

Comparison of Road Tunnel Design Guidelines

Hak Kuen Kim

Anders Lönnermark

Haukur Ingason



SP Technical Research Institute of Sweden



National Emergency Management Agency

Introduction

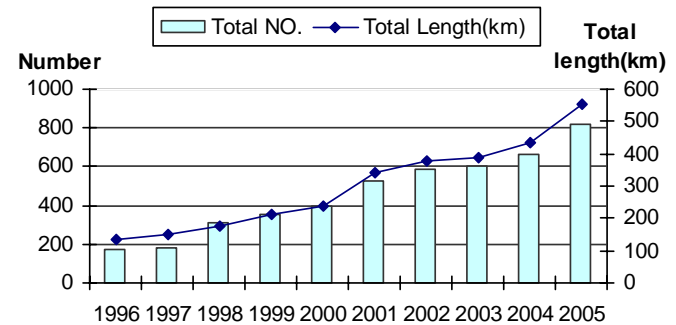
Increasing number
of road tunnels



Disastrous fires
in road tunnels



Examination of existing guidelines



Mont Blanc tunnel fire
Sturrottunnel fire in 1999 2001

Questions

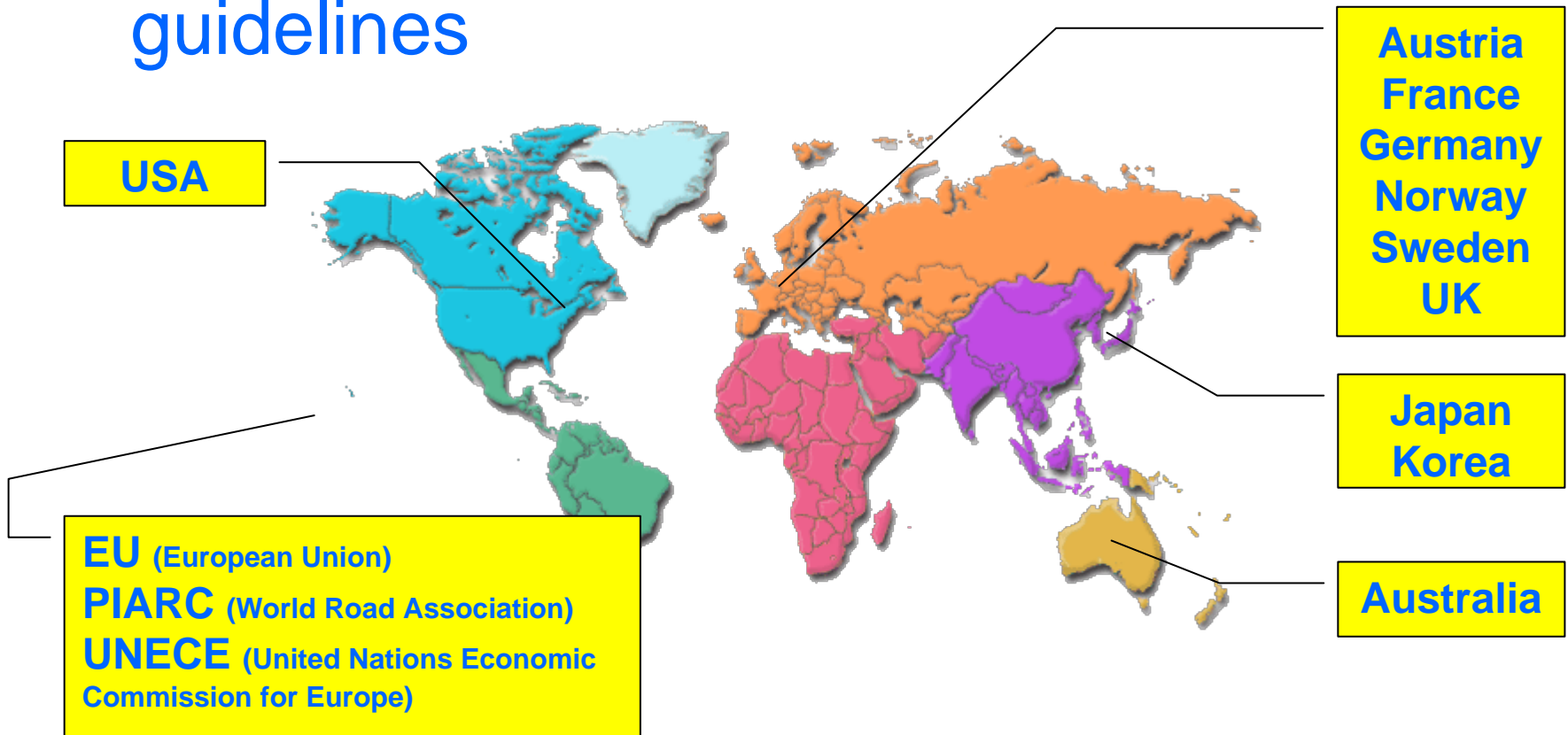
- Are existing fire safety requirements of road tunnels acceptable enough to satisfy society's demand?
- Is it necessary to develop new requirements to tackle upcoming threats?
- To what extent should existing or new requirements be revised or developed?

