



Traffic-Safety Technologies in Tunnels

Backgrounds and Cost-Value-Analysis

Topics

I. Example of the Mont-Blanc tunnel disaster

II. Danger sources (technical / human)

III. Accident statistics from Austria / Swiss

IV. Main important safety facilities in tunnels

V. Cost-Value Analysis

VI. Resumée

I. Example of the Mont-Blanc tunnel disaster

<https://youtu.be/Yzlk66-kGv0>

II. Danger sources

Human

Technical / Constructive

Traffic density

Table 1 : Accident statistics for road traffic tunnels in Austria 1999-2003

Kennzahl	Highway	Motorway	National Road	Tunnel
Accidents UR,Ö 1999-2003	0,137	0,151	0,433	0,104
Accidents with Injuries per 1 Million Fzg-km				
Verunglücktenrate VR,Ö 1999-2003	0,224	0,227	0,662	0,186
Accidents per 1 Million. Fzg-km				
Fatalities GR,Ö 1999-2003	7,4	15,3	20,1	15,4
Fatalities per 1 Milliarde Fzg-km				

Robatsch, K.; Nussbaumer, C., a. a. O., S. 6.

Tabelle 2: Accident statistics in road traffic tunnels in Swiss 1999 - 2003

Key-Figure	Free Road	Tunnel
Accidents rate $U_{R,S}$ 1999 Accidents per 1 Million. Fzg-km	0,47	0,35
Injuries $V_{R,S}$ 1999 Injuries per 100 Million Fzg-km	19,6	19,8
Related to 1 Million Fzg-km $V_{R,Ö}$:	0,196	0,198
Fatallities 1992-2002 Fatalities per 100 Injuries	2,7	2,8

Salvisberg, U.; Allenbach, R.; Cavegn, M. et al.: Verkehrssicherheit in Autobahn- und Autostrassentunneln des Nationalstrassennetzes - bfu-Report Nr. 51/2004. Schweizerische Beratungsstelle für Unfallverhütung (bfu), Bern, 2004, S. 3.

Table 3: Risk increase in % related to double factor of independent variable

Independent variable	Valid scale	Risk of accident	Risk of injuries
Length of tunnel	200 - 17.000 m	- 32 %	- 20 %
Erläuterung:	In einem Tunnel, der zweimal so lang ist wie ein Vergleichstunnel, sind nicht doppelt so viele Unfälle bzw. Verunfallte beobachtbar. Die Unfallzahlen steigen nur um den Faktor 1,68 (=2-0,32) und die Verunfalltenzahlen um den Faktor 1,8 (=2-0,2).		
Traffic density	2.000 - 100.000	+ 77 %	+ 38 %
Erläuterung:	Eine Verdopplung des DTV hat nicht eine Verdopplung des Unfallgeschehens zur Folge, sondern erhöht das Unfallrisiko überproportional um den Faktor 2,77 (=2+0,77) und das Verunfalltenrisiko um den Faktor 2,38 (=2+0,38).		
Tubes142	1 bzw. 2	- 45 %	- 53 %
Erläuterung:	Unfallrisiko und Verunfalltenrisiko sind in einem Tunnel mit Gegenverkehr, ungefähr doppelt so hoch wie in einem Tunnel mit Richtungsverkehr.		
HGV density	2,5 - 23 %	n. s.	+ 31 %
Erläuterung:	Der Anteil des schweren Güterverkehrs am DTV hat keinen signifikanten Einfluss auf das Unfallrisiko. Eine Verdoppelung des Anteils hat aller dings eine Erhöhung des Verunfalltenrisikos um den Faktor 2,31 (=2+0,31) zur Folge.		
SOS-Lane	0,5 - 2,8 m	- 43 %	n. s.
Erläuterung:	Die Bankettbreite hat keinen Einfluss auf das Verunfalltenrisiko, aber auf das Unfallrisiko. Eine Verdopplung der Bankettbreite bewirkt, dass das Unfallrisiko auf den Faktor 0,57 (=1-0,43) sinkt.		

