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RISK ASSESSMENT IN PUBLIC SPACES: ROAD TUNNEL

JOSE RANGEL, R^2+SBE Group- Civil Engineering

Epoka University, 07.05.2019.

CONTENT

- SHORT PRESENTATION
- PUBLIC SPACES
- RISK ASSESSMENT OF ROAD TUNNELS
- FIRE AND EGRESS PROBABILISTIC SIMULATION IN ROAD TUNNELS

Short presentation

RISK, RESILIENCE AND SUSTAINABILITY IN THE BUILT ENVIRONMENT

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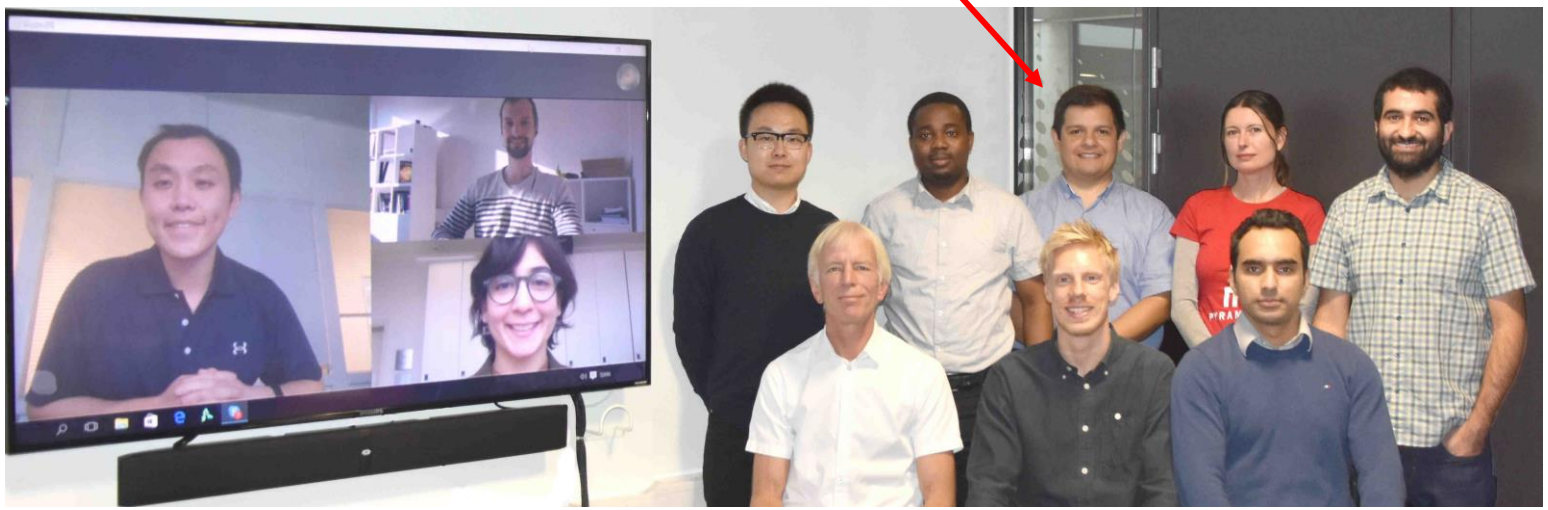
R2+SBE

José G. Rangel-Ramirez



- Civil Engineer, UAT, MX
- M. Eng. Structural engineering, UNAM, MX
- Ph.D. in Civil Engineering, AAU, DK
- **Topics within Risk and Reliability:** Earthquake engineering, risk-based inspection and maintenance planning of offshore wind turbines and jacket structures, fire and egress probabilistic modelling, software and apps for engineering.
- Postdoctoral Researcher at Aalborg University, Civil Engineering.

ABOUT PUBLIC SPACES

United Nations's definition
UNESCO – Educational, Scientific and Cultural Organization

A public space refers to an area or place that is open and accessible to all peoples, regardless of :

- gender,
- race,
- ethnicity,
- age or
- socio-economic level.

These are **public gathering spaces** such as plazas, squares and parks. **Connecting spaces**, such as sidewalks and streets, are also **public spaces**. In the 21st century, some even consider the **virtual spaces** available through the internet as a new type of public space that develops interaction and social mixing.

Maintained by a public institution
Own by public sector
Serve to the public sector
Promote social cohesion

ABOUT PUBLIC SPACES

United Nations's definition
UNESCO – Educational, Scientific and Cultural Organization

- **Public space** (communities and urban areas)
- **Public gathering spaces** (parks, museum, halls, churches)
- **Virtual spaces** (virtual communities, virtual gathering environment, virtual interactive spaces, etc).
- **Connecting spaces** (train stations, tunnels, subway, roads)

Hazards

- **Physical**
- **Health**
- **Environmental**

ABOUT PUBLIC SPACES

Unlawful-provoked harmful conditions

Wildfire

Earthquake event
(public gathering space)

Sri-Lanka terrorist attact
(at different public spaces)

Flooding
(public gathering space)

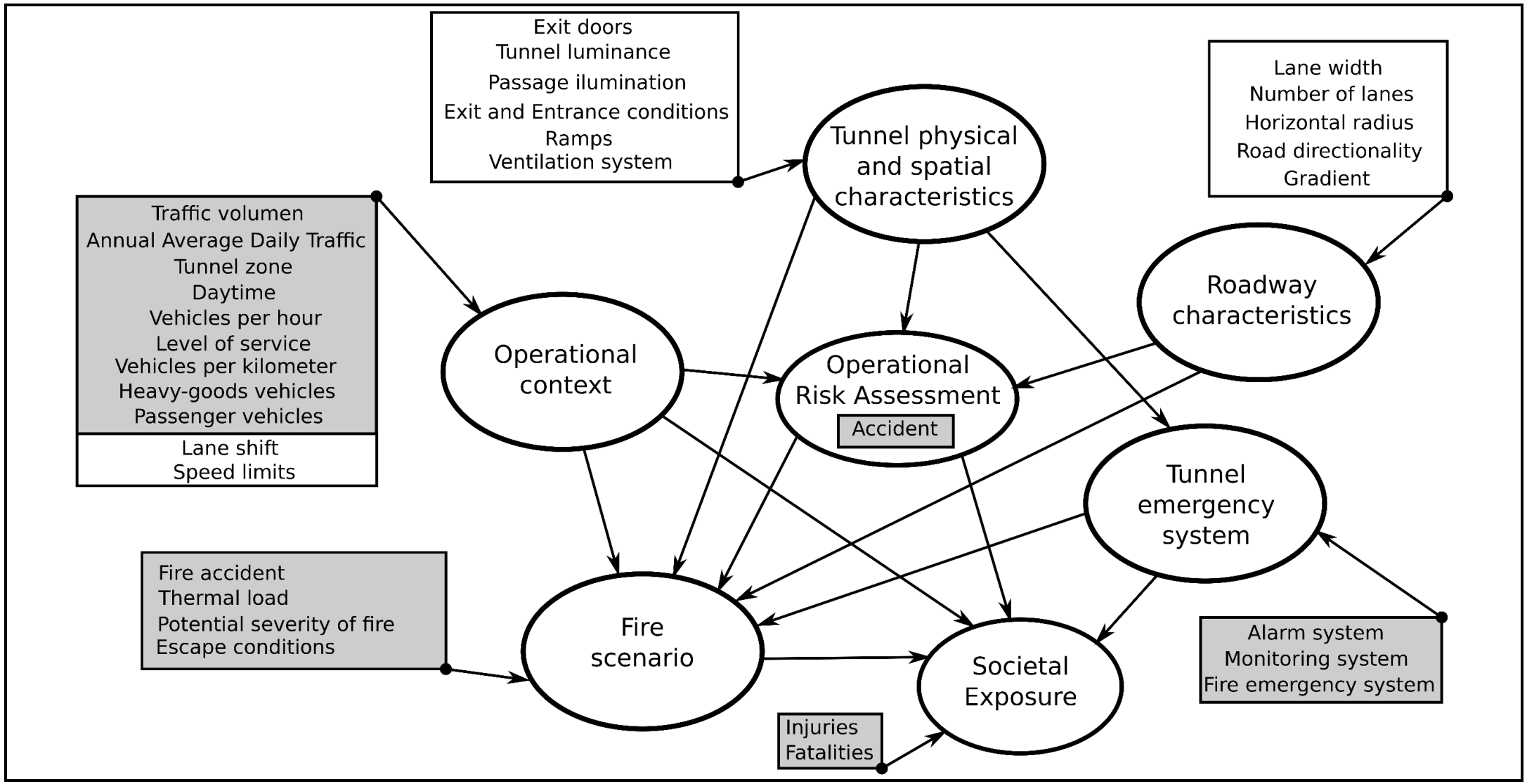
Fire scenario (Connection space)

ABOUT PUBLIC SPACES

- Operational conditions
- Physical and spatial characteristics (road and tunnel).
- Prospective hazardous incidents
- Emergency and evacuation systems
- User’s characteristics

RISK ASSESSMENT OF ROAD TUNNELS

RISK ASSESSMENT OF ROAD TUNNELS



From "***Development of a best practice methodology for risk assessment in road tunnels***"
Matrisk GmbH; Høj, Peter N. ; Köhler, Jochen and Faber, Michael H.

ROAD TUNNELS

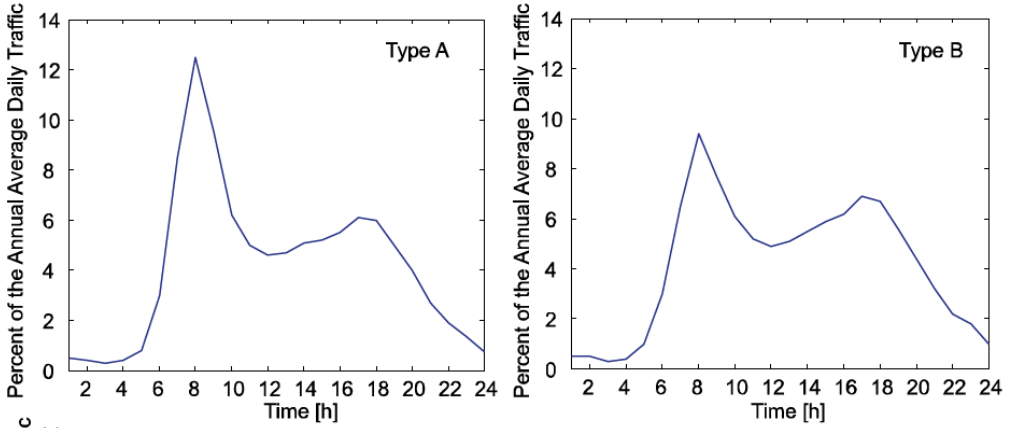
ANNUAL AVERAGE DAILY TRAFFIC CURVE

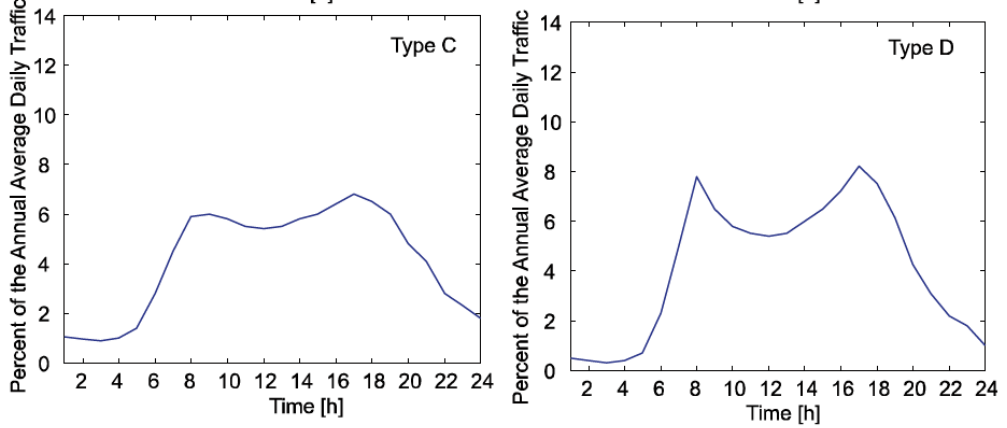
Traffic volumen
Annual Average Daily Traffic
Tunnel zone
Daytime
Vehicles per hour
Level of service
Vehicles per kilometer
Heavy-goods vehicles
Passenger vehicles

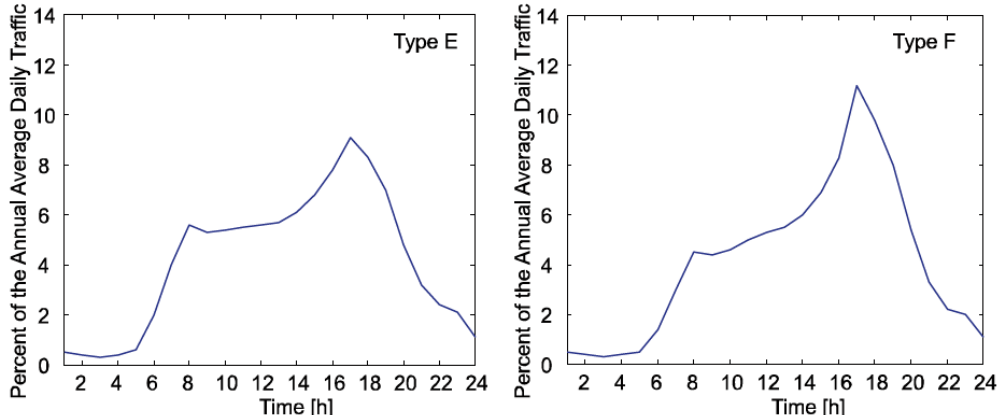
Lane shift
Speed limits

- Type A: pronounced peak in the morning.
- Type B: peak in the morning combined with small peak in the afternoon.
- Type C: relative equally distributed traffic during the day.
- Type D: Pronounced peak in the morning and in the afternoon.
- Type E: pronounced peak in the afternoon, small peak in the morning.
- Type F: pronounced peak in the afternoon.

- Interregional traffic with commuters (refers to Type B)
- Commuters (refers to Type D)
- Local traffic (refers to Type E)
- Regional traffic (refers to Type F)
- Leisure Traffic (refers to Type C)







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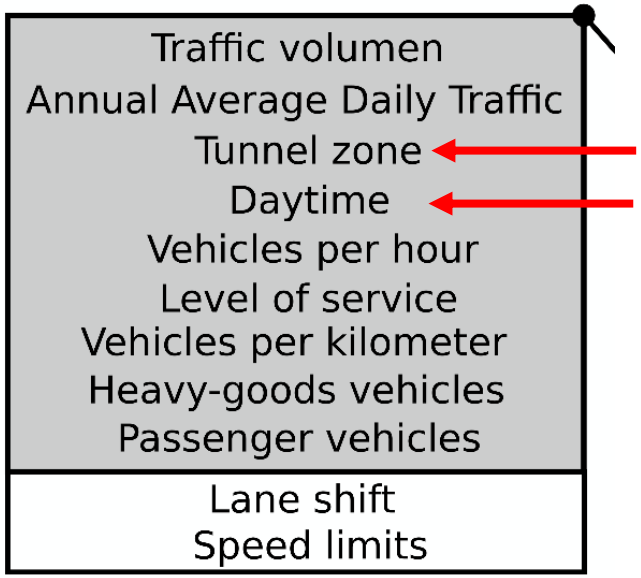
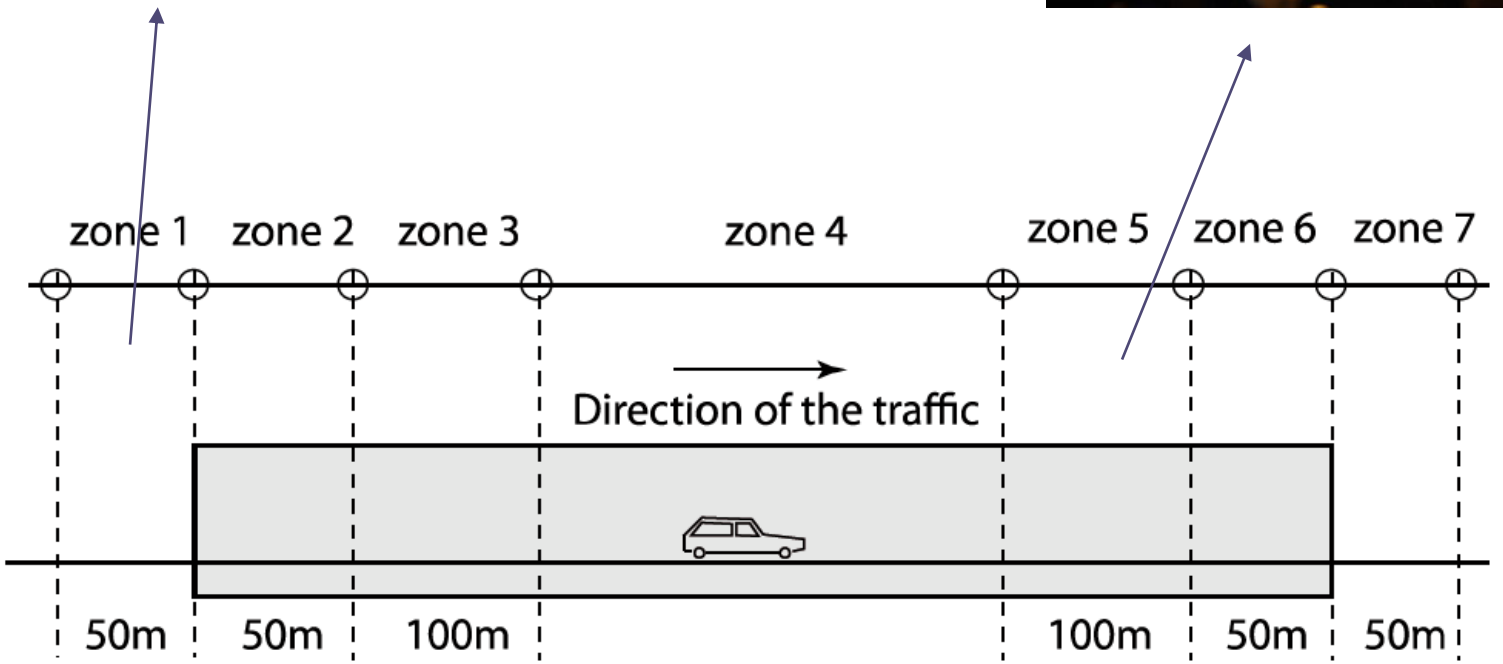
ROAD TUNNELS