Objectives

- To evaluate standard fire safety levels of different countries.
- To provide meaningful information from which beneficial conclusions can be derived for improvement to future tunnel safety worldwide.
- To propose specific recommendations for Korean fire and road authorities.

Method

- Comparison of fire safety design guidelines



Fire Safety Design Guidelines

Country	Title	ID	Type	Publisher/Year
Australia	Fire Safety guideline for road tunnels	-	Guideline	Australasian Fire Authorities Council (2001)
Austria	Guidelines and Regulations for Road Design	RVS	Guideline	Transportation and Road Research Association (2001)
France	Inter-ministry circular n°2000-63 of 25 August 2000 relating to the Safety of tunnels in the national highways network	Circ 2000/63A2	Regulation	Ministry for infra structure, transport, spatial planning tourism and the sea (2000)
Germany	Guidelines for equipment and operation of road tunnels	RABT 02	Guidelines	Road and Transportation Research Association (2002)
Japan	Design Principles, Volume 3 (Tunnel) Part (4) (Tunnel Safety facilities)	-	Guideline	Japan Highway Public Corporation (1998)
Korea	National Fire Safety Codes	NFSC	Regulation	Korea National Emergency Management Agency (2005)
	Guideline for Installation of Safety facility in road Tunnels	GIST	Guideline	Ministry of Construction & Transportation (2004)
Norway	Roads Tunnels	Håndbok 021	Guideline	Norwegian Public Roads Administration, Directorate of Public Roads (2004)
Sweden	Tunnel 2004	Tunnel 2004	Guideline	Swedish National Road Administration (2004)
UK	Design manual for roads and bridges, Volume 2 Highway structure design Section 2, Part 9, BD 78/99: Design of road tunnels	BD78/99	Guideline and Requirement	The Highway Agency (1999)
USA	Standard for road tunnels, bridges and other limited access highways	NFPA 502	Standard	National Fire Protection Association (2004)
EU	Directive 2004/54/EC of the European parliament and of the council	Directive 2004/54/EC	Directive	European Parliament and the Council (2004)
PIARC	Fire and Smoke Control in Road Tunnels	PIARC	Guideline	PIARC (1999)
UNECE	Recommendations of the Group of Experts on Safety in Road Tunnels. (Final Report)	TRANS/AC.7/9	Guideline	UNECE Ad hoc Multidisciplinary Group of Experts on Safety in Tunnels (2001)

Application criteria

- **The installation of required facilities is decided mainly based on the length of tunnels.**
 - Other criteria
 - Traffic volume : Japan, Norway, Sweden and UK
 - Danger potential : Austria
 - Risk analysis : Korea
 - Location, traffic type, risk of congestion and human supervision : France or Germany

Minimum length of tunnels

- The minimum length of tunnel for application varies from country to country.

Country	Minimum length for application.
Germany and Korea	All tunnels
USA	90 m
Japan and Sweden	100 m
UK	150 m
France	300 m
Norway and EU	500 m

Traffic volume

- The minimum values of traffic volume adopted by guidelines vary.

Country	Minimum values of AADT	Estimation year of AADT after opening
Sweden	100	20
UK	100	15
Norway	250	20
Japan	500	10
Korea	No limit	20

✓ AADT: Annual Average Daily Traffic

Comparison

- Totally 27 fire safety equipment or safety measures are described and compared.
- Selected 2 features
 - Hand held extinguishers
 - Equipment resistance to fire

