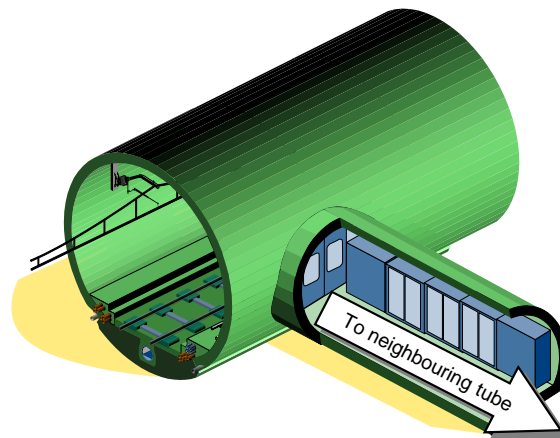


Cross-Passages in Rail Tunnels - Technical & Legal Requirements

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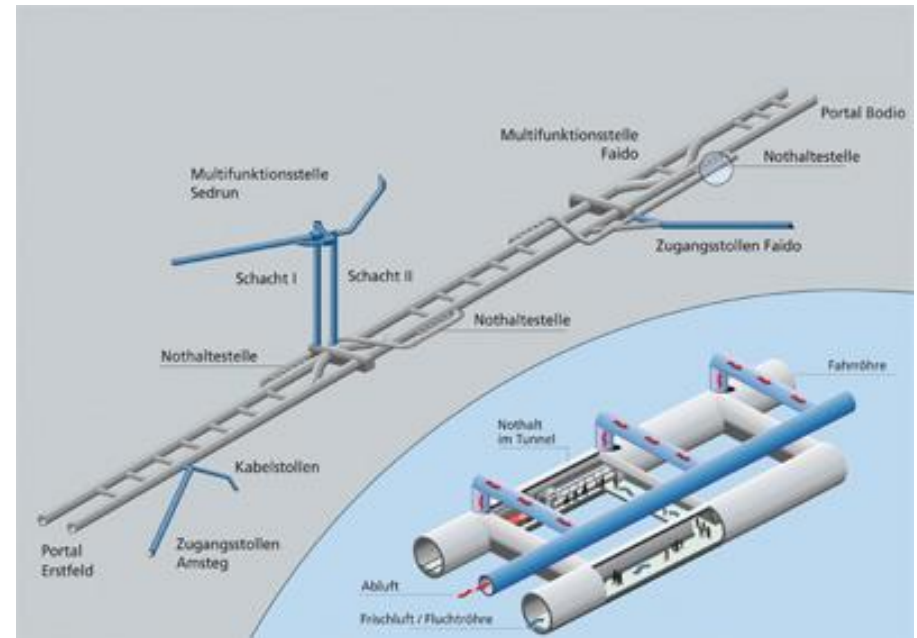


Motivation

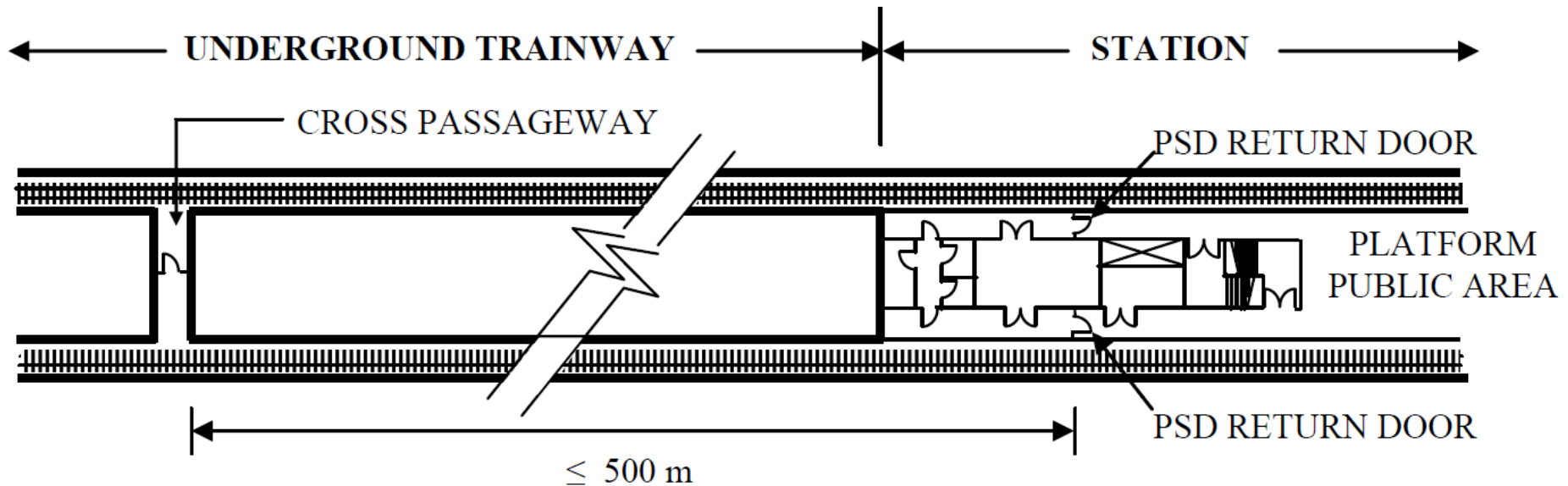
- Cross-passages are specified in many tunnels to facilitate self-rescue and intervention
- Construction can be technically challenging and expensive
- To what extent are such cross-passages legally required?