ANNUAL AVERAGE DAILY TRAFFIC CURVE

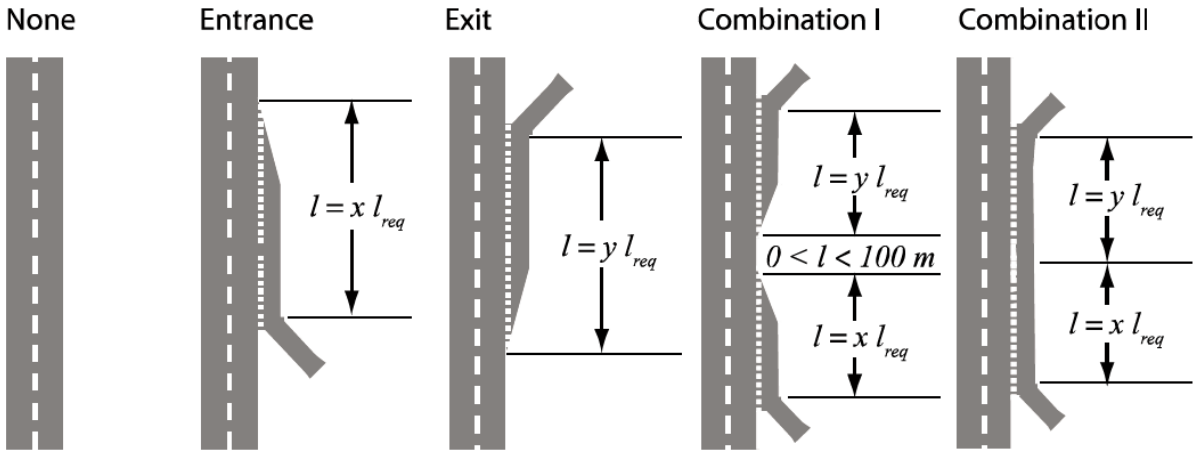




RISK ASSESSMENT OF ROAD TUNNELS

EXIT AND ENTRANCE CONDITIONS

Exit doors
Tunnel luminance
Passage ilumination
Exit and Entrance conditions
Ramps
Ventilation system



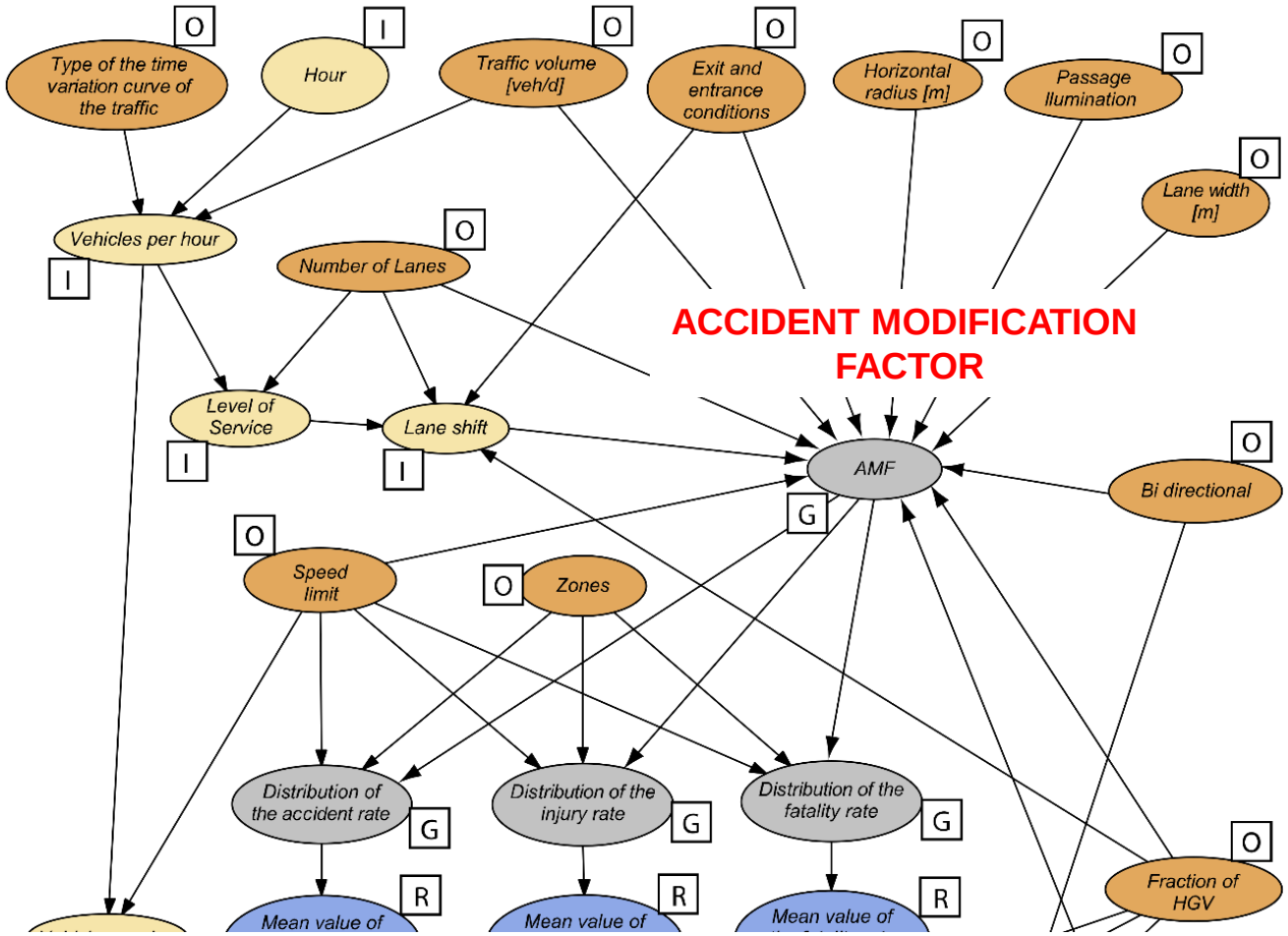
RISK ASSESSMENT OF ROAD TUNNELS

EXIT AND ENTRANCE CONDITIONS

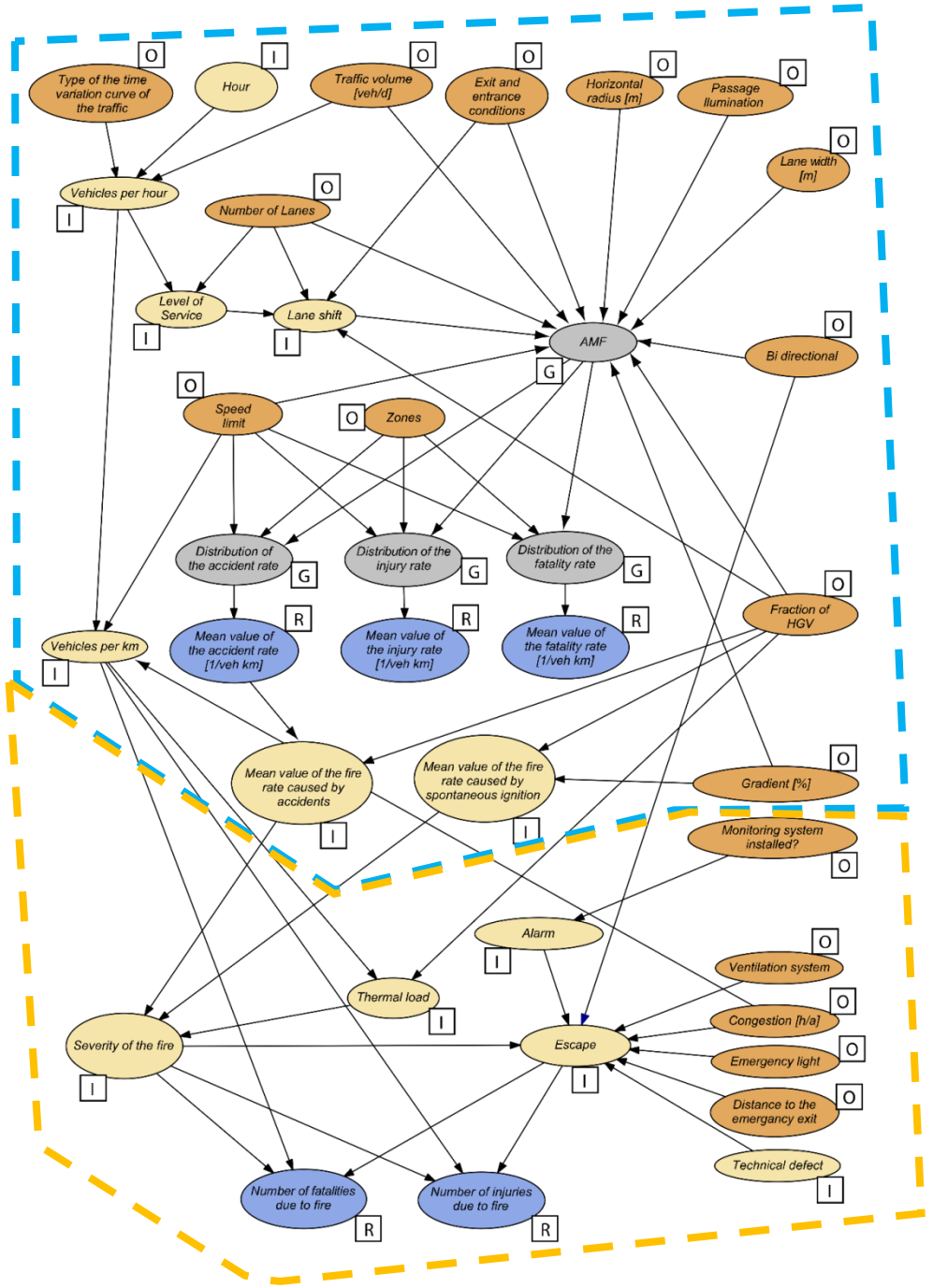
Lane width
Number of lanes
Horizontal radius
Road directionality
Gradient

RISK ASSESSMENT OF ROAD TUNNELS

BAYESIAN PROBABILISTIC NETWORK as a probabilistic tool to assess and perform decision analysis under the contribution of each of the variables

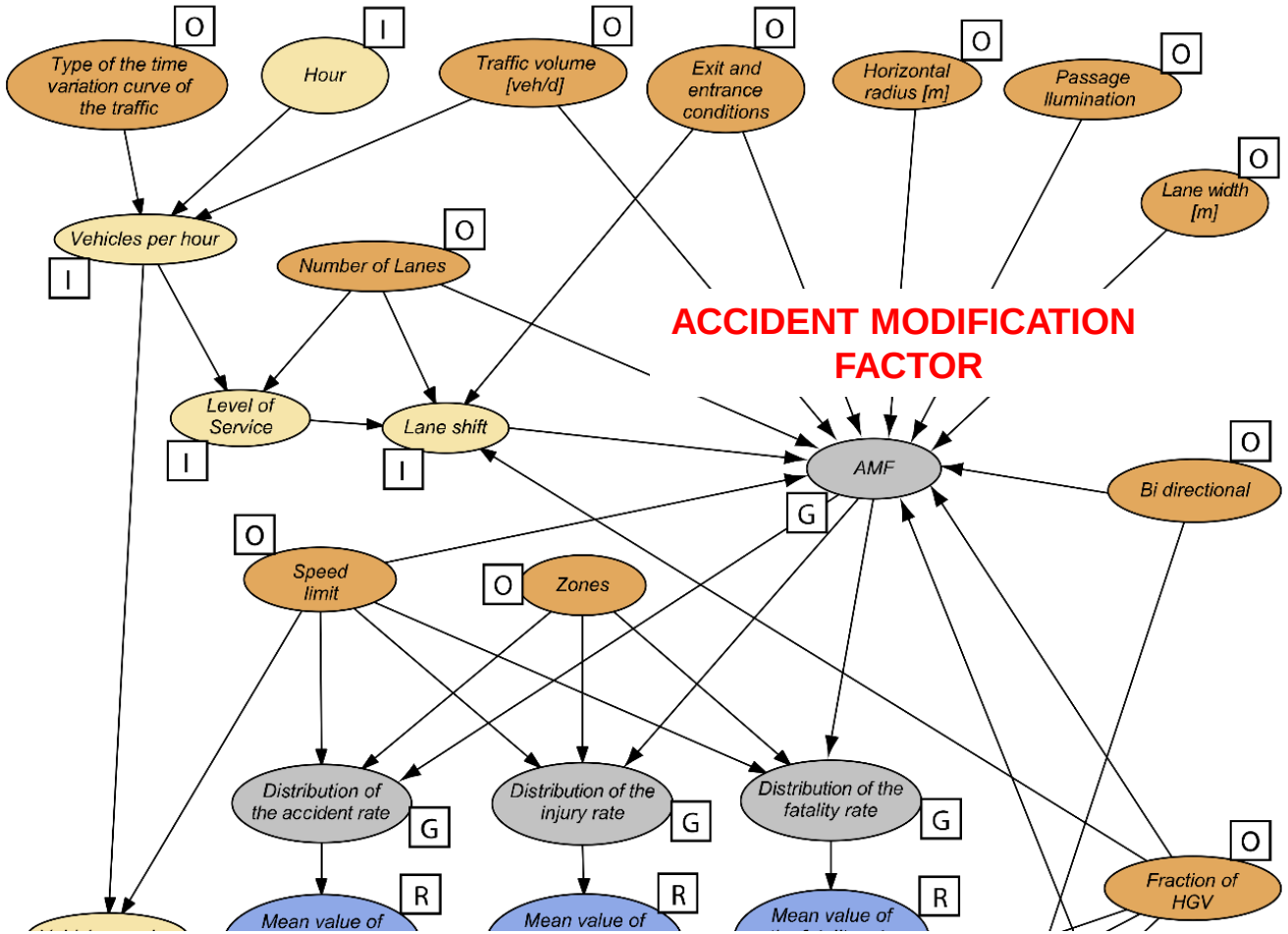


ACCIDENT MODIFICATION FACTOR



RISK ASSESSMENT OF ROAD TUNNELS

BAYESIAN PROBABILISTIC NETWORK as a probabilistic tool to assess and perform decision analysis under the contribution of each of the variables