From the report

Fire safety equipment	Australia	Austria	France	Germany	Japan	NFSC Korea	GIST Norway	Sweden	UK	USA	EU	PIARC	UNECE	
Fire fighting facilities														
Hand held extinguishers	•	•	•	•	•	•	•	•	•	•	•	•	▲	
Water supply and hydrants	•	•	•	•	•	•	•	•	•	•	•	•	▲	
Fire department connections	X	X	X	X	X	X	X	X	X	X	X	X	X	
Fixed fire suppression system ^{a)}	•	•	X	X	•	X	•	•	X	•	X	▲	▲	
Fire detection and communication														
Manual fire detection system	X	•	▲	•	•	•	•	X	•	•	•	X	▲	X
Automatic fire detection system	X	•	•	•	•	•	•	X	•	•	•	•	▲	X
Loudspeakers	X	•	▲	•	•	X	•	X	•	X	X	•	▲	▲
Emergency telephones	•	•	•	•	•	X	•	•	•	•	X	•	▲	X
Radio communication systems	X	•	•	▲	•	•	•	•	•	•	•	•	▲	•
Structural measures relevant to safety														
Parallel escape tube	▲	▲	▲	▲	•	X	•	X	X	▲	X	X	▲	▲
Emergency cross-passage	X	•	•	•	X	•	•	•	•	•	•	•	▲	•
Tuning areas	X	•	•	•	X	X	•	X	•	X	•	X	X	X
Emergency access for rescue staff														
Separate galley for emergency vehicles	X	▲	X	•	X	X	X	X	X	X	X	X	X	X
Cross-passage for rescue vehicle	X	•	•	X	X	•	X	X	X	X	X	•	•	•
Emergency services parking	X	X	•	X	X	X	X	X	•	▲	X	X	X	X
Lighting														
Emergency lighting	X	X	•	•	•	•	•	•	•	•	•	•	•	X
Smoke extraction ventilation														
Smoke control ventilation	X	▲	•	•	•	•	•	▲	•	•	•	•	•	•
Signage														
Traffic signals outside the tunnel	X	•	•	•	•	X	•	•	•	•	•	•	X	X
Traffic signals inside the tunnel	X	X	•	•	•	X	•	•	•	•	•	•	X	▲
Emergency exit sign	X	X	•	•	•	X	•	X	•	X	X	X	•	•
Monitoring equipment														
CCTV	•	•	•	•	•	X	•	•	•	•	•	•	•	•
Power supply														
UPS and emergency generator	▲	•	•	•	•	•	•	•	•	•	•	•	•	X
Fire brigade power tool sockets	X	X	•	•	X	•	•	X	X	•	X	X	X	X
Drainage of flammable liquids														
Inclination (slope) of tunnel	X	•	•	X	X	X	X	X	•	•	X	X	X	X
Liquid sump	▲	•	•	•	X	X	X	X	•	•	▲	•	X	X
Response of structure and equipment to fire														
Structural fire resistance	▲	•	•	•	X	X	X	•	•	•	▲	▲	X	▲
Equipment resistance to fire	▲	•	•	•	X	•	•	•	•	•	•	▲	X	X

Hand held extinguisher

Country		Application criteria	Capacity	Spacing	Automatic alarm
Korea	NFSC	All tunnels	Two 3.3 kg (≥ 3 unit capacity)	<50 m	-
	GIST	All tunnels	Two 3.3 kg (≥ 3 unit capacity)	<50 m	Extinguisher removal alarms
Australia		-	Dry chemical and CO ₂ extinguishers	60m	-
Austria		>500 m	6 l and 9 l extinguishers	250 m	Automatic alarm
France		≥ 300 m	Two 6 kg	200 m	Extinguisher removal alarms
Germany		>400 m	Two 6 kg (net) extinguishers	<150 m	Automatic alarm
Japan		Class D (≥ 100 m)	Two 6 kg	50 m	-
Norway		Category $\geq B$	Two 6 kg extinguisher	62.5-250 m	Extinguisher removal alarms
Sweden		All classes (≥ 500 m)	6 kg ABC-powder	150 m	-
UK		\geq Class B	Two extinguishers	50 m	-
USA		≥ 240 m	9 kg (maximum)	≤ 90 m	-
EU		≥ 500 m	Two extinguishers	≤ 150 m	-
PIARC		-	The minimum content of 6 kg. The maximum content is 9 kg.	-	Extinguisher removal alarms
UNEC		-	Fire extinguishers should be installed systematically in tunnels and at their entrances.	-	-

Hand held extinguisher

- **The minimum length of targeted tunnels differs:**
 - All tunnels : Korea
 - ***Minimum value for the application of equipment is necessary because safety facilities are useless in very short tunnels.***
 - 100 m : Japan
 - 240 m : USA
 - 300 m : France
 - 400 m : Germany
 - 500 m : Sweden and EU

Hand held extinguisher

- **The minimum capacity:**
 - 3.3 kg (3 unit-capacity): Korea
 - 6 kg : Austria, France, Germany, Japan, Norway, Sweden, PIARC
 - *The capacity of Korean extinguisher is lower than ones of other countries.*
 - *It is necessary for Korea to consider the increase of minimum capacity.*

