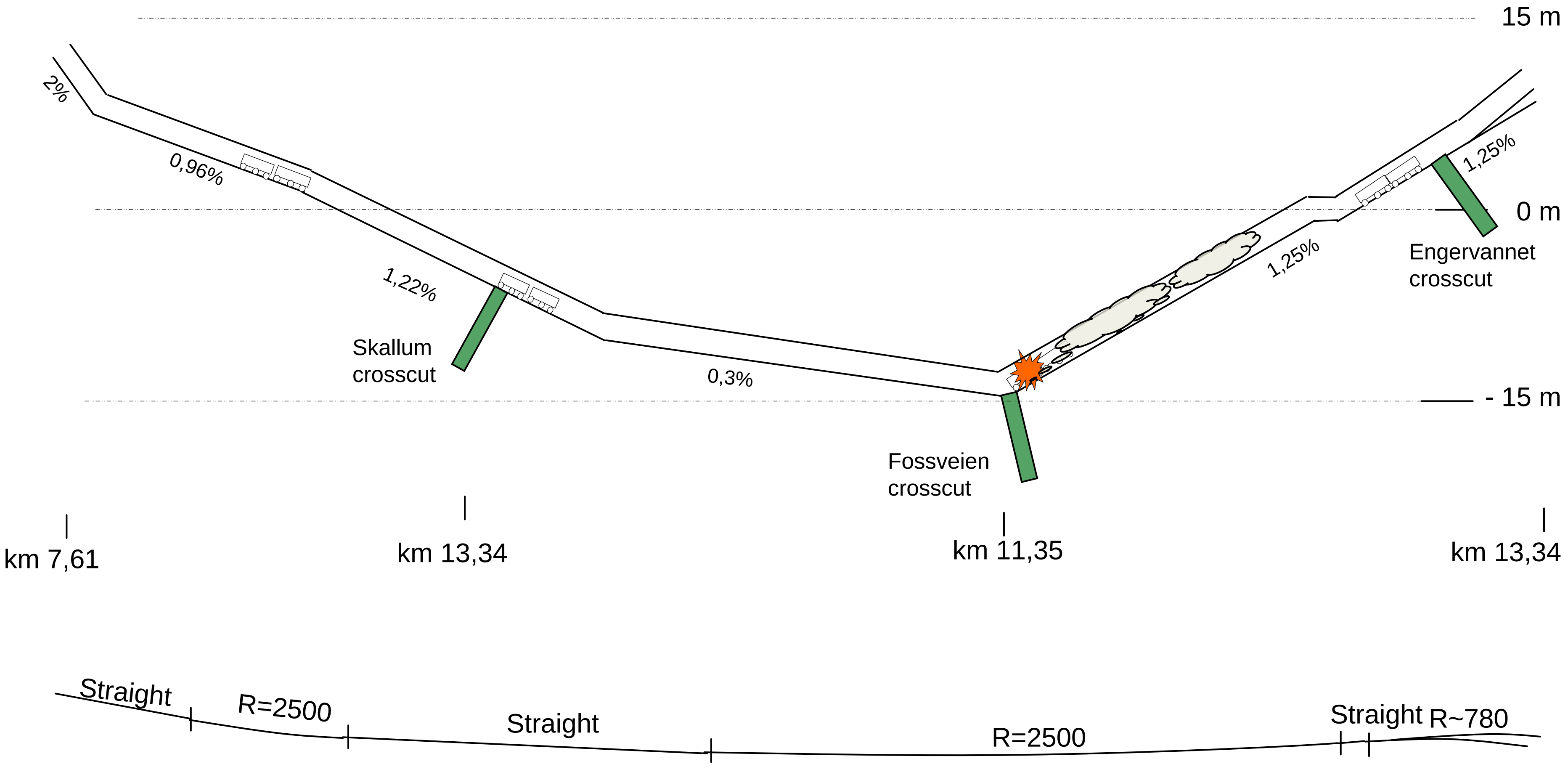
The system, Bærumstunnelen



The system, some data

Attribute	Value	Unit	Comment
Total length	5,7	km	
Cross-section, w x h	~13 x ~8	m^2	Curved ceiling
Distance low-point to opening	~2 and 3,7	km	Horizontally
Height low-point to opening	27 and 22	m	Vertically
“Steep” sections	~1,85 and ~2	km	Grade: ~1,2%, each end
“Flat” section	1,8	km	Grade: 0,3%
Design speed	160	km / h	The majority of the pass. trains
Crosscuts	3	-	Used for tunnelling
Additional exits	3	-	Due to TSI requirement
Expected number of trains	~110 000	/ year	Both directions
Fraction passenger trains	~90%	-	4% freight trains, 6% empty trains
Fraction of double train-sets	~25%	-	Of the passenger trains

Sketch of Bærumstunnelen



Potential risk reducing measures

- Additional exits
- Forced ventilation
- Separate evacuation tunnel, entire or in sections
- Smoke extraction at crosscuts