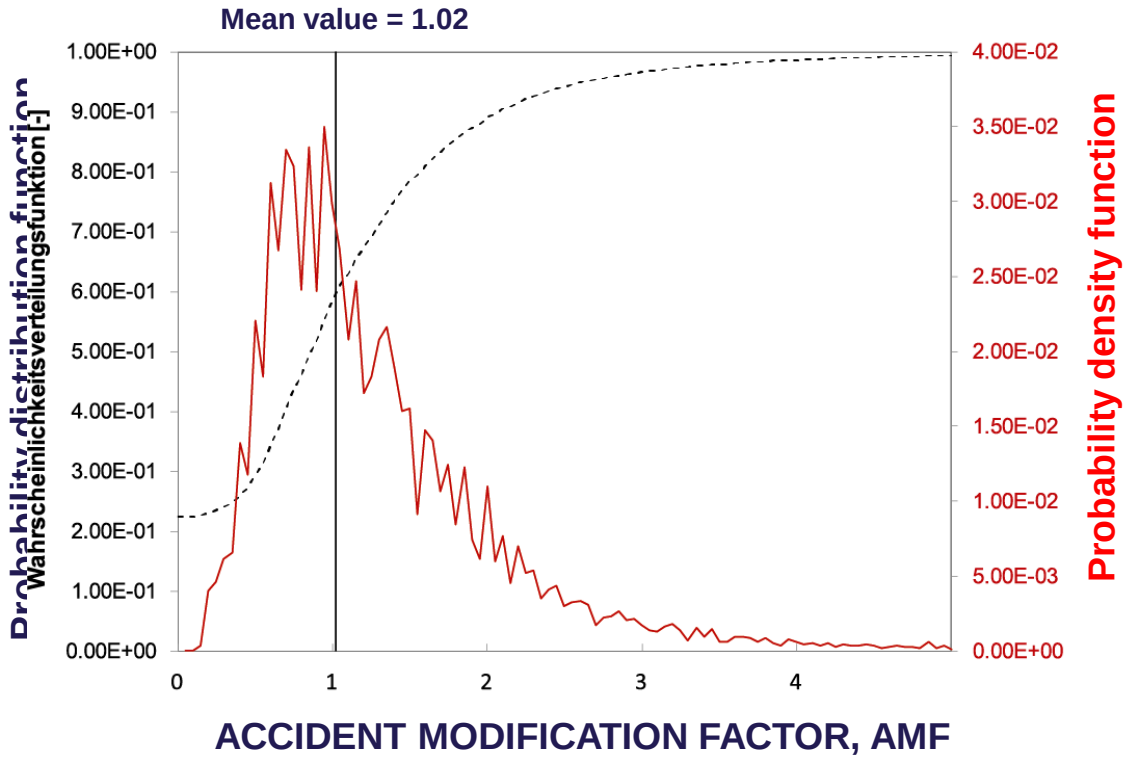
ACCIDENT MODIFICATION FACTOR

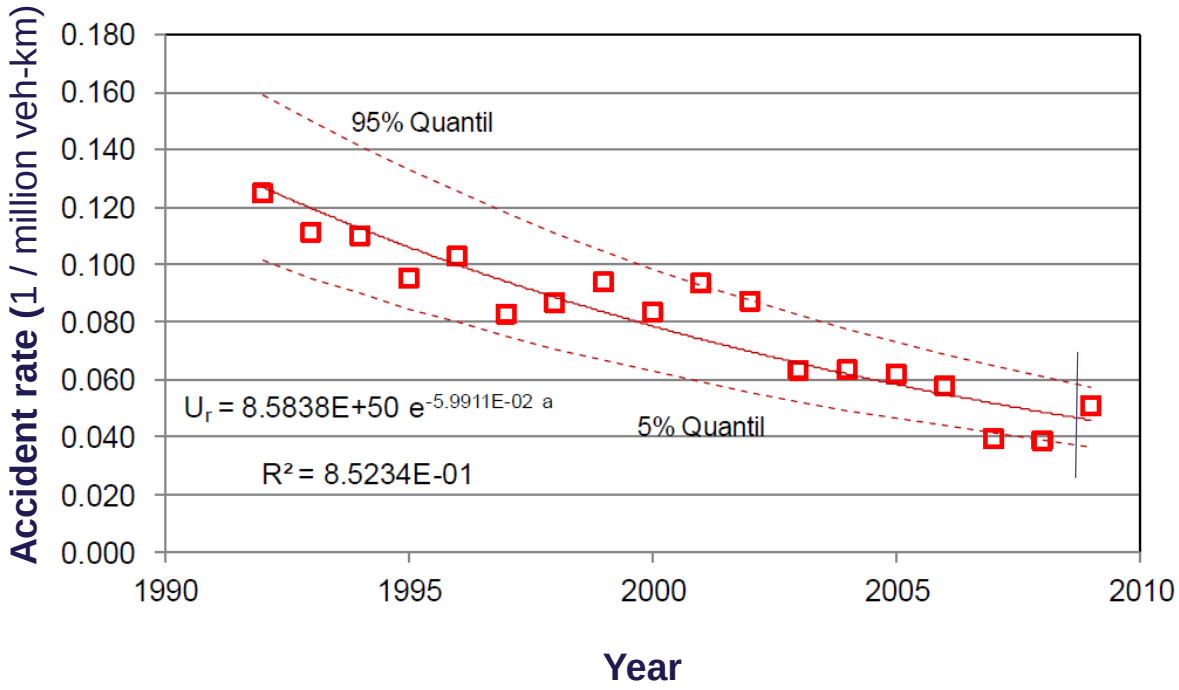
It is used to describe the **deviation of an accident rate from the normal base rate**. Accident modification factors (UMF) are often used to model the influence of changes to the road infra structure on accident frequency.

A change in the accident rate that can be expected if one or more indicators deviate from the normal case. The difficulty lies in defining what is normal. Since accident statistics usually do not differentiate between different risk indicators, it can be assumed that **the accident rate in tunnels represents the mean across all tunnels in a country**.

RISK ASSESSMENT OF ROAD TUNNELS

BAYESIAN PROBABILISTIC NETWORK as a probabilistic tool to assess and perform decision analysis under the contribution of each of the variables





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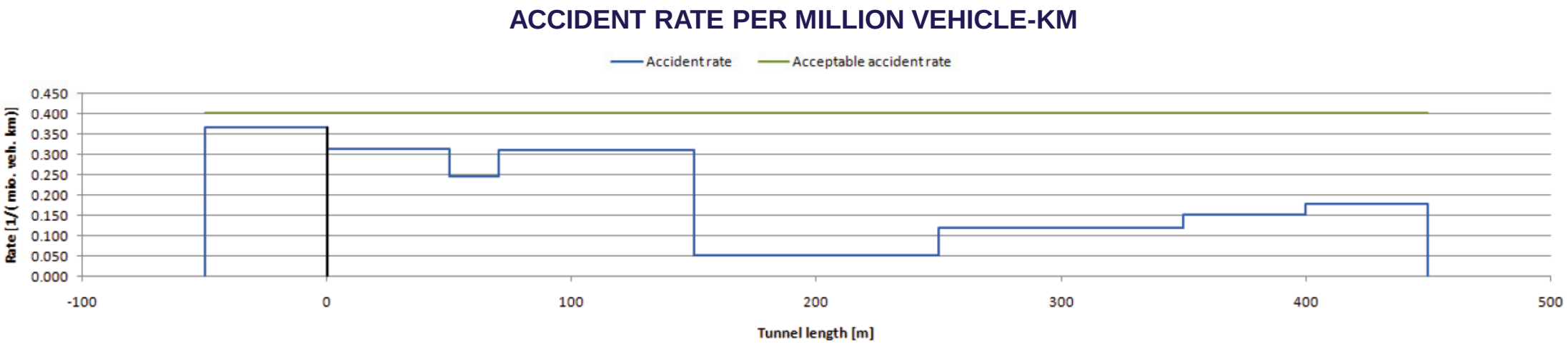

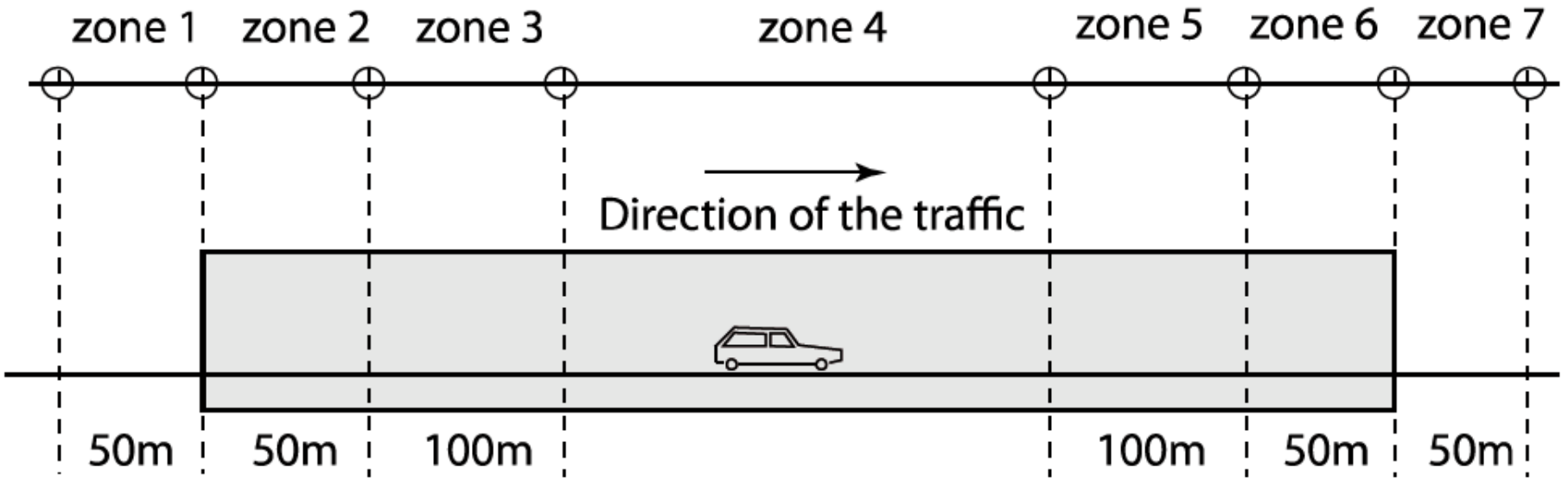

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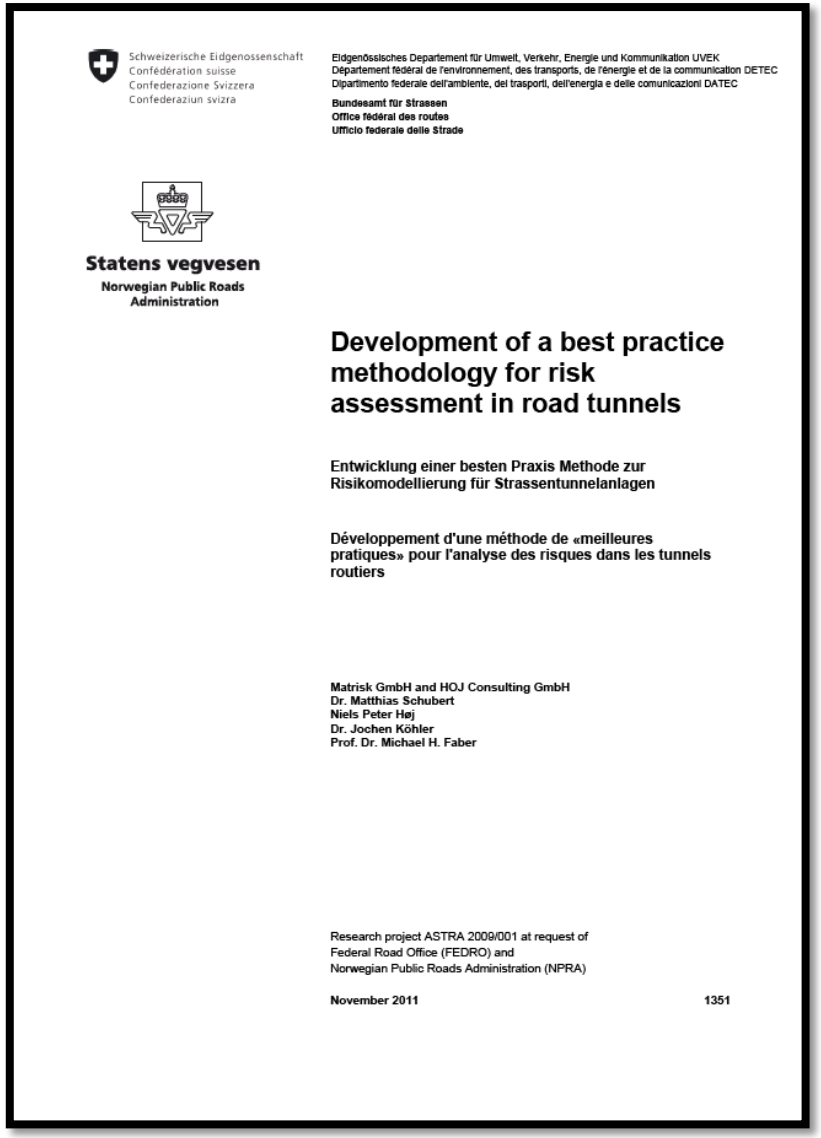

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Département fédéral de l'environnement, des transports, de l'énergie et de la communication DETEC
Dipartimento federale dell'ambiente, dei trasporti, dell'energia e delle comunicazioni DATEC

Bundesamt für Strassen
Office fédéral des routes
Ufficio federale delle Strade

Statens vegvesen
Norwegian Public Roads Administration

Development of a best practice methodology for risk assessment in road tunnels

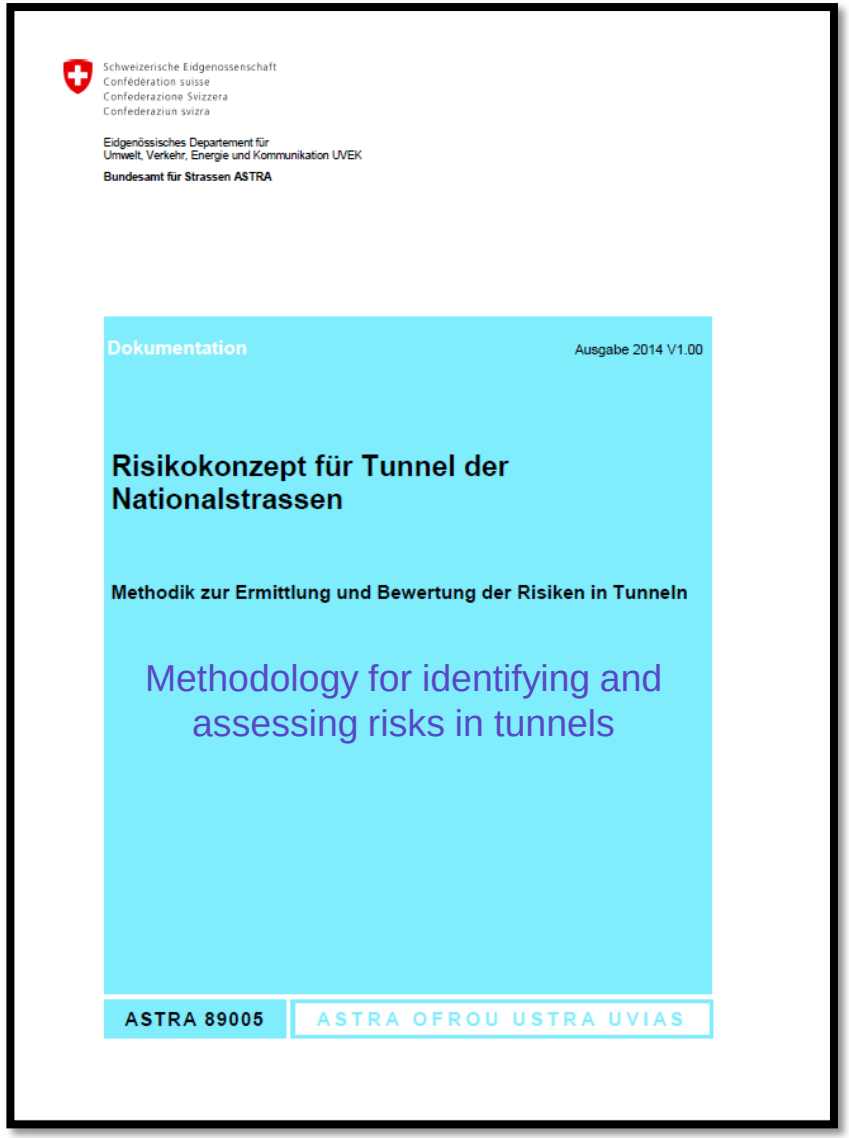
Entwicklung einer besten Praxis Methode zur Risikomodellierung für Strassentunnelanlagen

Développement d'une méthode de «meilleures pratiques» pour l'analyse des risques dans les tunnels routiers

Matrisk GmbH and HOJ Consulting GmbH
Dr. Matthias Schubert
Niels Peter Høj
Dr. Jochen Köhler
Prof. Dr. Michael H. Faber

Research project ASTRA 2009/001 at request of
Federal Road Office (FEDRO) and
Norwegian Public Roads Administration (NPRA)

November 2011 **1351**



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Eidgenössisches Departement für
Umwelt, Verkehr, Energie und Kommunikation UVEK