Overview

- Standards & practice
- Challenges in design & construction
- Legal requirements and tests
- Example application



Metro Tunnel Cross-Passages



Rail Tunnel Cross-Passage Spacing

Standard	Territory	Maximum Cross-Passage Spacing (m)
NFPA-130	North America / International	244
AS 4825	Australia	240
TSI	Europe	500
SFSRTS	Singapore	250

Rail Tunnel Walkway





Genesis of NFPA-130 Guideline

- NFPA-130 based on 800 feet (244 m) cross-passage spacing
- Derived from the MARTA (Atlanta) Subway project.
- Distance people could walk downstream of a train fire site before flashover occurred and made the downstream environment untenable

European Rail Tunnel Projects

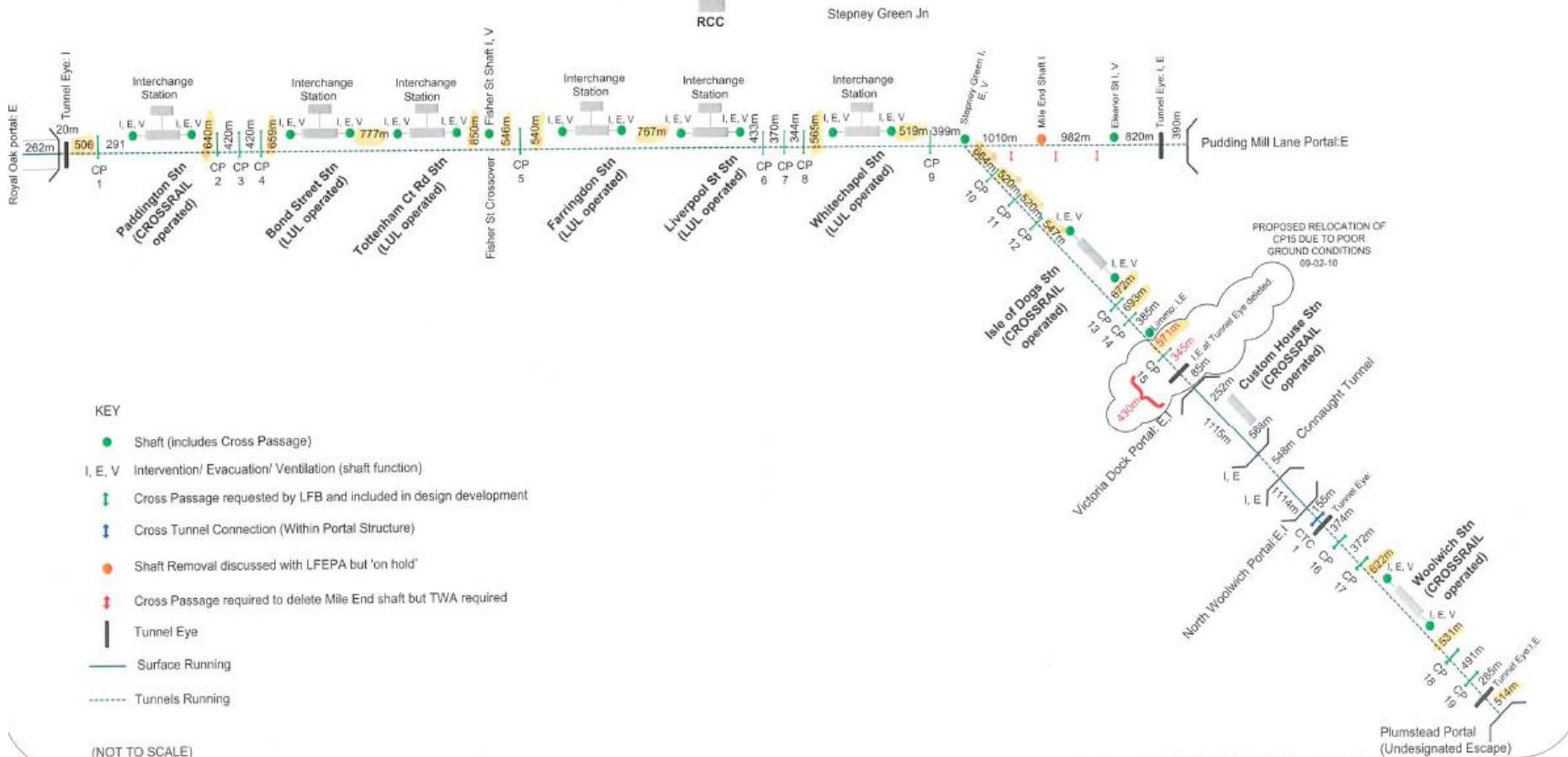
Project	Country	Maximum Cross-Passage Spacing (m)
Gotthard Base Tunnel	Switzerland	312
Brenner Base Tunnel	Austria - Italy	333
Mont d'Ambin Base Tunnel	France - Italy	333
Lötschberg Base Tunnel	Switzerland	333
Eurotunnel	UK - France	375