Table 4: Types of accidents in tunnels compared with classic roads in Swiss 2002 ¹⁴⁷

* 46 1-tube tunnels, 100 2-tube tunnels

Type of accident:	Total		Classic roads		Tunnel*	
	abs.	%	abs.	%	abs.	%
Sliding crash	4.296	53	4.100	54	196	34
Frontal crash	54	1	34	1	20	4
Overtaking crash	395	5	369	5	26	5
Rear crash	2.007	24	1.767	23	240	42
Passing-by-crash	890	11	820	11	70	12
Other	455	6	437	6	18	3
Total	8.097	100	7.527	100	570	100

Table 5: Types of accidents in tunnels compared with classic roads in Austria 2001-2003 ¹⁴⁷

* 20 1-tube tunnels, 119 2-tube tunnels

Type of accident:b	Total		Classic roads		Tunnel*	
	abs.	%	abs.	%	abs.	%
Single caused accident	3.262	40	3.202	40	60	27
Single direction accidents	4.465	54	4.344	55	121	55
Multi direction accidents	229	3	191	2	38	17
Other types	241	3	239	3	2	1
Total	8.197	100	7.976	100	221	100

Table 6: Accident influences Swiss 2002 154

Influences	Total		Classic roads		Tunnel	
	abs.	%	abs.	%	abs.	%
Drivers influence	5.149	39	4.759	39	390	41
- Personal status	1.547	12	1.463	12	84	9
- Handling error	608	5	565	5	43	5
- Inobservance	2.663	20	2.442	20	221	23
- Other drivers influences	331	2	289	2	42	4
Outside influences	807	6	792	6	15	1
Vehicle defaults	229	2	218	2	11	1
Traffic flow / discipline	6.919	52	6.382	52	537	56
- Speed	3.410	25	3.243	26	167	17
- Lane changing	1.163	9	1.054	9	109	11
- Overtaking	382	3	357	3	25	3
- Distance	1701	13	1.475	12	226	24
- Other	263	2	253	2	10	1
Unknown	150	1	141	1	9	1
Total	13.254	100	12.292	100	962	100

Table 7: Reasons for injuries in road traffic tunnels in Austria 1999-2003 ¹⁶⁰

Reason (multiple influence per event)	Tunne	
	abs.	%
Drivers mistake	235	31,3
- Distance failure	128	17,1
- Overtaking failure	25	3,3
- Right driving failure	20	2,7
- Other	62	8,2
Estimating failure	175	23,3
- Road direction	2	0,3
- Vehicle in front	38	5,0
- Stopped vehicle	72	9,6
- Weather conditions	48	6,4
- Other	15	2,0
Observation failure (Vigilanz)	238	31,7
- Fatigue	46	6,1
- Dassling	4	0,5
- Deviation	22	2,9
- Unobservance	158	21,1
- Medical failure (hard attack; etc...)	8	1,1
Speed	61	8,1
- Inadequate speed	49	6,5
- Overspeeding	12	1,6
- Other	0	0,0
Unpredictive events	18	2,5
Technical failures	23	3,1

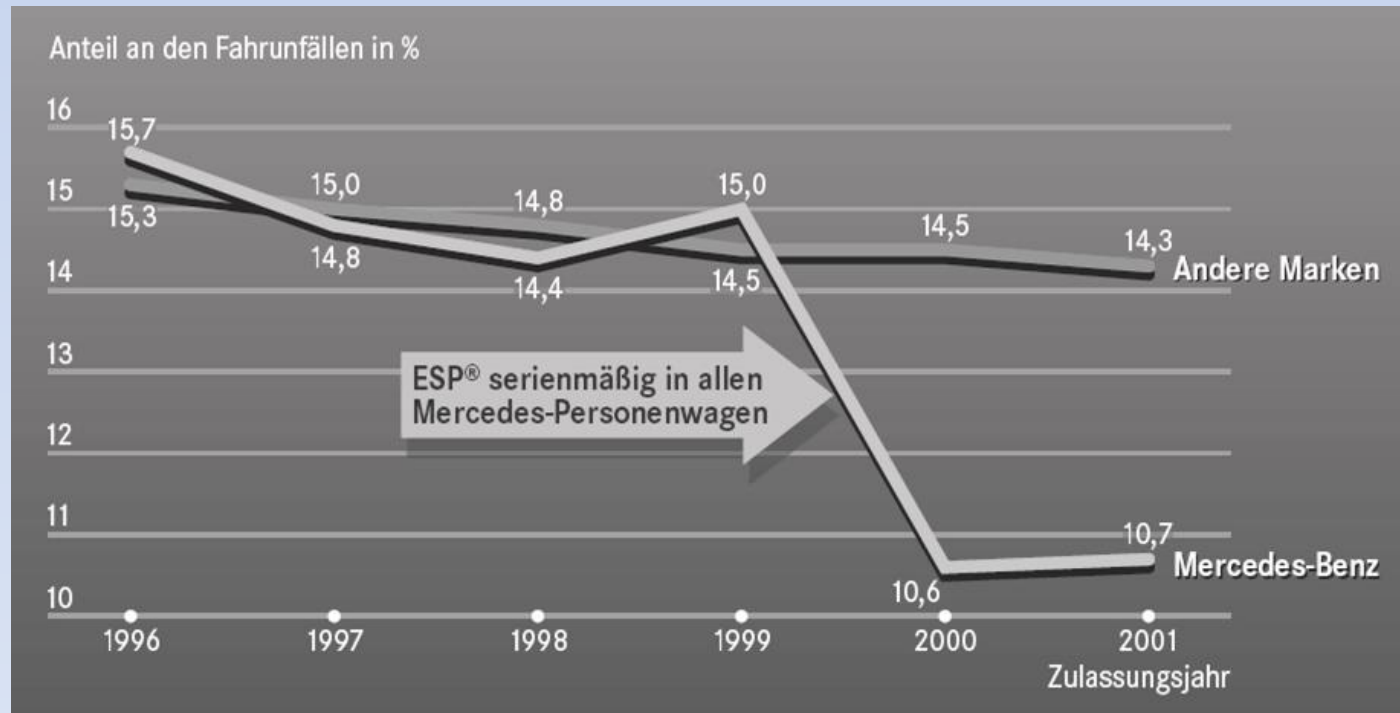
Table 8: Cost factor of injuries and fatalities in Europe 2002²⁰⁴