Bundesamt für Strassen ASTRA

Dokumentation Ausgabe 2014 V1.00

Risikokonzept für Tunnel der Nationalstrassen

Methodik zur Ermittlung und Bewertung der Risiken in Tunneln

Methodology for identifying and assessing risks in tunnels

ASTRA 89005 ASTRA OFROU USTRA UVIAS

FIRE AND EGRESS PROBABILISTIC SIMULATION IN ROAD TUNNELS

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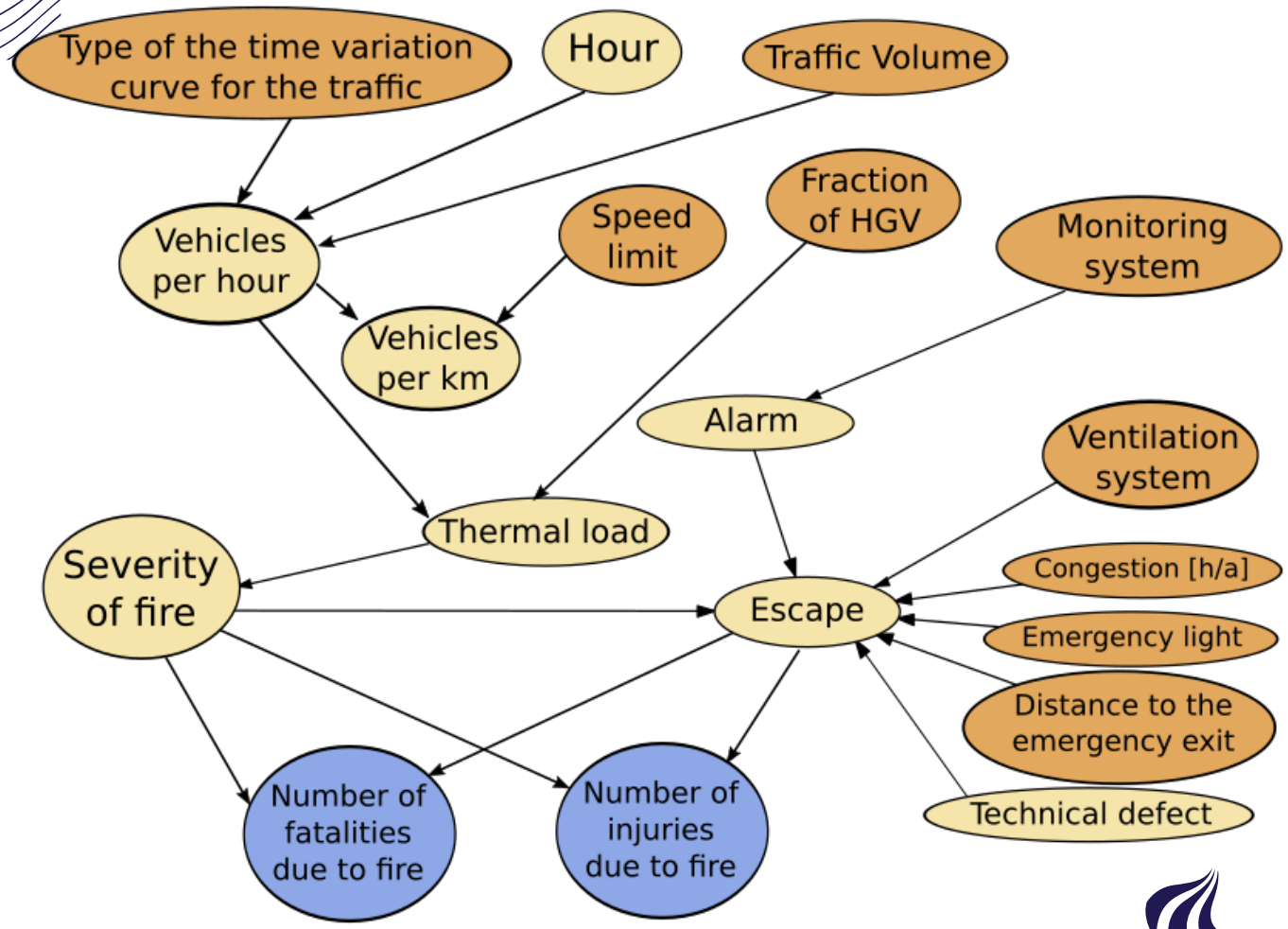
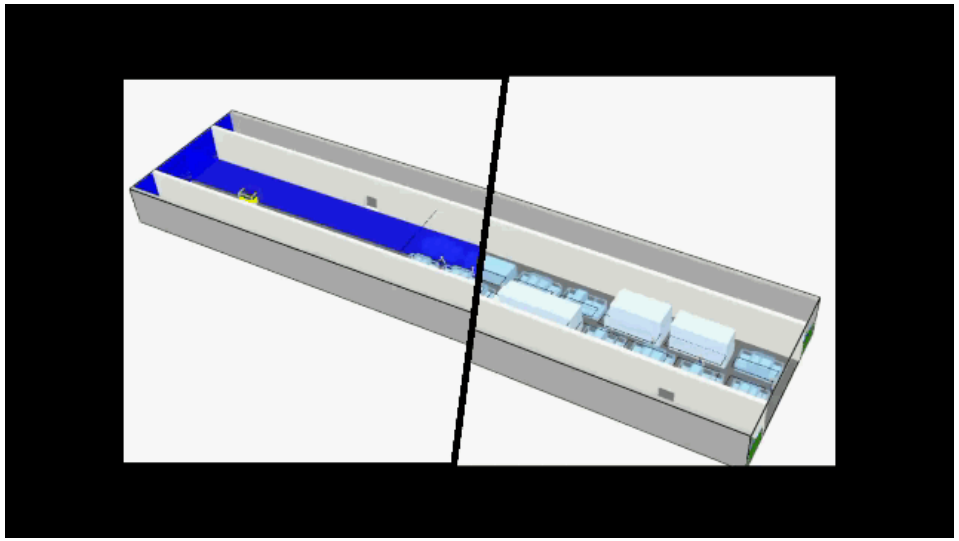
FIRE AND EGRESS PROBABILISTIC SIMULATION IN ROAD TUNNELS





FIRE AND EGRESS PROBABILISTIC SIMULATION IN ROAD TUNNELS

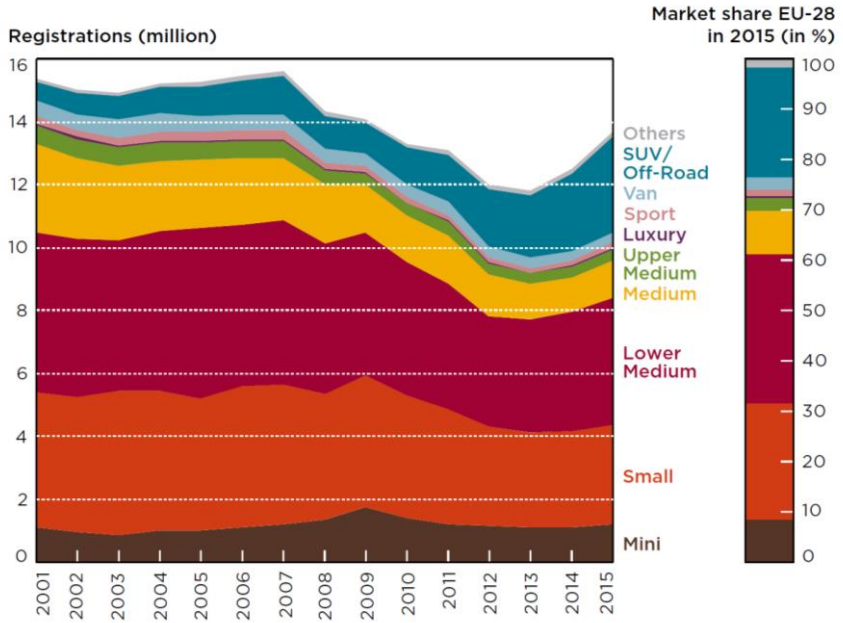


Table 5.1 Prior Knowledge of vehicle population

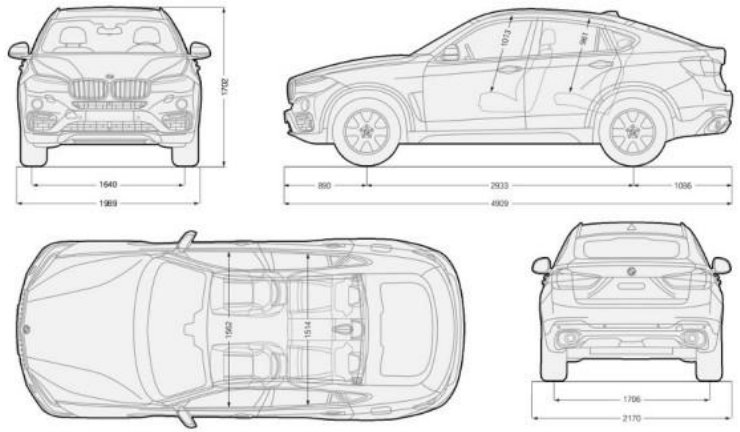
TYPE ($\tilde{v}_{mpv}$)	European classification	Group	Description ($\tilde{v}_{pn}$ and $\tilde{v}_{hn}$)	$\tilde{v}_{ppv}$, Prior knowledge of PAV [ref. XXX]**	$\tilde{v}_{phg}$, Prior knowdlege of HGV [ref. XXX]**
1	M1*	PAV	Mini cars	0.08	--
2	M1	PAV	Small vehicles	0.24	--
3	M1	PAV	Medium cars – small family vechiles	0.3	--
4	M1	PAV	Large cars – Large family vehicles	0.07	--
5	M1	PAV	Executive vehicles	0.03	--
6	M1	PAV	Luxury vehicles	0.005	--
7	M1	PAV	Sport vehicles	0.02	--
8	M1	PAV	Multi-purpose vehicles	0.35	--
9	M2	PAV	SUV and off-roads vehicles	0.2	--
10	M3 , N	PAV	Others (Bus/Coach)	0.02	--
11	N1	HGV	Box Van	--	0.2305
12	N2	HGV	Tipper Truck	--	0.1452
13	N2	HGV	Curtain sided vehicle	--	0.1263
14	N3	HGV	Drop side Lorry	--	0.0767
15	N3	HGV	Flat Lorry	--	0.0699
16	N1, N2	HGV	Refuse disposal truck	--	0.0624
17	N1	HGV	Insulated Van	--	0.0496
18	N2	HGV	Skip loader vehicle	--	0.0481
19	N3	HGV	Tanker	--	0.0299
20	N1	HGV	Panel Van	--	0.0217
21	N1	HGV	Street Cleasing vehicle	--	0.0189
22	N3	HGV	Car Transporter vehicle	--	0.0185
23	N3	HGV	Concrete Mixer	--	0.0167
24	N3	HGV	Live Stock Carrier	--	0.0160
25	N2, N3	HGV	Heavy-Goods transporter	--	0.0092
26	T	HGV	Tractor	--	0.0082
27	N2, N3	HGV	Skeletal Vehicle	--	0.0067
28	N2, N3	HGV	Tower Wagon	--	0.0064
29	N1, N2	HGV	Motorhome	--	0.0064
30	N2	HGV	Luton Van	--	0.0039
31	N1, N2, N3	HGV	Others	--	0.0278

PAV=Passenger vehicles, HGV=Heavy-goods vehicles. *Some mini-cars do not have four wheels. **Prior knowledge is relative of the group of vehicles.

FIRE AND EGRESS PROBABILISTIC SIMULATION IN ROAD TUNNELS

Compare with other car classification [edit]

Vehicle classification							view · talk · edit
Not well-defined / vernacular			Defined by law or regulation				Examples
Market segment (American English)	Market segment (British English)	Market segment (Australian English)[6]	US EPA Size Class[7]	Euro NCAP Structural Category[8]	Euro NCAP Class (1997–2009)	Euro Market Segment[9]	
Microcar	Microcar, Bubble car	N/A	N/A	—	Quadricycle	A-segment mini cars	Bond Bug, Isetta, Mega City, Renault Twizy
Subcompact car Economy car	City car	Microcar	Minicompact	Passenger car	Supermini		Citroën C1, Fiat 500, Hyundai Eon, Mitsubishi i-MiEV, Renault Twingo
	Supermini	Light car	Subcompact			B-segment small cars	Ford Fiesta, Kia Rio, Opel Corsa, Peugeot 208, Volkswagen Polo
Compact car	Small family car	Small car	Compact		Small family car	C-segment medium cars	Honda Civic, Mazda3, Suzuki Ciaz, Renault Mégane, Toyota Corolla
Mid-size car	Large family car	Medium car	Mid-size		Large family car	D-segment large cars	Chevrolet Malibu, Ford Fusion, Peugeot 508, Subaru Legacy, Volkswagen Passat
Entry-level luxury car	Compact executive car	Medium car above $60,000	N/A				Alfa Romeo Giulia, Audi A4, Lexus ES, Mercedes-Benz C-Class
Full-size car	Executive car	Large car	Large		Executive	E-segment executive cars	Chevrolet Impala, Ford Taurus, Mazda Xedos 9, Hyundai Grandeur, Holden Commodore, first and second generation
Mid-size luxury car		Large car above $70,000	N/A				Audi A6, BMW 5 Series, Cadillac CTS, Mercedes-Benz E-Class, Tesla Model S
Full-size luxury car	Luxury car	Upper large car above $100,000	N/A		—	F-segment luxury cars	BMW 7 Series, Lincoln Town Car, Mercedes-Benz S-Class, Porsche Panamera, Maserati Quattroporte
Grand tourer	Grand tourer	Sports car	N/A		—	S-segment sports coupés	Aston Martin DB9, Bentley Continental GT, Ferrari GTC4Lusso, Jaguar XK, Maserati GranTurismo
Supercar	Supercar		N/A		—		Bugatti Veyron, LaFerrari, Lamborghini Aventador, Pagani Zonda, Porsche 918 Spyder
Convertible	Convertible		N/A		—		BMW 6 Series, Chevrolet Camaro, Mercedes CLK, Volvo C70, Volkswagen Eos
Roadster	Roadster		Two-seater		Roadster sports		BMW Z4, Lotus Elise, Mazda MX-5, Porsche Boxster, Mercedes-Benz SLK
—	Mini MPV	N/A	Minivan	MPV	Small MPV	M-segment multi purpose cars	Citroen C3 Picasso, Ford B-Max, Opel Meriva, Fiat 500L
MPV	Compact MPV	People mover					Chevrolet Orlando, Ford C-Max, Opel Zafira, Renault Scenic, Volkswagen Touran
Minivan	Large MPV				Large MPV		Chrysler Town and Country, Kia Carnival, Citroën C4 Grand Picasso, Renault Espace, Toyota Sienna



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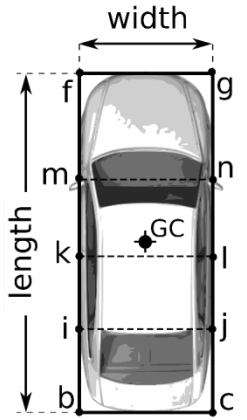
FIRE AND EGRESS PROBABILISTIC SIMULATION IN ROAD TUNNELS

VEHICLES' GEOMETRY



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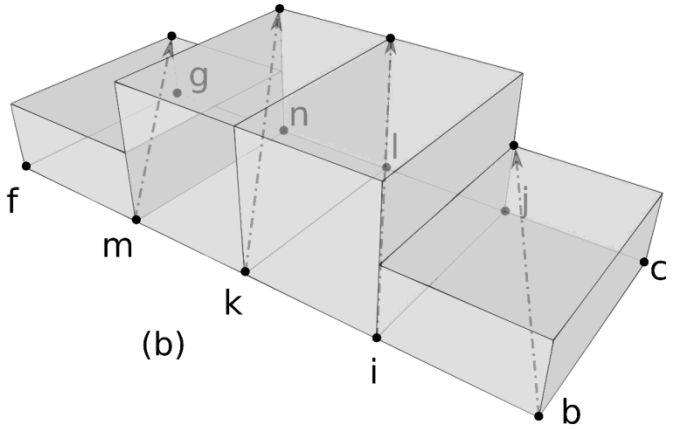

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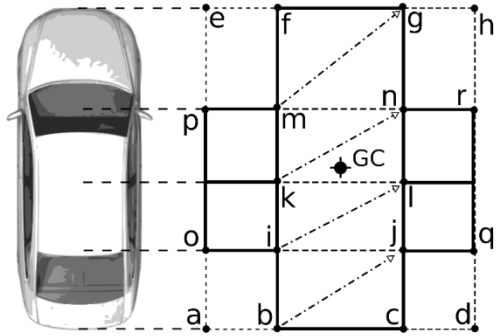

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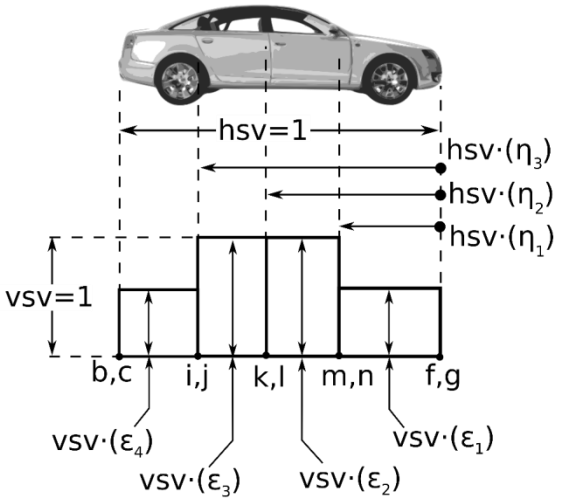

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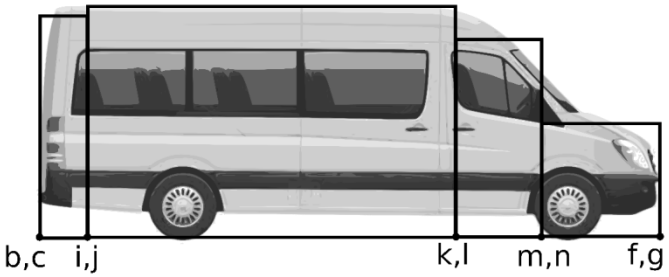

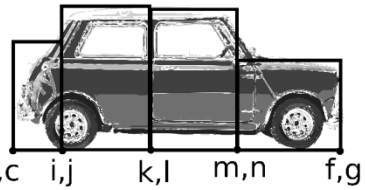

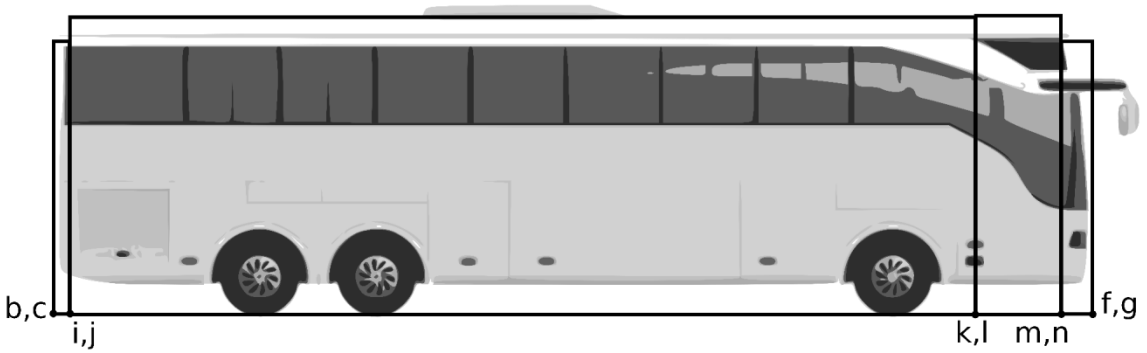

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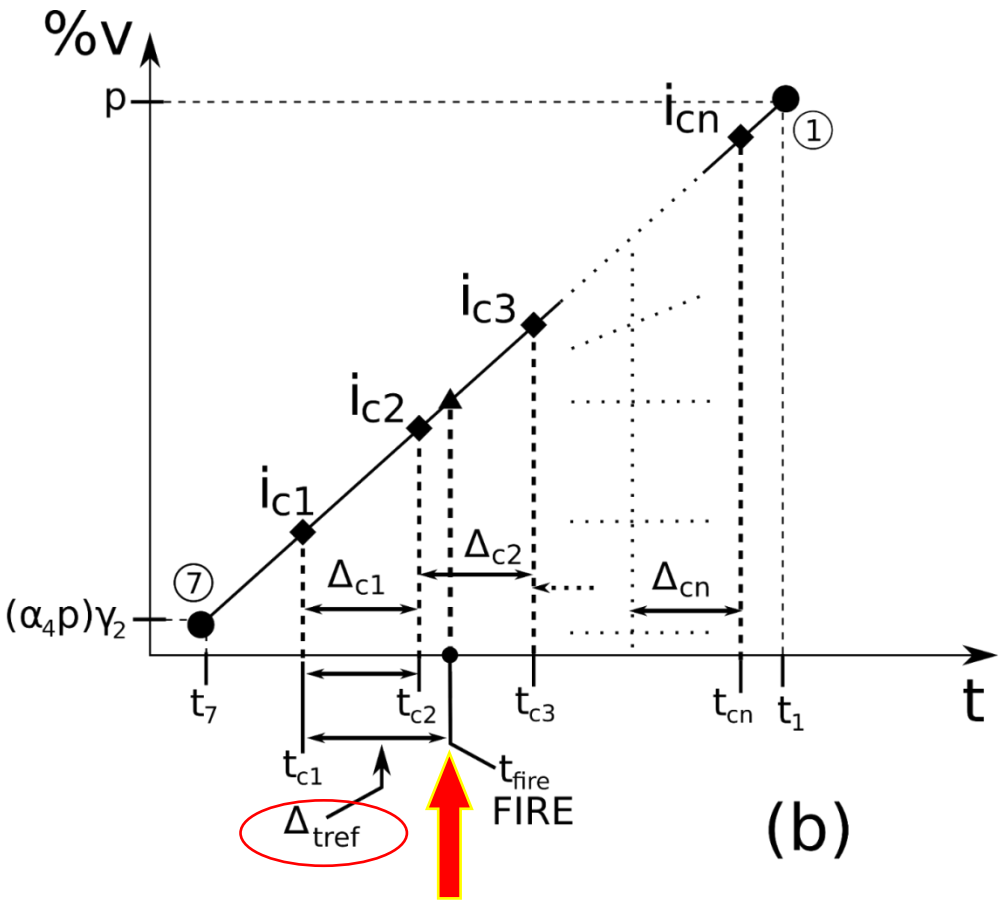
FIRE AND EGRESS PROBABILISTIC SIMULATION IN ROAD TUNNELS