Crossrail, London

- The London Crossrail scheme has cross-passages at approximately 500m spacings, with a maximum spacing of up to 693m, after negotiation with the London Fire Brigade.

Crossrail, London





Challenges in Cross-Passage Construction

- Urban environment with existing buildings, foundations and piles
- Pre-existing tunnels and underground spaces
- Airport runways sensitive to settlement
- Soft ground tunnelling
- River-crossing tunnels



Legal Requirements

- Focus on common law countries (UK, Australia, Singapore)
- Outline of civil law requirements in Europe



Risk Assessment - 1

- Management of Health and Safety at Work Regulations (1999):
- “Suitable and sufficient risk assessments”



Risk Assessment - 2

- The Regulatory Reform (Fire Safety) Order 2005:
- Duty on the “responsible person” to make a suitable and sufficient assessment of the risks to which relevant persons are exposed.



Good Practice

- Health and Safety Executive, UK: risk mitigation measures established by “good practice” should be considered as a means of discharging the duty-holder’s duty of care.
- Guidelines and standards can be considered “good practice” which establish a baseline risk level.



Alternative Measures

- Article 2.3.6 of EU Regulation No 402/2013:
- “Where an alternative approach is not fully compliant with a code of practice, the proposer shall demonstrate that the alternative approach pursued leads to at least the same level of safety”

Common Law

Edwards v National Coal Board [1949]:

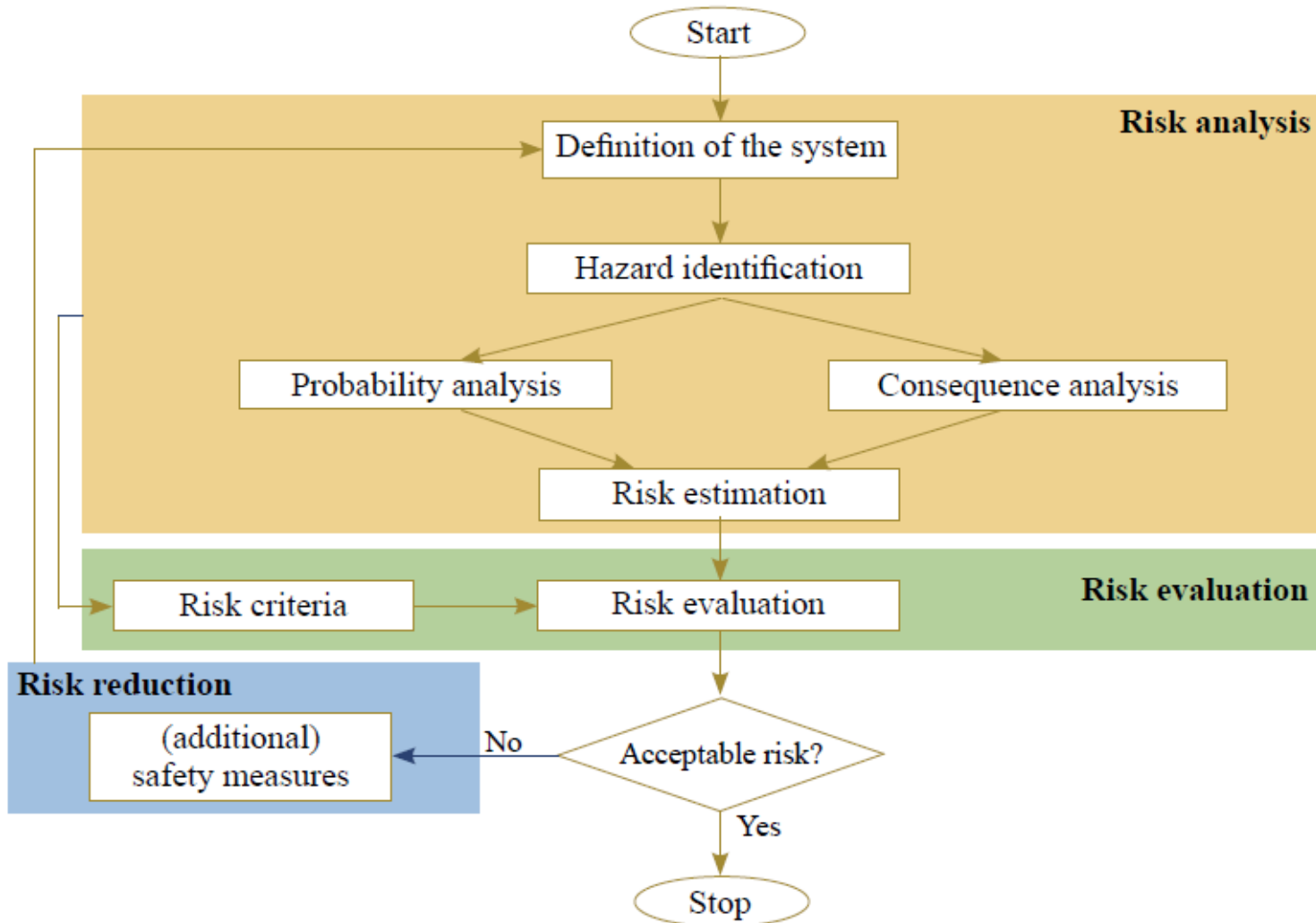
“... a computation must be made by the owner in which the **quantum of risk** is placed on one scale and the sacrifice involved in the **measures necessary for averting the risk** (whether in money, time or trouble) is placed in the other, and that, if it be shown that there is a **gross disproportion** between them – the risk being insignificant in relation to the sacrifice – the defendants discharge the onus on them”