Country	Fatalities (€)	Highly injured persons(€)	Lightly injured persons(€)
CH	1.649.197	145.364	15.488
GB	1.458.190	163.857	12.635
FIN	1.402.261	189.000	36.580
NL	1.302.700	-	-
S	1.270.792	226.712	12.700
D	1.117.382	77.723	3.401
HU	835.379	57.965	7.672
LT	660.900	15.040	178
DK	644.608	66.632	18.187
LV	525.664	42.503	-
CZ	488.302	-	-
I	452.136	-	-
ES	211.920	-	-
SK	206.316	36.642	656

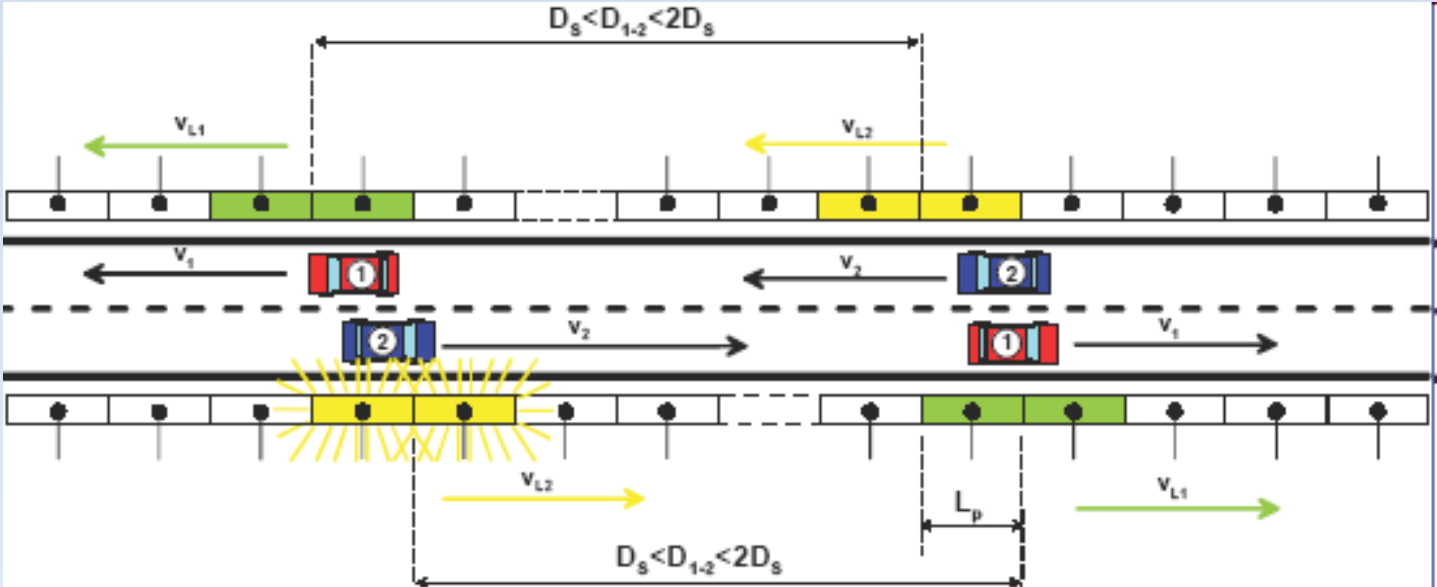
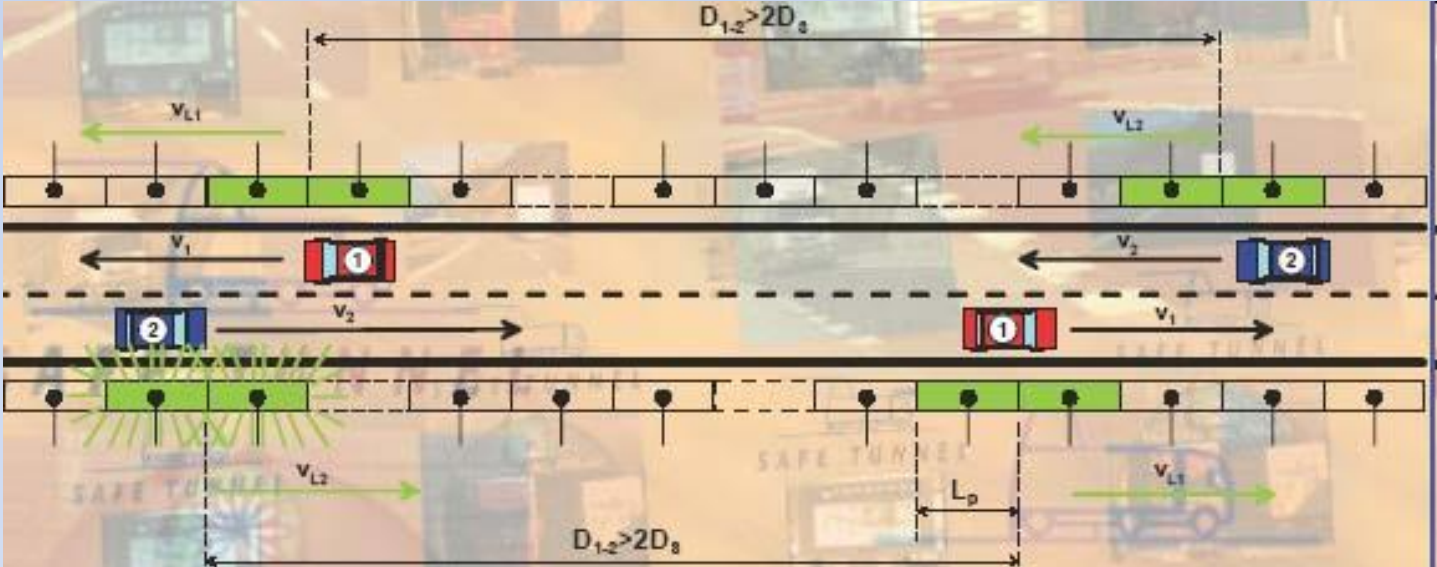
Safety Technologies for Tunnels