VEHICLES' DYNAMICS

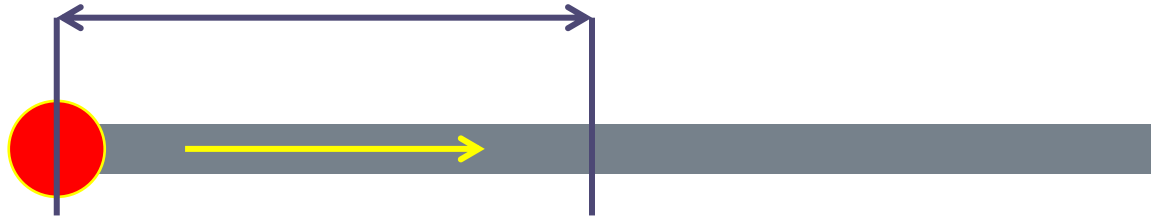


ANNUAL AVERAGE DAILY TRAFFIC CURVE

Time of arrival at fire scenario?

Vehicle cohort in the conflict point?

How many vehicles will be there in seconds?



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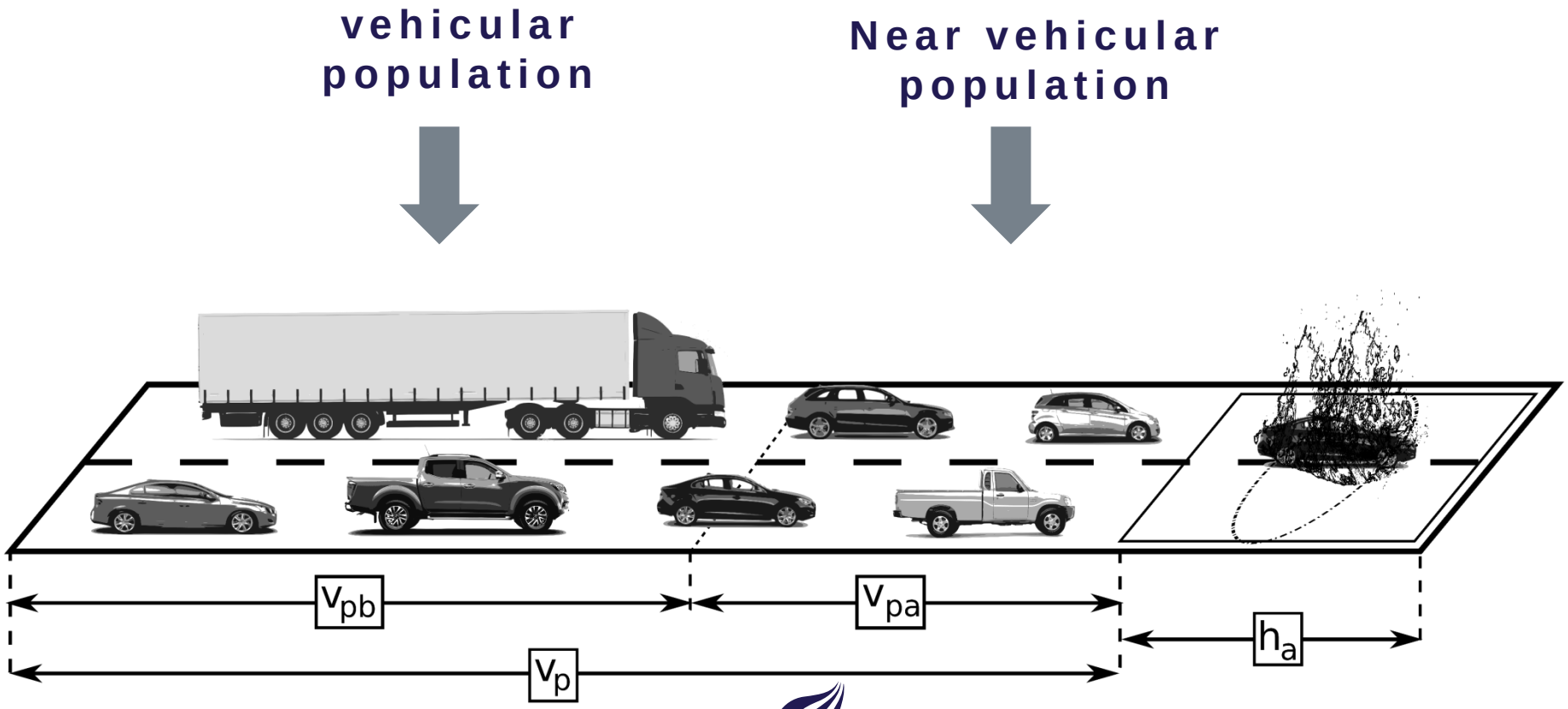
FIRE AND EGRESS PROBABILISTIC SIMULATION IN ROAD TUNNELS



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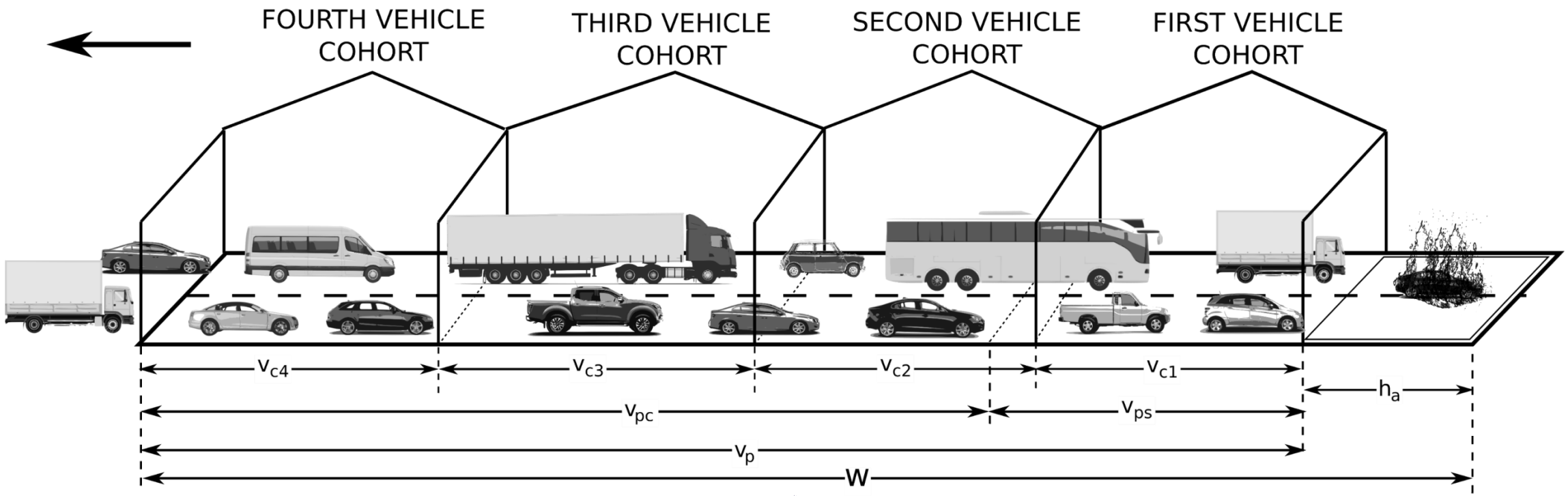
FIRE AND EGRESS PROBABILISTIC SIMULATION IN ROAD TUNNELS

VEHICLES' DYNAMICS

ANNUAL AVERAGE DAILY TRAFFIC CURVE



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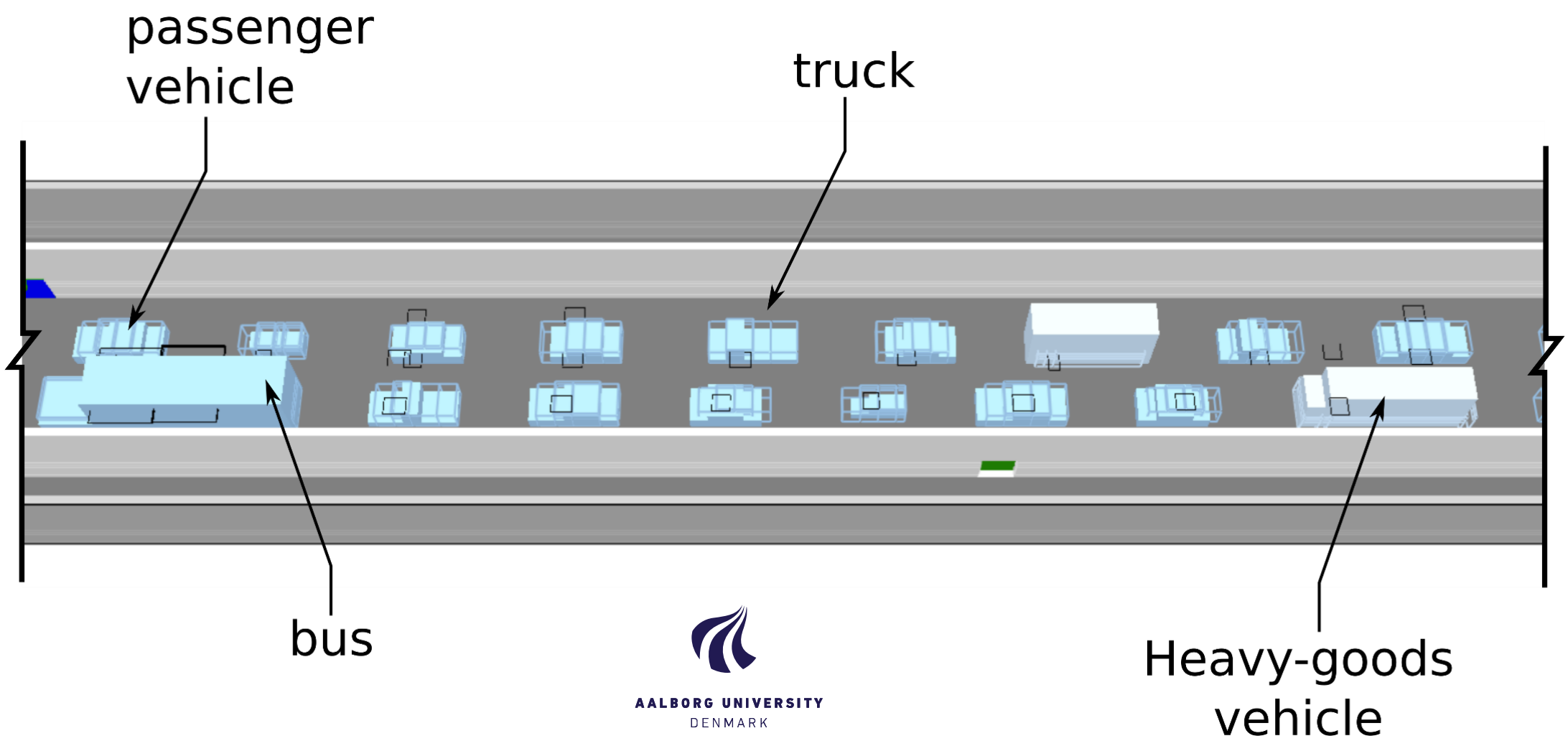
FIRE AND EGRESS PROBABILISTIC SIMULATION IN ROAD TUNNELS

VEHICLES' GEOMETRY AND DYNAMIC



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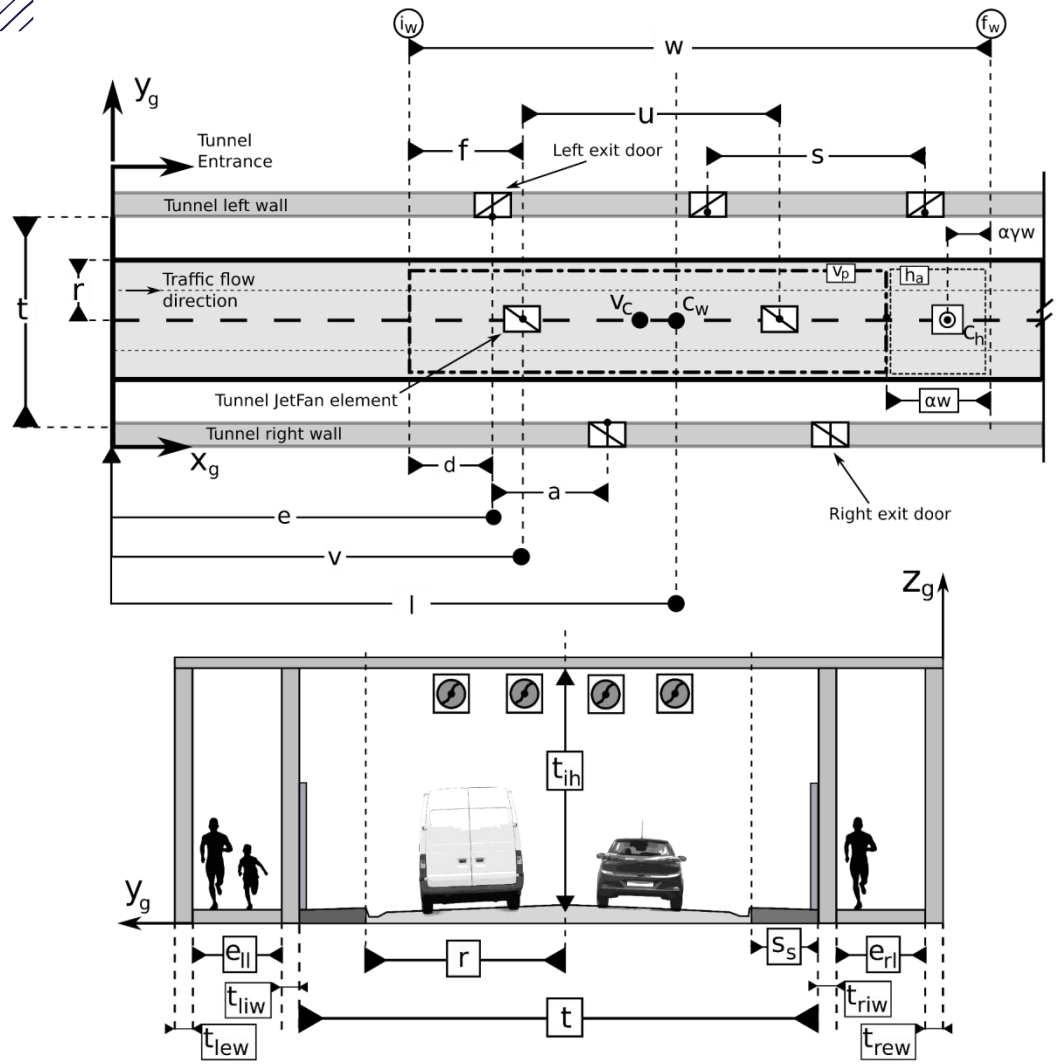
Tunnel spatial context



TUNNEL SPATIAL COMPONENTS

- Roadway characteristics (lane width and shoulders)
- Exit doors (distance between, size and arrangement)
- Ventilation system and components
- Fire source (intensity, HRR, ignition temperature,…)
- Spatial consideration of vehicle population