Hand held extinguisher

- **Maximum installation spacing varies considerably.**
 - 50 m : Korea, Japan and the UK
 - 60 m : Australia
 - 90 m : USA
 - 150 m : Germany, Sweden and EU
 - 200 m : France
 - 250 m : Austria and Norway
 - ✓ *Relationship between capacity and spacing.*

Hand held extinguisher

- **Automatic removal alarms are found in the guidelines of**
 - Austria, France, Germany,
 - Norway, the UK and PIARC.
- **Automatic removal alarms are designed to be raised when extinguishers are removed.**
 - *For rapid response to tunnel fires, automatic removal alarm systems should be included in all guidelines.*

Equipment resistance to fire

<Ventilation fans>

Country		Equipment	The minimum temperature and time
Korea	NFSC	Air supplier and auxiliary equipment of ventilation systems.	250 °C for 60 minutes
	GIST	All electrical and structural components essential to the continued operation of ventilation fans	250 °C for 60 minutes
France		Extraction fans	200 °C for 120 minutes
Germany		Extraction fans	400 °C for 90 minutes
		Jet fans	250 °C for 90 minutes and (in some case) up to 400 °C for 90 minutes.
Sweden		All installations	250 °C for 45 minutes.
UK		All electrical and structural components essential to the continued operation of ventilation fans	250 °C for 120 minutes.
USA		Tunnel ventilation fans and all related components	250 °C for 60 minutes.
EU		The level of fire resistance of all tunnel (≥ 500 m) equipment shall aim to maintain the necessary safety functions.	-

Fire resistance of equipment

<Ventilation fans>

- The minimum fire resistance temperature
 - From 200 to 400 °C
- The minimum fire endurance time
 - From 45 to 120 minutes
 - *It is difficult to judge which combination is more appropriate.*
 - *It is a matter of cost-benefit issues.*

Discussion

- **Further study is needed on relationship between capacity and spacing for firefighting equipment.**

Low capacity
dense spacing.



vs

High capacity
long spacing.



Capacity vesus Spacing

Country	Extinguisher	
	Capacity	Spacing
Austria	6 l and 9 l	250 m
France	6 kg	200 m
Germany	6 kg	150 m
Korea	3.3 kg	50 m
Japan	6 kg	50 m
Norway	6 kg	62.5-250 m
Sweden	6 kg	150 m
USA	9 kg (maximum)	90 m

Country	Hydrant	
	Water flow rate Flow pressure	Spacing
Austria	1200 l/min, 0.6 MPa	250 m
France	1000 l/min, 0.6 MPa	200 m
Germany	1200 l/min, 0.6-1.0 MPa	150 m
Japan	130 l/min, 0.17 MPa	50 m
Korea	130 l/min, 0.17 MPa	50 m

Discussion

- **More attention has been drawn to the Installation of fixed fire suppression systems.**
 - **Installation cases: Australia, Austria, Japan, Korea, Norway, Sweden and USA.**
 - **Europe does not require a water system.**
 - **Japan and Korea: mandated for certain type & traffic.**
 - **Australia: new tunnels are equipped with this systems.**
 - ***It is expected that we will encounter more tunnels with fixed fire suppression systems.***

Conclusion

- **Most requirements depend on the tunnel length.**
- **The minimum tunnel length for application and the minimum traffic volume adopted by guidelines vary from country to country.**
- **Further study is needed on the relationship between the capacity and spacing for firefighting equipment.**
- **More attention has been drawn to the installations of fixed fire suppression systems.**

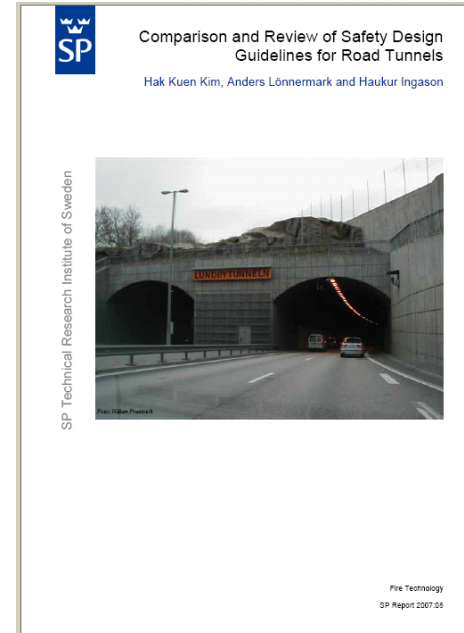
Conclusion

- **Further focus and research on**
 - Verification and assessment of existing requirements or recommendations.
 - Performance-based approach or risk analysis.
 - Reasonable solutions on controversial topics such as a cost-benefit issue and balance between capacity and spacing.

Information

You can see the original report at SP website:
<http://www.sp.se>

Thank you for your
kind attention!



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