- Stopping niches and breakdown bays
- Acoustic tunnel monitoring
- Autark Energy
- Fire extinguisher bay
- Escape and rescue routes
- High-tech tunnel monitoring
- Intelligent light management
- Emergency call equipment
- Radio reception
- Spray mist system
- Thermal Scanner
- Moving Spot Light System
- I2C Distance Control
- Section Control
- Intelligent Speed Adaptation
- Incident detection

Excurs ESP



Moving Spot Light System

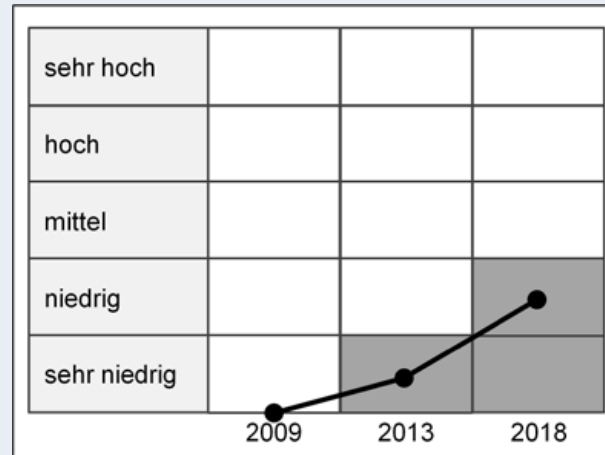


Moving Spot Light System²⁷⁰

Market penetration:

Legenda

very low 0-5 %
 low: 6-20 %
 medium: 21-50
 % high: 51-80
 %
 very high: 81-100
 %



Cost per tunnel:

520.000 €/km

Price decrease by 10% per year

per ca.. 21,5 Millionen Euro 2009 – 2018

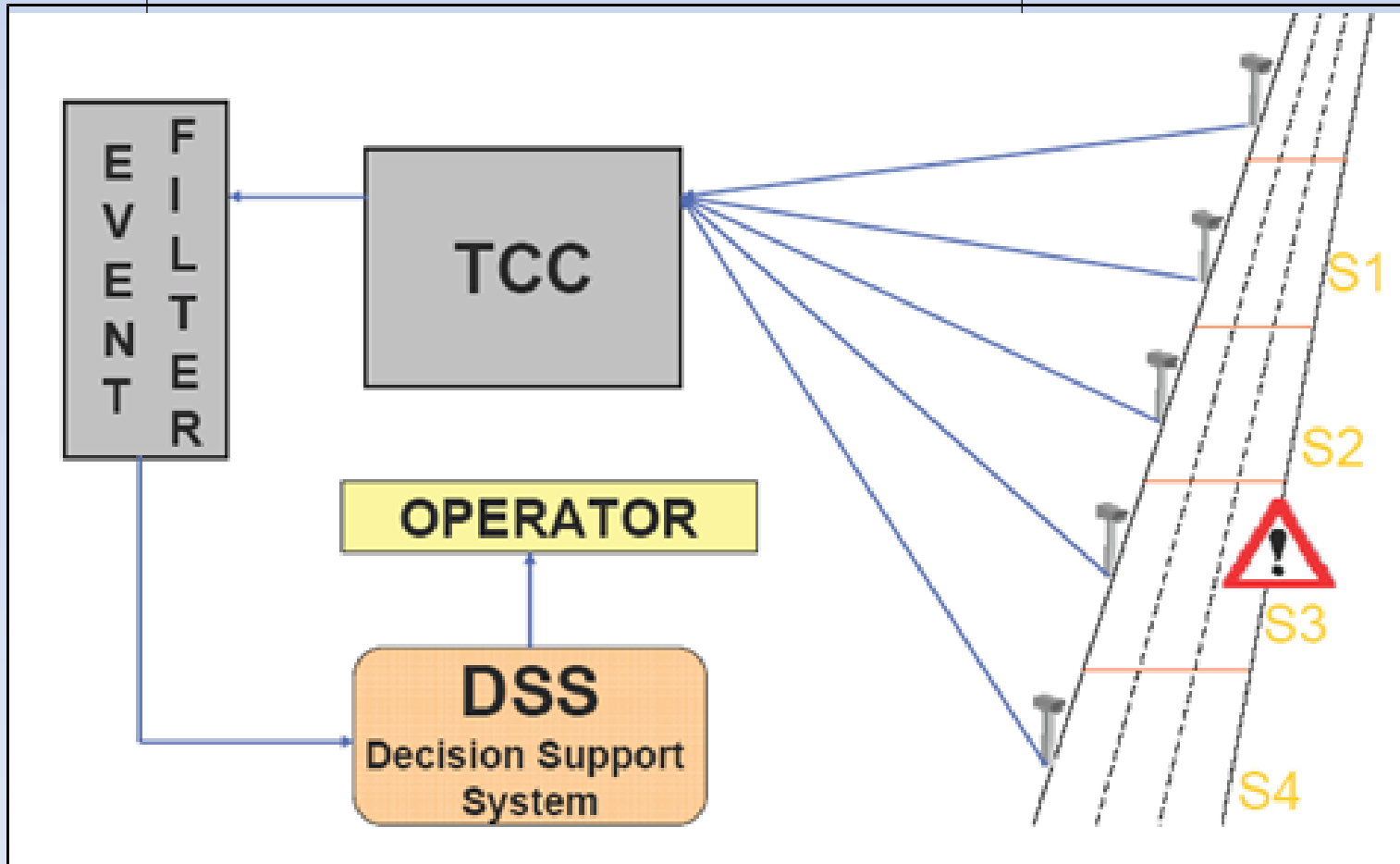
Cost per car:

0 €

Effects:

64 % reduction of rear-end collisions

I2C Distance-Control

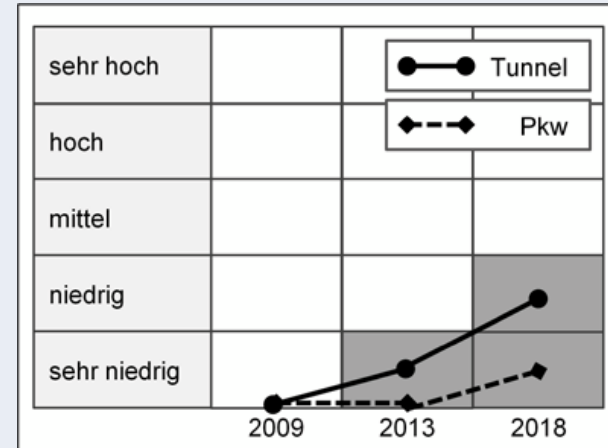


I2C-Distance warning²⁹⁶

Market penetration:

Legenda

very low:	0-5 %
Low:	6-20 %
medium:	21-50 %
high:	51-80 %
very high:	81-100 %



Cost per tunnel:

11.000 €/km
 price deduction by 10% per year
 per circa 573.000 Euro from 2009 bis 2018

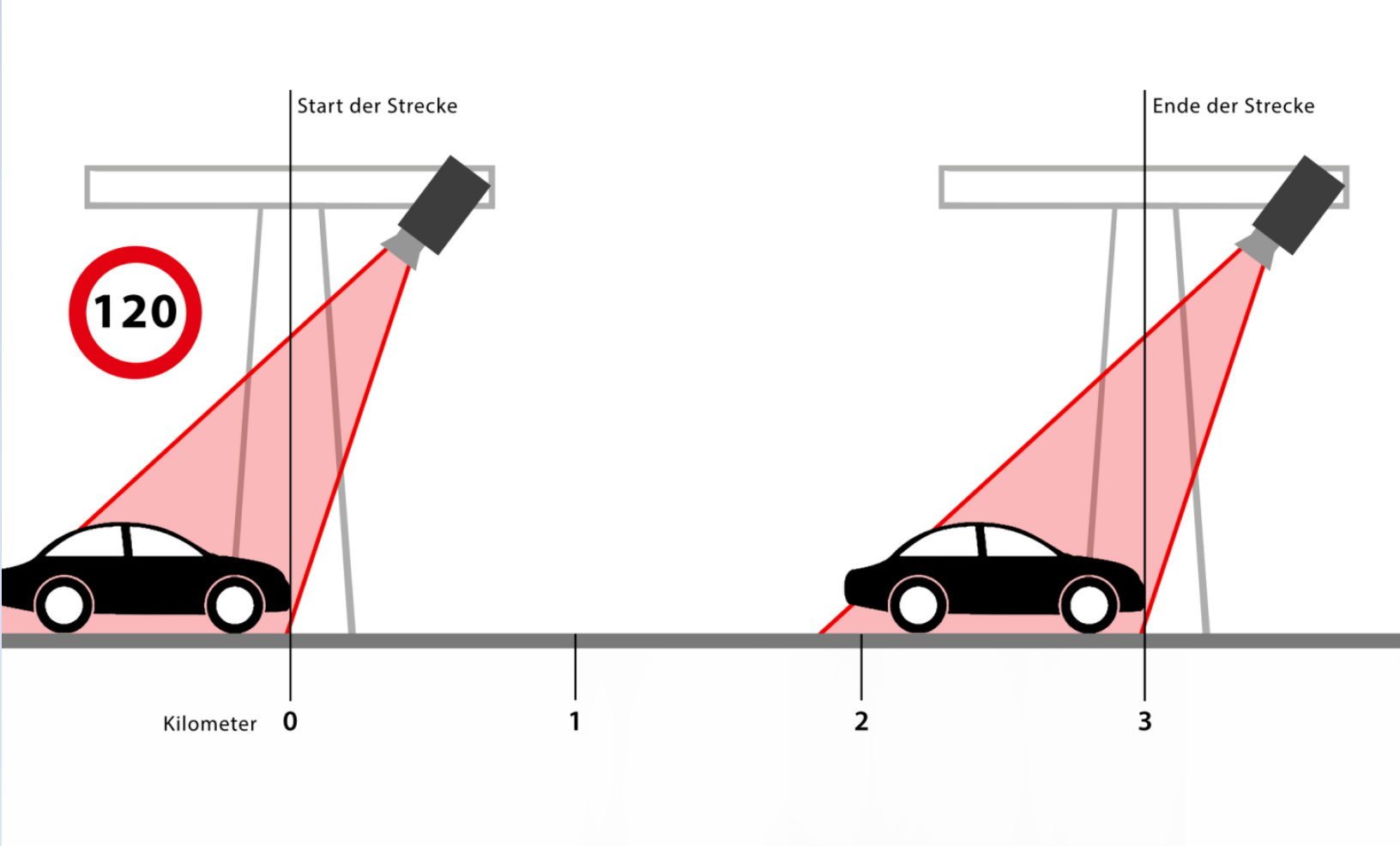
Cost per car:

200 €/passenger car
 Price deduction by 30 % per year
 per ca. 71 Millionen Euro from 2009 bis 2018

Effects:

60 % of rear-end collisions

Section control

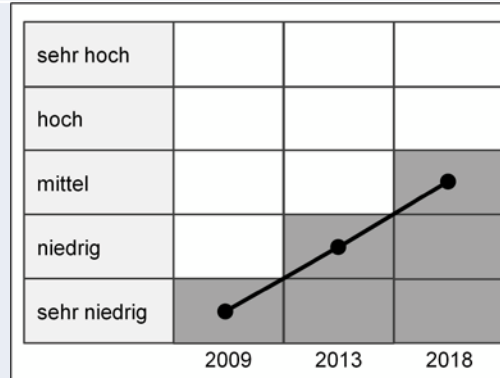


Section Control³⁰⁴

Market penetration:

Legenda

Very low: 0-5 %
low: 6-20 %
medium 21-50 %
high: 51-80 %
very high: 81-100 %



Cost per tunnel:

600.000 €/tube
Price deduction by 10% per year
per ca. 20 Millionen Euro from 2009 to 2018

Cost per car:

0 €

Effects:

65 % reduction of all kind of accidents

Intelligent Speed Adaptation

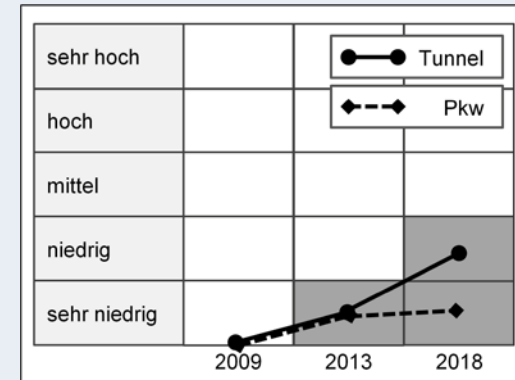


Intelligent Speed Adaptation³³¹

Market penetration:

Legenda

very low:	0-5 %
low:	6-20 %
medium	21-50 %
high:	51-80 %
very high:	81-100 %



Cost per tunnel:

10.000 €/km
 price deduction by 10% per year
 per ca. 520.100 Euro from 2009 to 2018

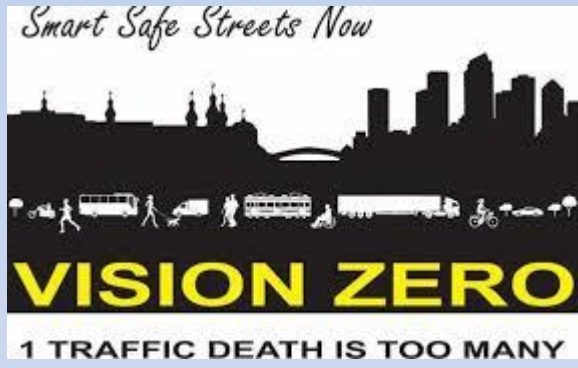
Cost per car:

300 €/car
 Price deduction by 30% per year
 Per ca. 212 Millionen Euro from 2009 to 2018

Effects:

76 % of all kind of accidents

VISION ZERO.
FEHLER SIND NICHT VERMEIDBAR. SCHWERE UNFÄLLE SCHON.



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Keiner kommt um. Alle kommen an.