CROSS SECTION

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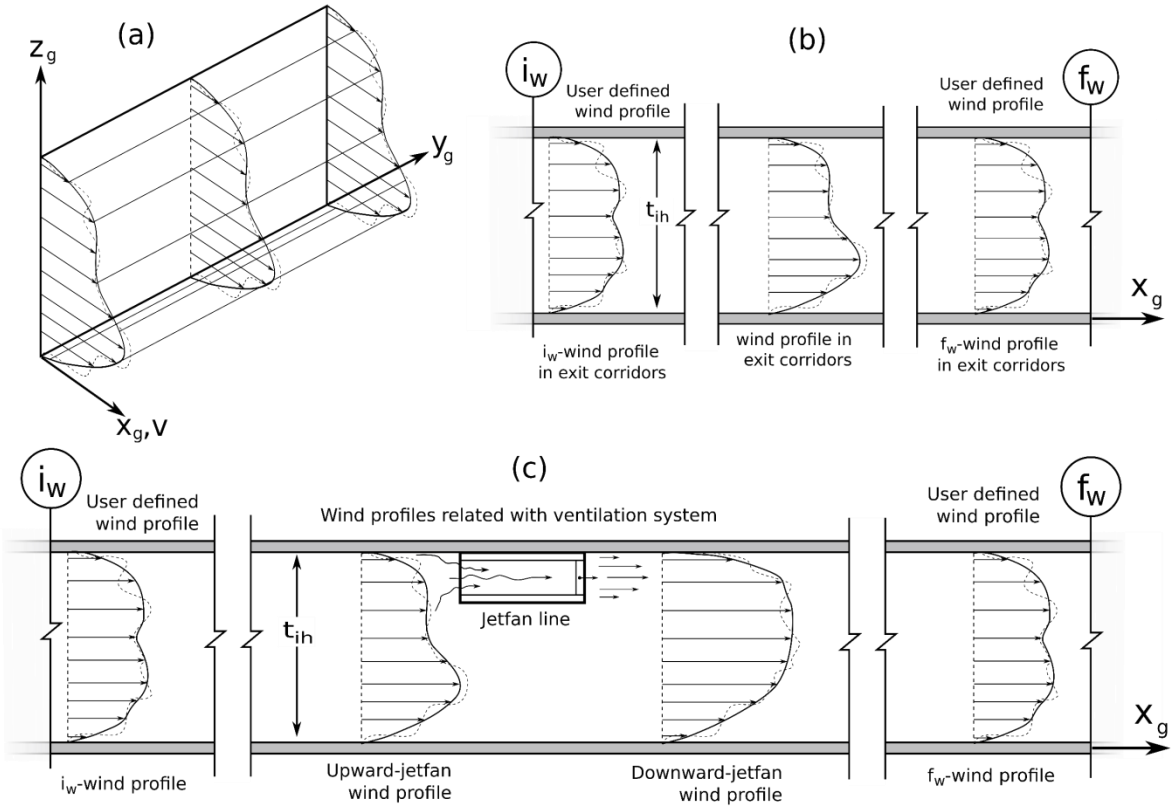
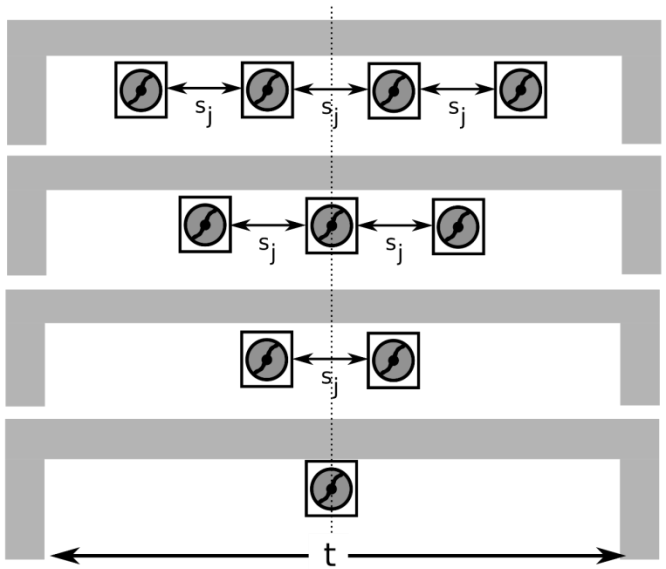
Wind profiles in the tunnel





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AGENT-BASED MODELING

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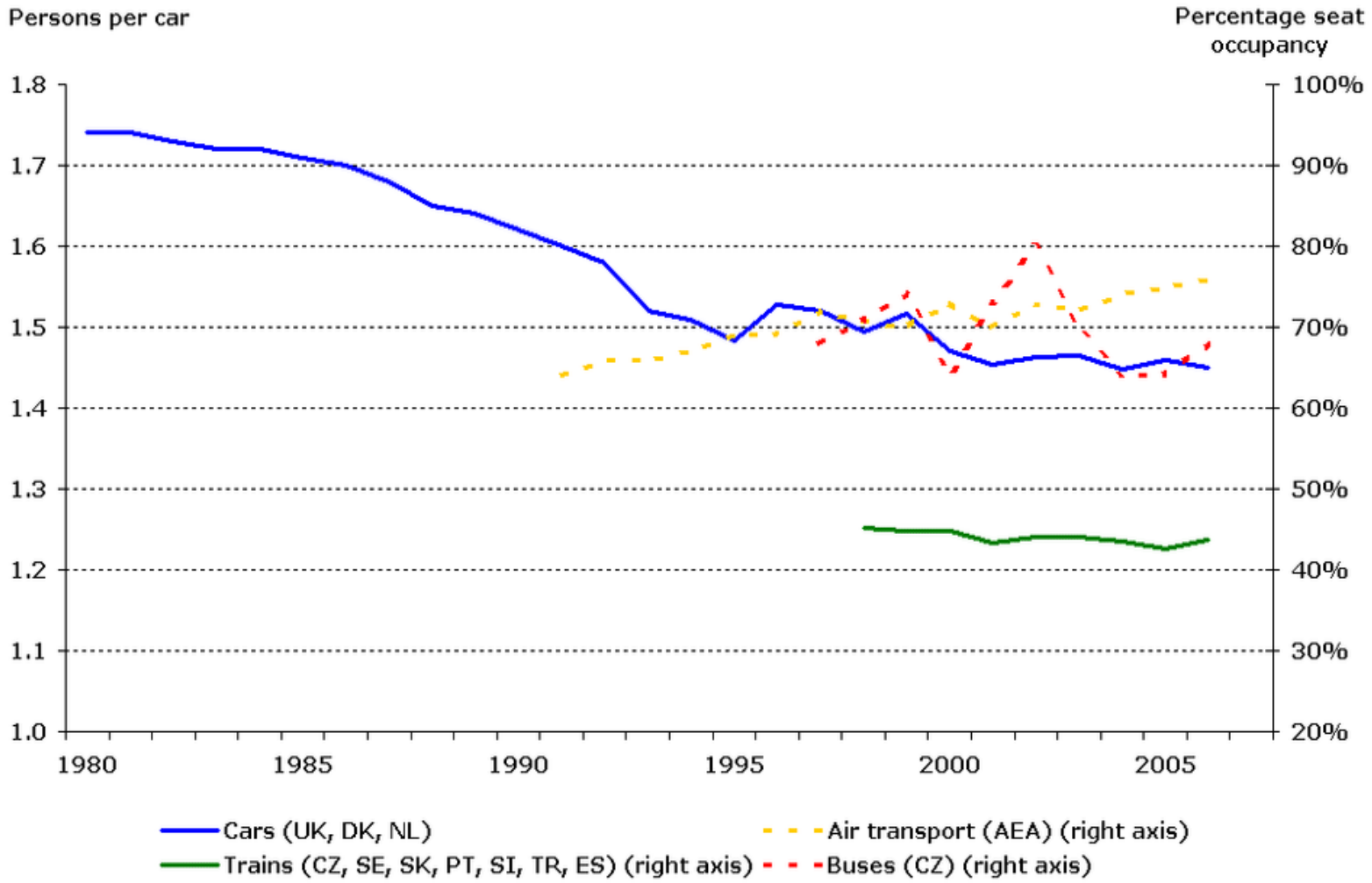
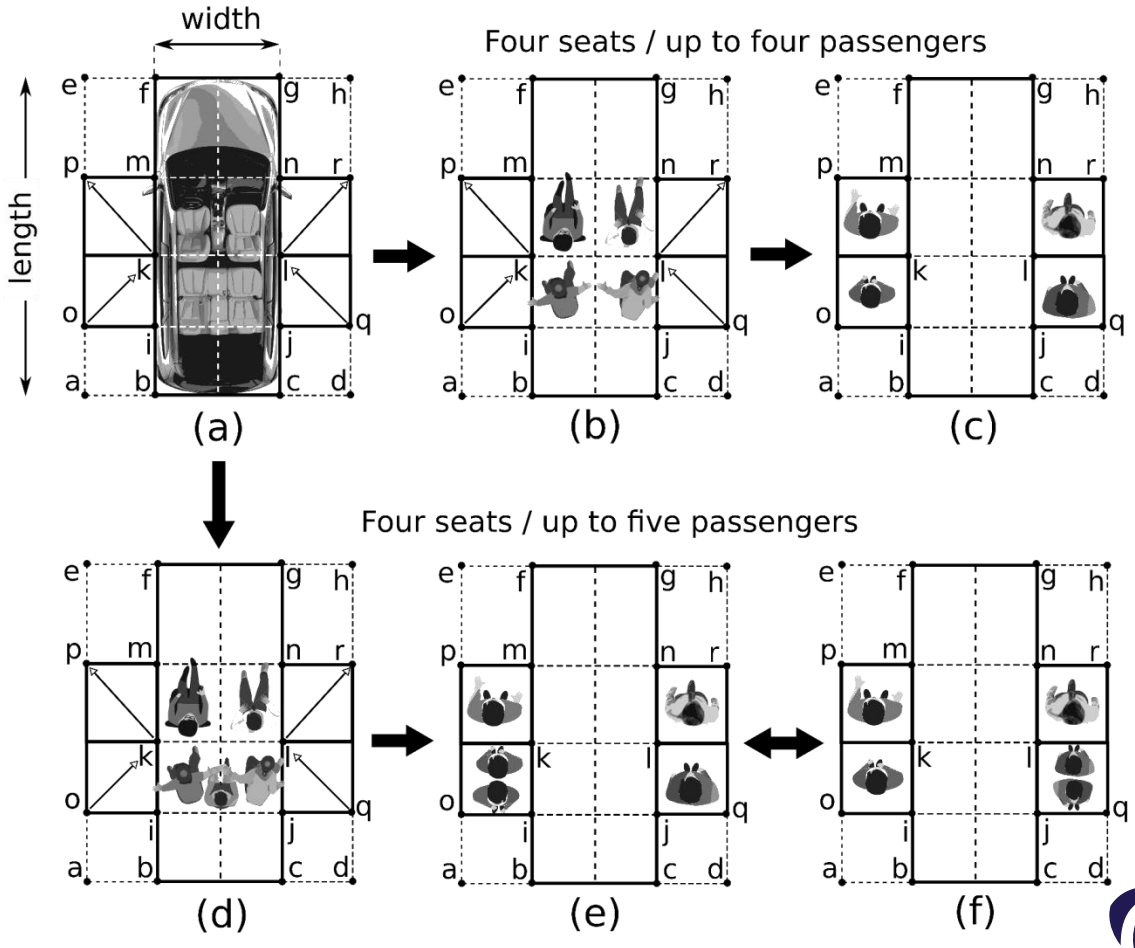
Agent-based modeling

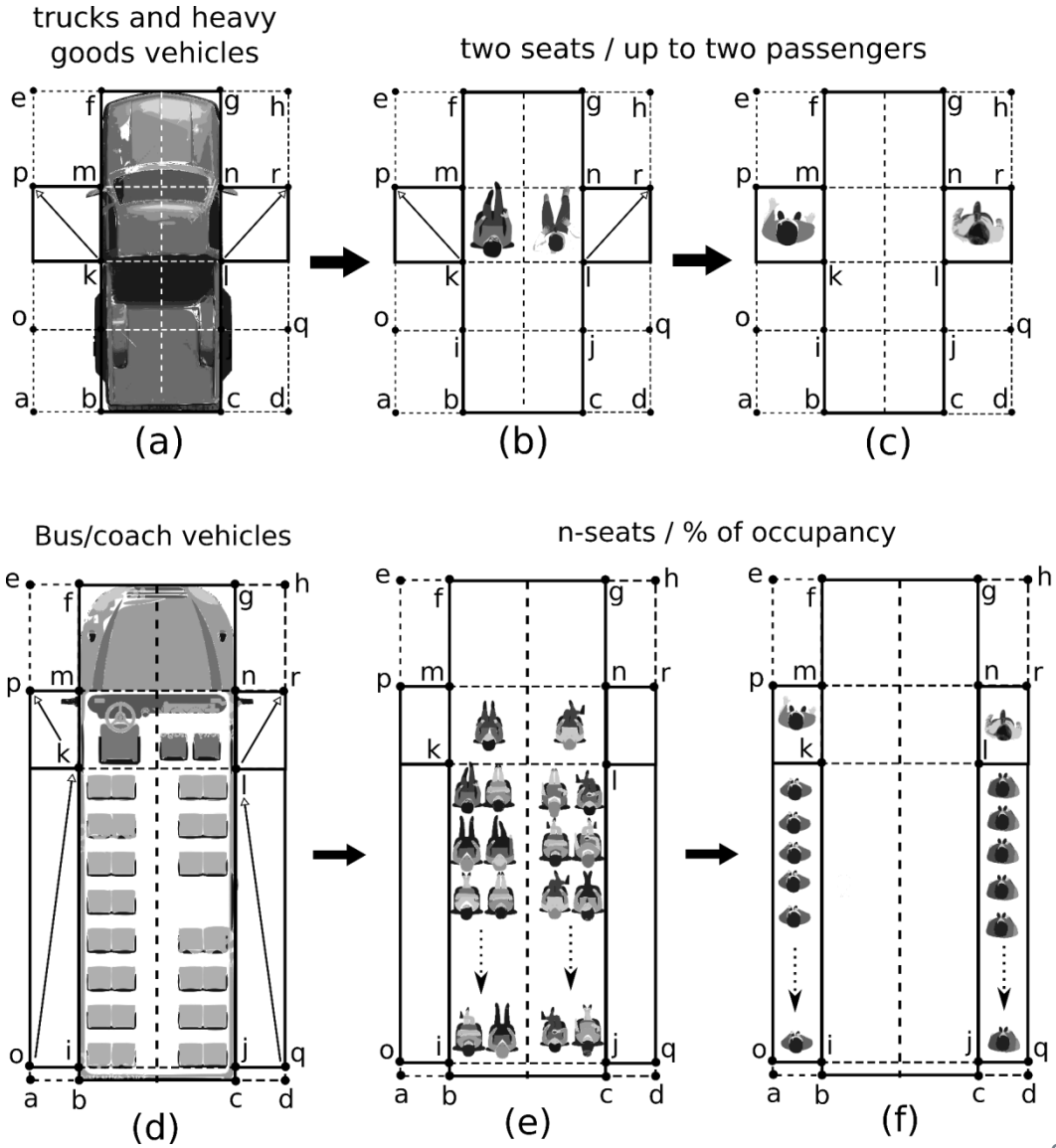
Europe statistics of passengers



Agent-based modeling

Passengers location





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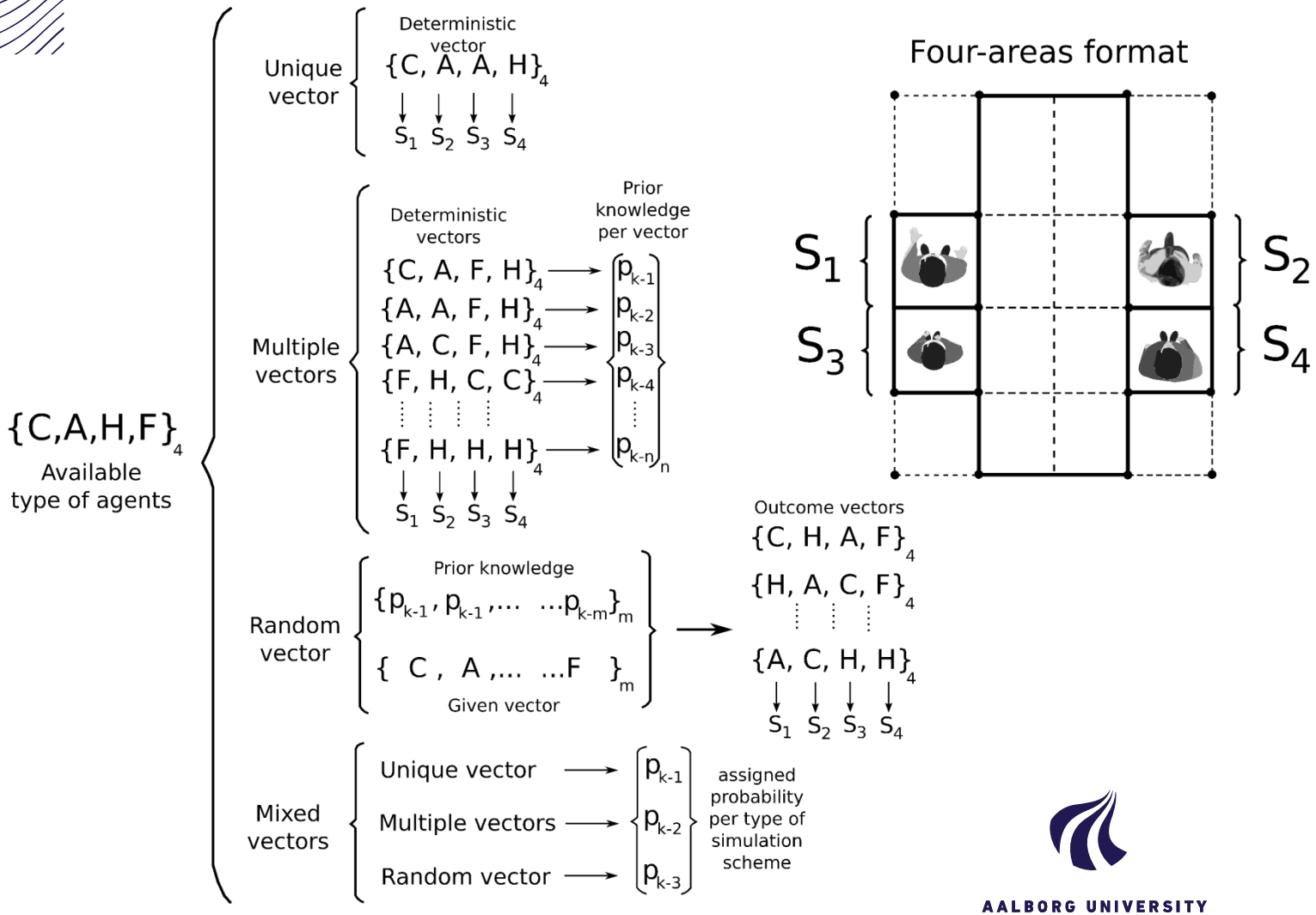
Agent-based modeling