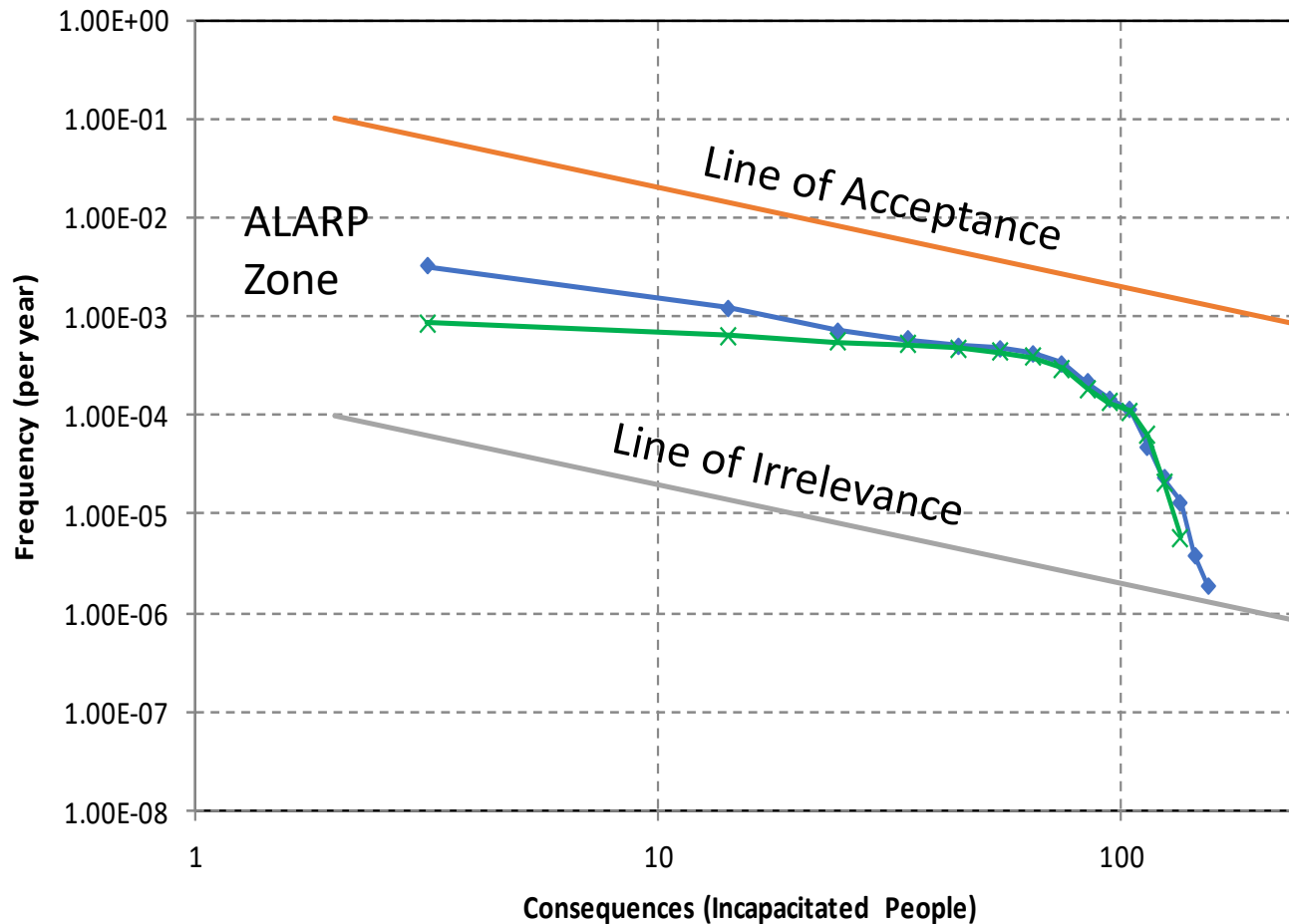
Cost / Benefit Ratios

- Cost/Benefit ratios in safety submission to Health & Safety Executive for the 1987 Sizewell B Inquiry:
- Up to 3 for workers
- Up to 2 for low risks to public
- Up to 10 for high risks

Risk Assessment Process



Typical Frequency-Consequence Diagram





Departures from Standards

- Existing design forms baseline risk (e.g. Australia, EU's Common Safety Method)
- Alternative designs can pass the test if integrated risk is the same or less



Fire Scenarios

- Majority of train fires will be small (< 5 MW)
- Evacuees will preferably walk upstream of the ventilating airflow (into safety)
- Evacuees walking downstream of the fire are unlikely to survive for large fires, regardless of cross-passage spacing

Cost/Benefit Ratios

- Very low risk of train fires
- Cost/Benefit ratios for additional cross-passages typically $\gg 10$
 - Do not merit legal enforcement on the basis of cost/benefit
- BUT other mitigation measures may be necessary to reduce the level of risk to ALARP



Potential Mitigation Measures

- More fire-resistant rolling stock
- Heat detection at portals (for brakes & transformers)
- Fire suppression (infrastructure or rolling-stock)
- Fire and smoke detection
- Smoke ventilation



Summary

- Standards for cross-passage spacing imply a certain 'baseline risk'
- If spacing is increased:
 - Marginal increase in life safety risk
 - Other measures may be required
- Reduction in spacing generally not justifiable from Cost/Benefit perspective



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