- Segmentation of the overhead catenaries
- Plattform at the station entry signals

The problem of selecting approach

- What is the clue, is this dangerous?
- Which scenarios should prevail?
- What is dangerous in a railway tunnel? (that requires attention in the evacuation concept?)

Selection of fire scenarios

Aim: Select a ”reasonable worst case”

- One that is rarely exceeded

Solution:

- Work by Haukur Ingasson and SP consulted
- Accident investigation inquiry reports consulted

Result:

- 30 MW for a passenger train wagon
- 150 MW for a freight train wagon
- Rapid fire growth to flashover
  - 10 min, 7 min after train stopped

CFD studies

Given design fires, burned material (smoke production):

- Rapidity of smoke spread?
- Thickness (composition) of smoke?
- Influence of fans?

Human response

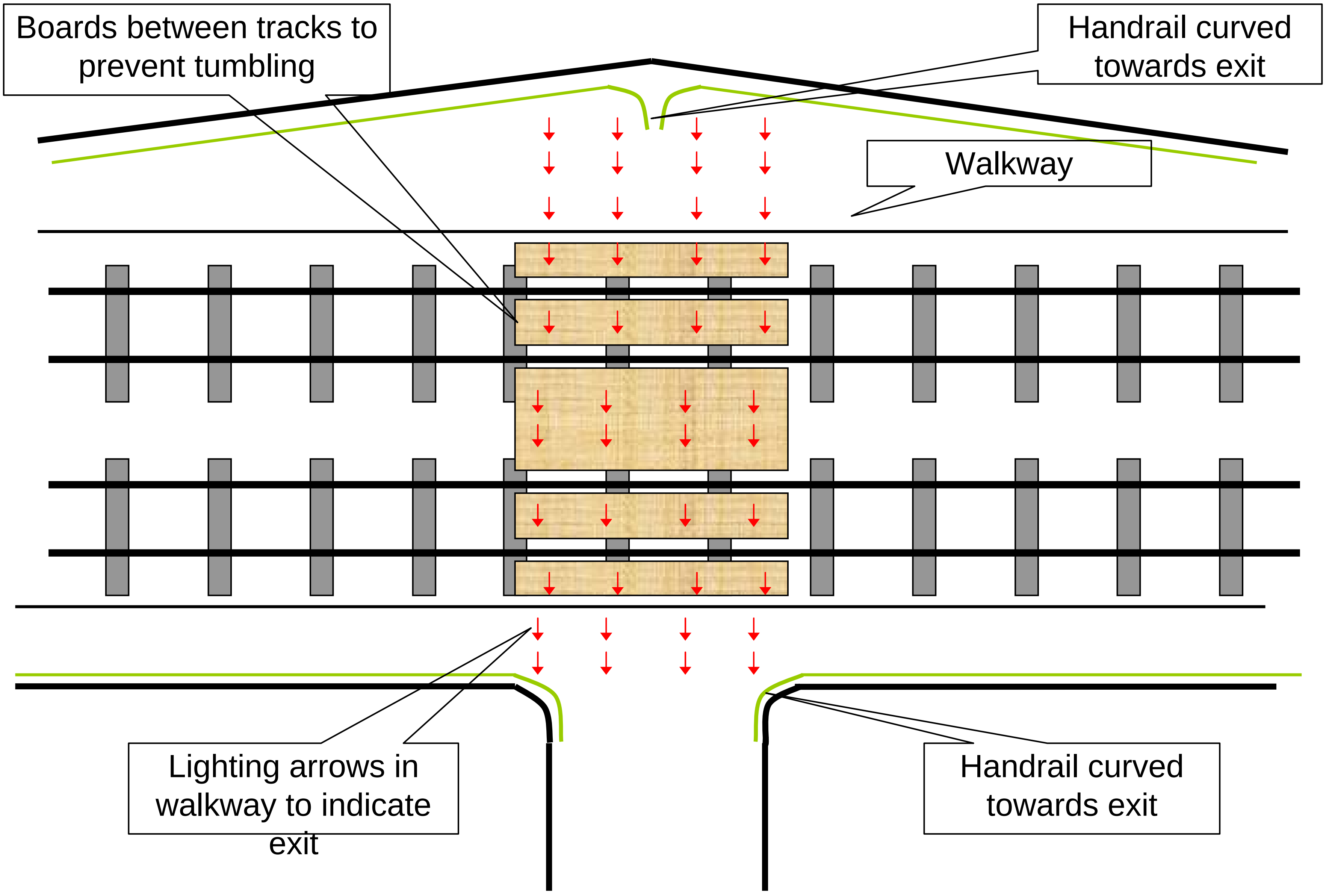
What is likely time required to open doors of a train on fire in a tunnel?

How far may a person walk in smoke?

What concentration x time may a person survive?

Important to find the first exit!

Marking the exits



Risk assessments

Fire consequences

- Smoke spread and time to evacuate
- Passing the location of fire

Probabilities

- Incident database consulted
- Probability of large fires given fire incident
- Probability of undetected fires
- Probability of a stopping fire

Evaluation of measures

Forced ventilation 

Segmenation of the catenary 

Evacuation tunnel 

Smoke extraction 

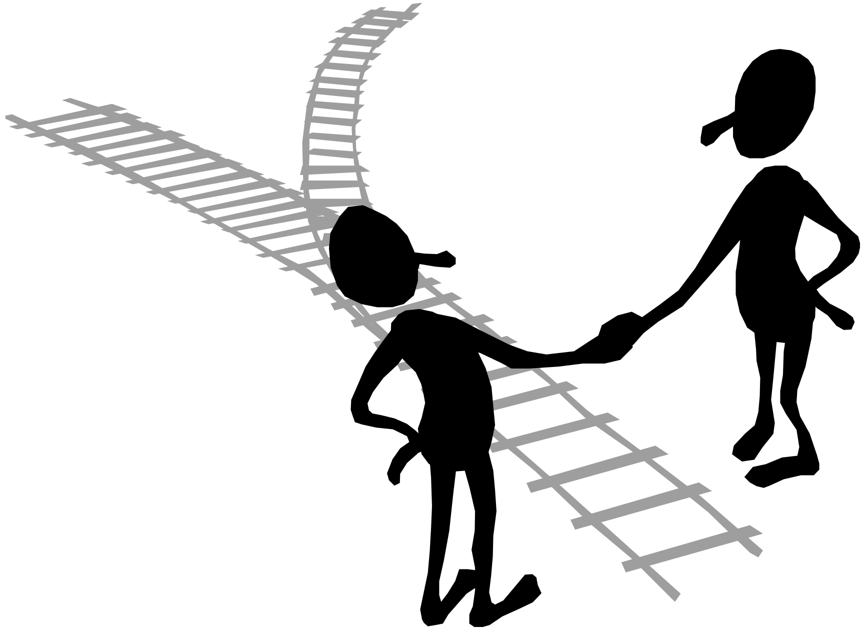
Platform at station entry signal 

Conclusions

ALARP process works!

There is no link between cost and benefit of measures

The results obtained are valid for this tunnel only



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