Humanoid-agents's behaviour:

Active (A)
Conservative (C)
Follower (F)
Herding (H)

Agent-based modeling



Humanoid-agents's behaviour:

Active (A)
Conservative (C)
Follower (F)
Herding (H)

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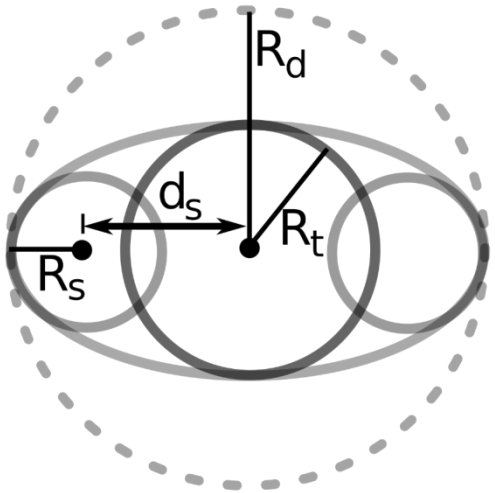
Agent-based modeling

Body type considerations

Table 6.1- Unimpeded walking velocities and body dimensions in FDS+Evac. The offset of shoulder circles is given by $ds = R_d - R_s$, for the definition of the other body size variables, R_d, R_t, R_s, see Fig. 3.5 The body sizes and walking velocities of the agents are personalised by using them from uniform distributions, whose rages are also given. Table taken from ref. [XXX]

Body type	R_d (m)	R_t/R_d	R_s/R_d	d_s/R_d	Speed (m/s)
Adult	0.255±0.035	0.5882	0.3725	0.6275	1.25±0.30
Male	0.270±0.020	0.5926	0.3704	0.6296	1.35±0.20
Female	0.240±0.020	0.5833	0.3750	0.6250	1.15±0.20
Child	0.210±0.015	0.5714	0.3333	0.6667	0.90±0.30
Elderly	0.250±0.020	0.6000	0.3600	0.6400	0.80±0.30

Table from ref. [XXX]



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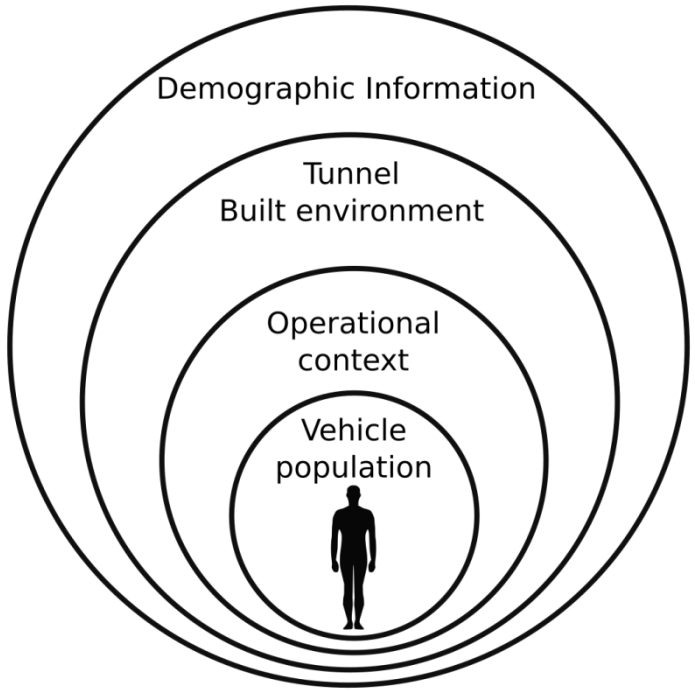
SOCIETAL APPROACH



PROBABILISTIC APPROACH

Number and composition of the population (users)

What if….

- **Elderly individuals** are a majority in coming social groups?
- **Visiting people** is totally unfamiliar with public spaces because because they spend most of their time in virtual spaces (fornite, youtube, internet, facebook)?
- **Social cohesion** is going from homogeneous to heterogenous condition because policies, operational scenarios, historical and beliefs?
- **Physical characteristics** would affect a most of the user in a specific fire scenario? (obesity, elderly population..)

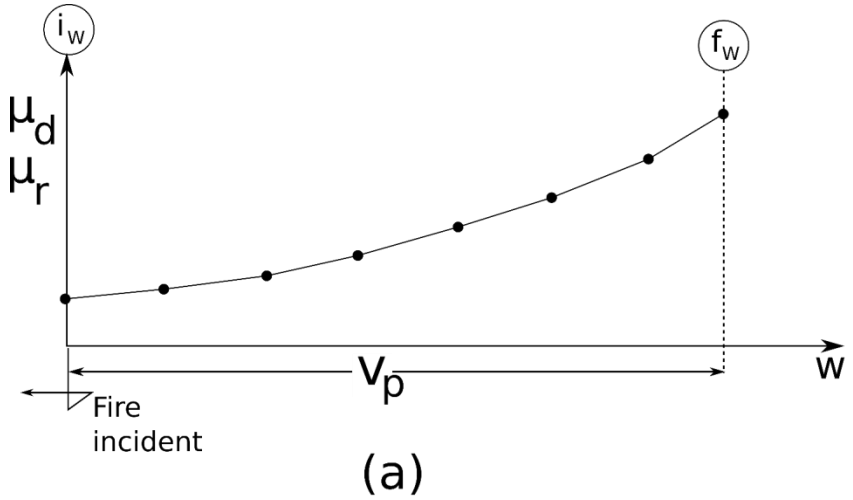
Operational context

What if….

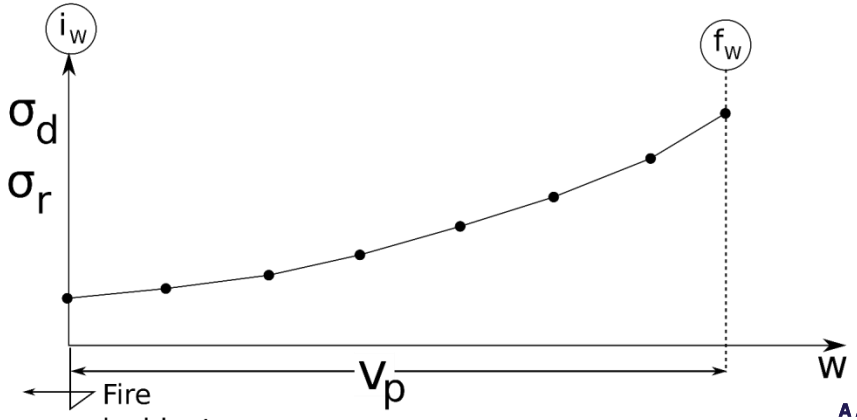
- **Infrastructure and vehicle traffic** is changing, making more critical any fire incident.
- **Vehicle market** is changing affecting occupancy rate.
- **Mobility paradigms** change having higher occupancy rates and accidents.

Agent-based modeling

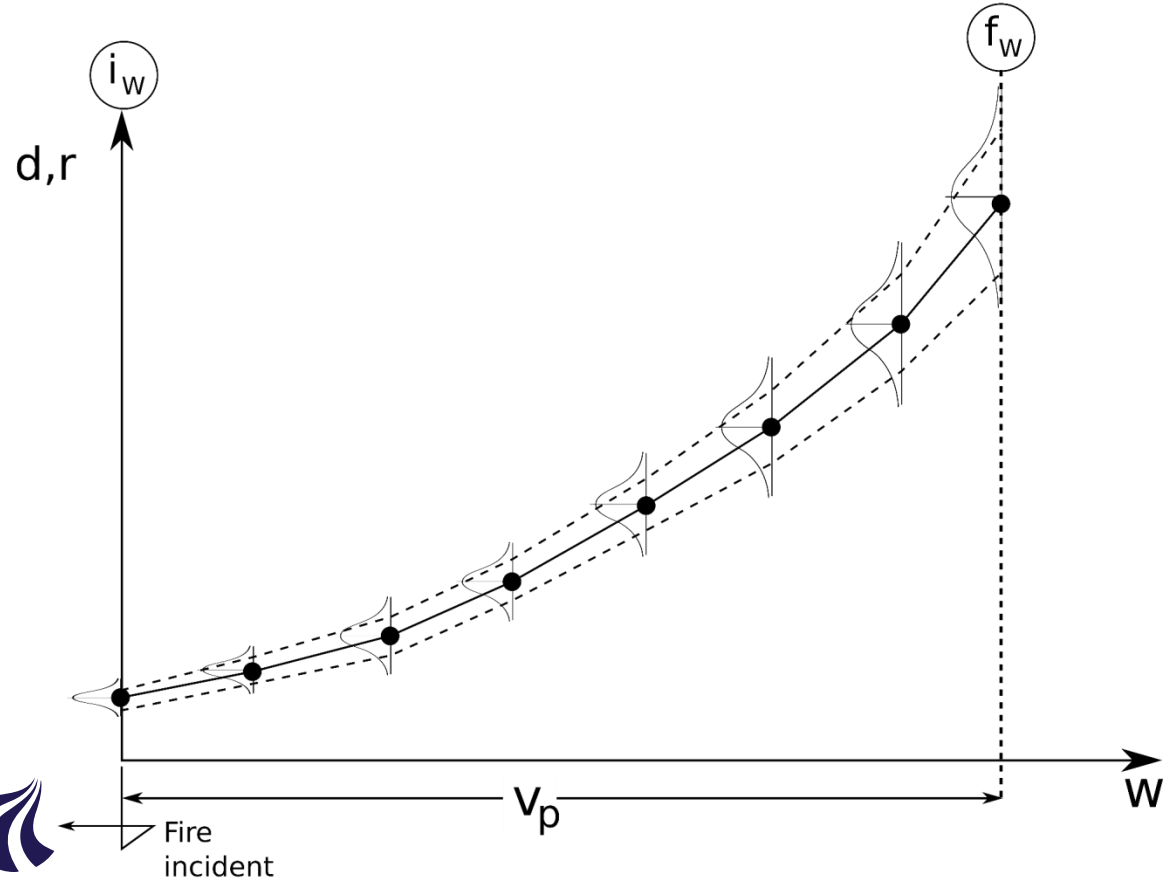
Detection and reaction time



(a)



(b)



(c)

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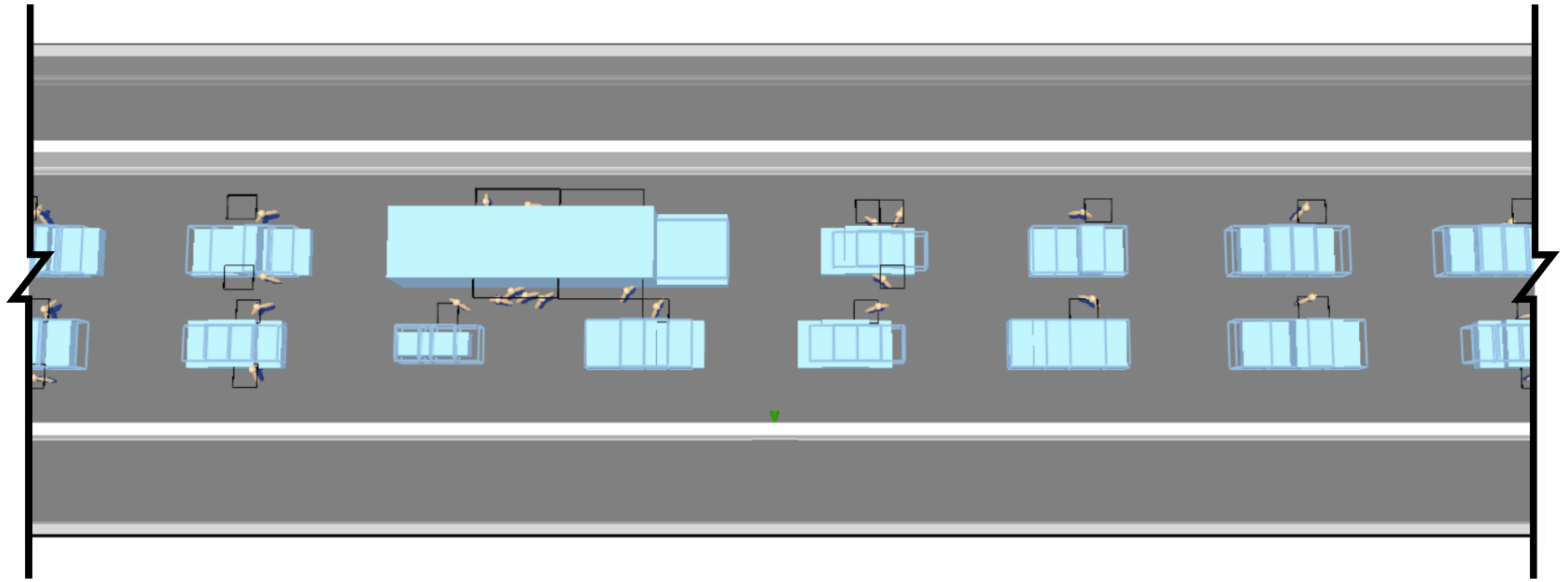
Agent-based modeling

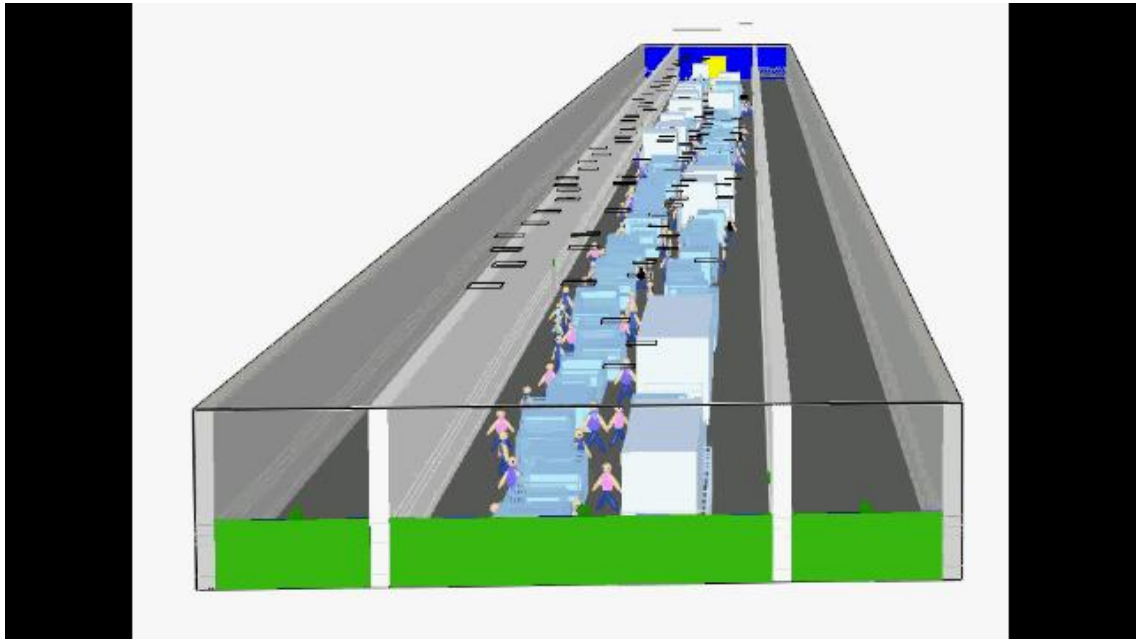
Rational location of passengers

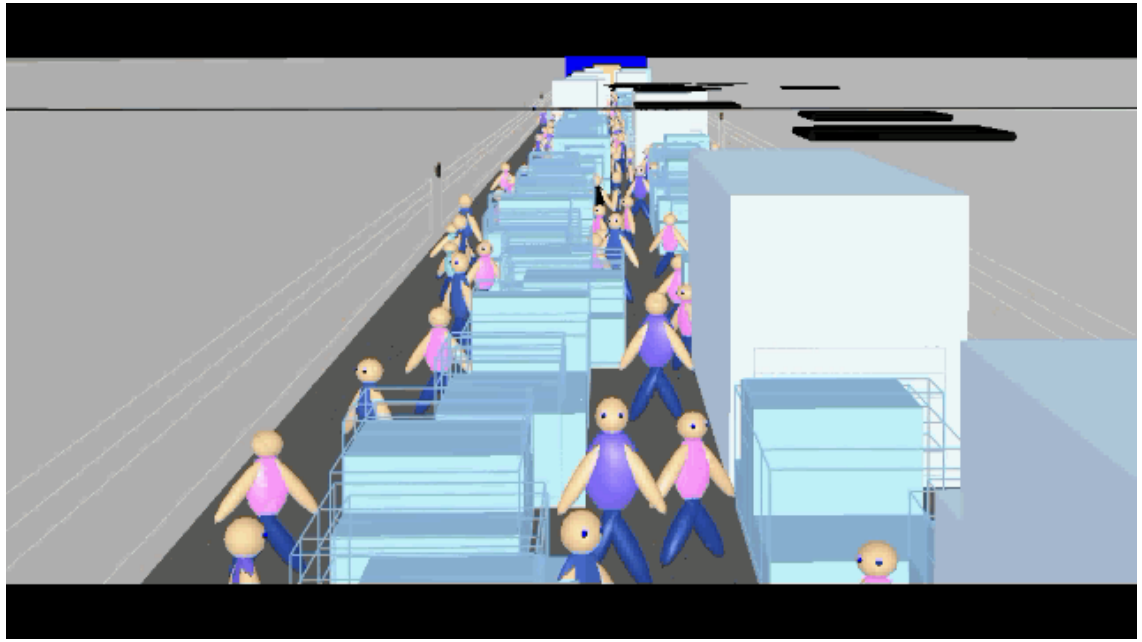


Location according:

- Operational features
- Demographic composition
- Vehicle occupancy statistics
- Agents models

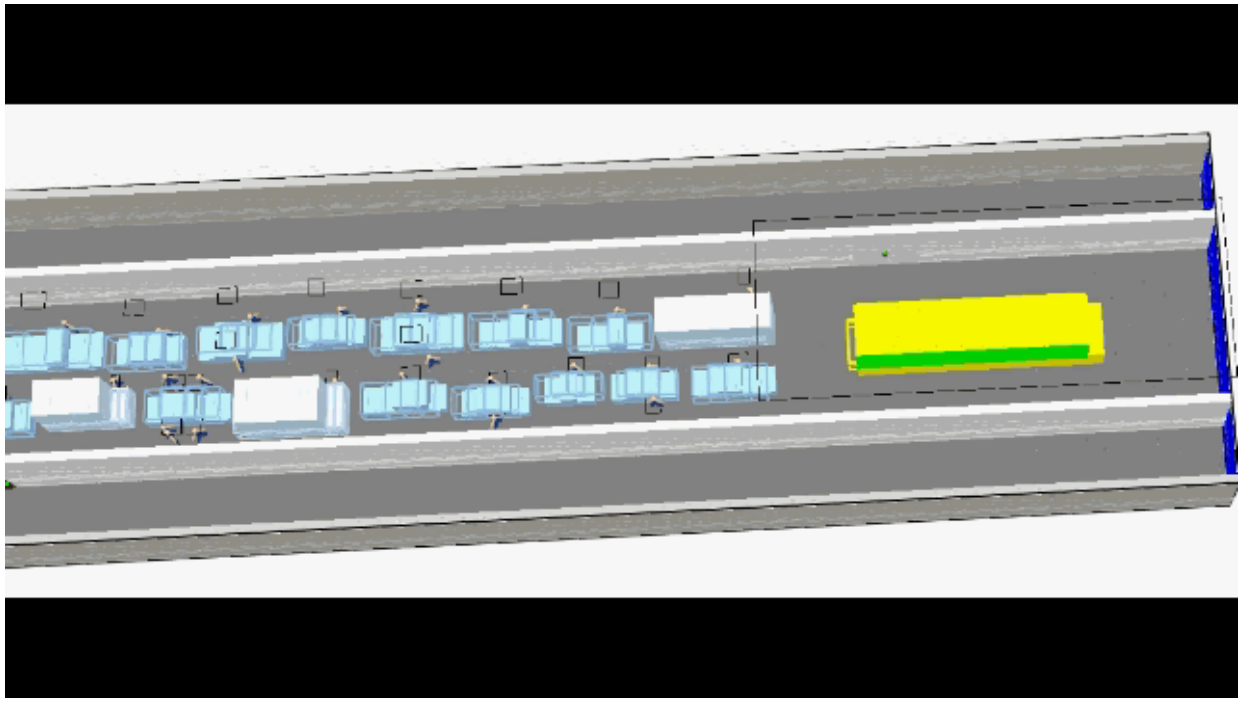
Agent-based modelling



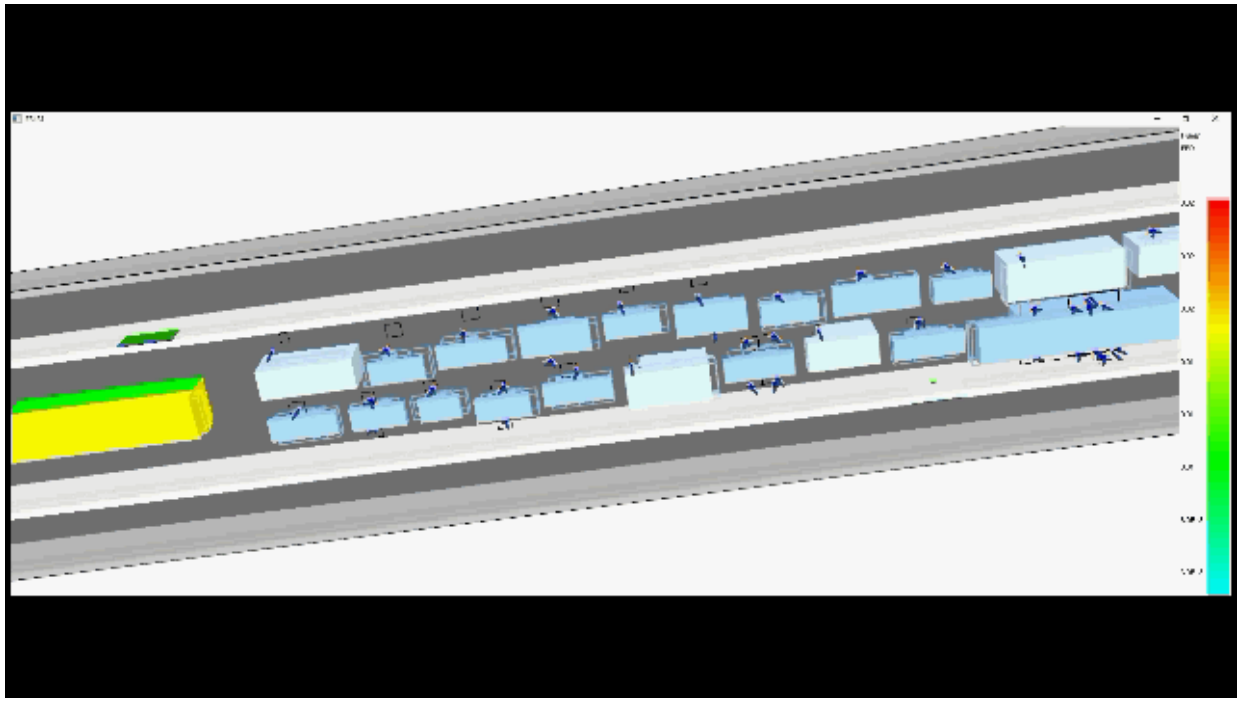


Agent-based modeling

TOP VIEW



BOTTOM VIEW



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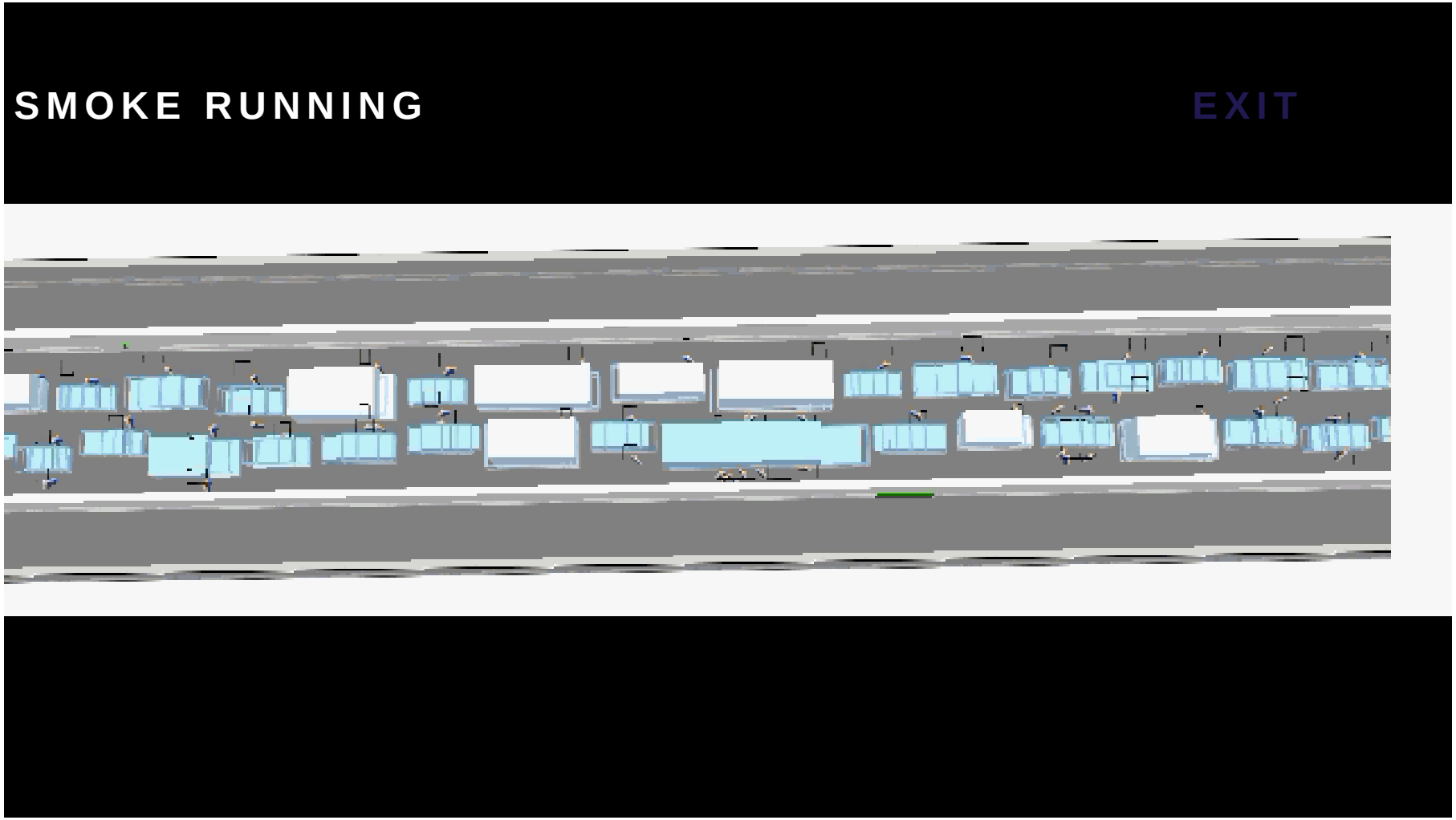
Agent-based modeling

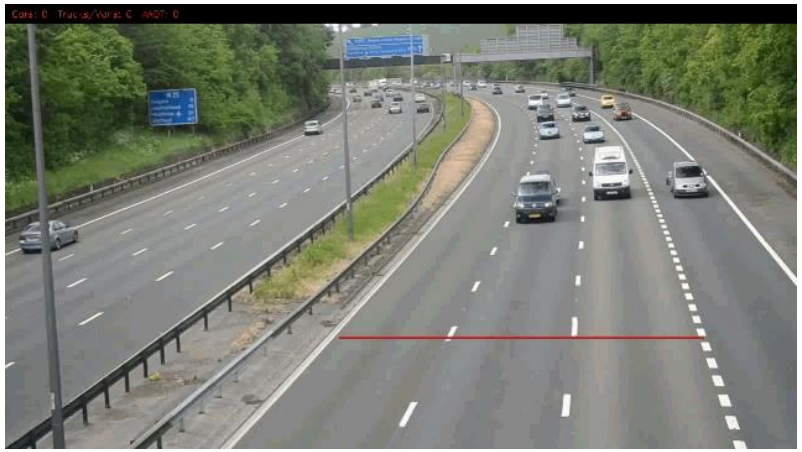


REAL-TIME RISK ASSESSMENT

Real-time Risk Assessment

Monitoring and Fire-Emergency system

- Traffic volumen
- AADT-real time curve
- Vehicles per hour
- Vehicles per kilometer
- Heavy-goods vehicles
- Daytime
- Level of service
- Thermal load
- Potential Severity of fire



Traffic volumen
Annual Average Daily Traffic
Tunnel zone
Daytime
Vehicles per hour
Level of service
Vehicles per kilometer
Heavy-goods vehicles
Passenger vehicles

Alarm system
Monitoring system
Fire emergency system

- Fire accident
- Monitoring system
- Fire emergency system
- Tunnel zone

Fire accident
Thermal load
Potential severity of fire
Escape conditions

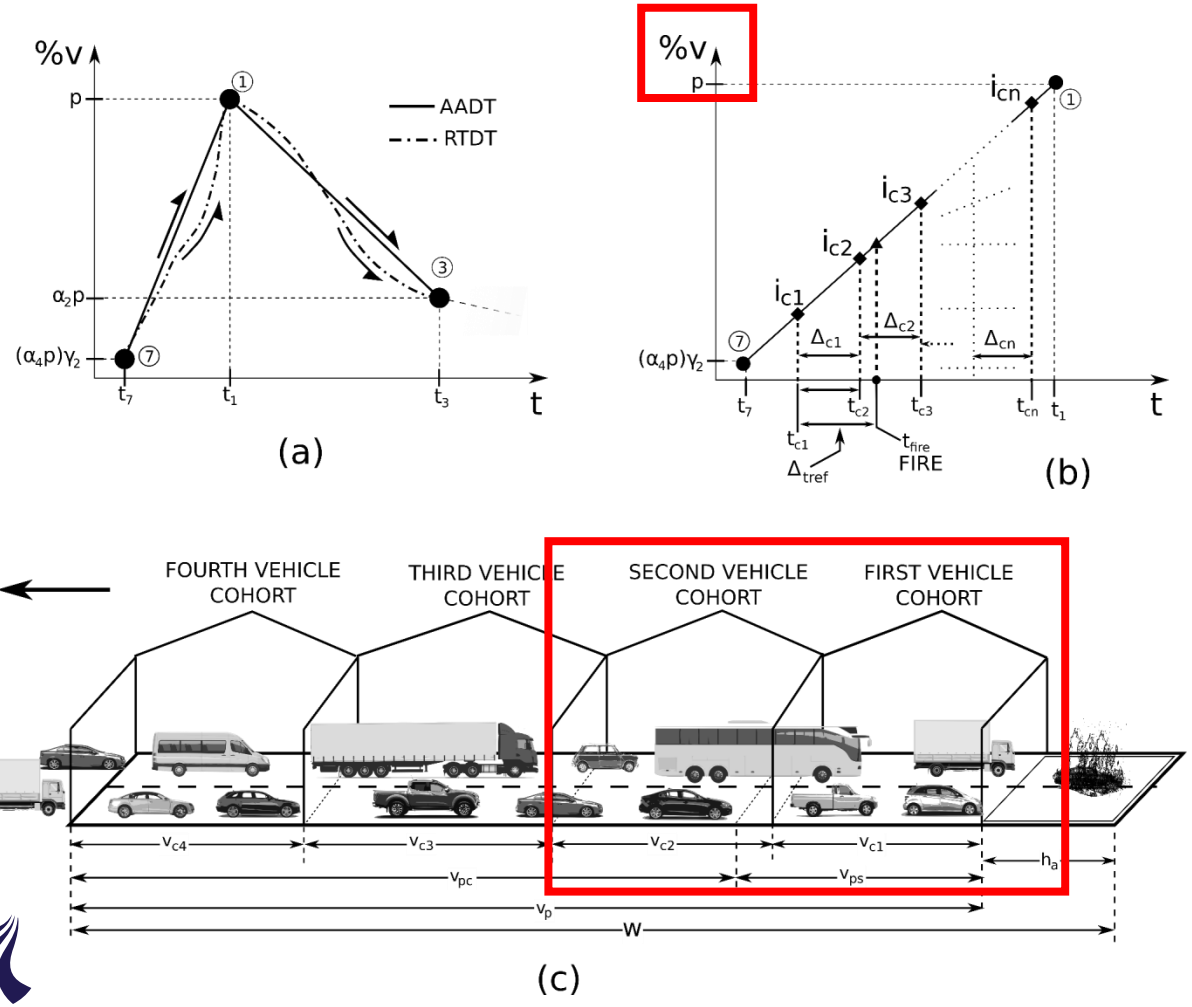
Real-time Risk Assessment

Monitoring and Fire-Emergency system

- Traffic volumen
- AADT-real time curve
- Vehicles per hour
- Vehicles per kilometer
- Heavy-goods vehicles

- Daytime
- Level of service
- Thermal load
- Potential Severity of fire

- Fire accident
- Monitoring system
- Fire emergency system
- Tunnel zone



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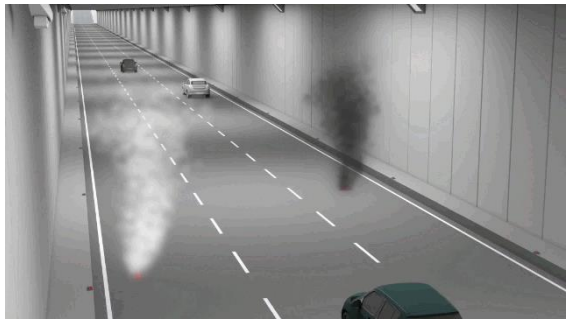
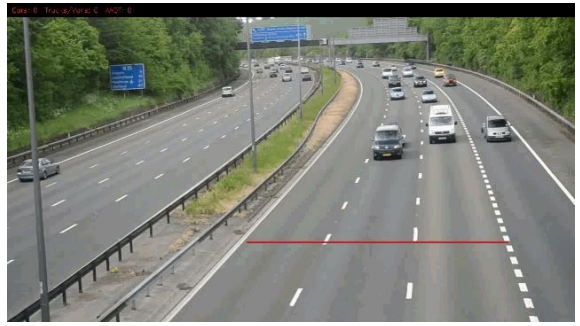
Real-time Risk Assessment

Monitoring and Fire-Emergency system

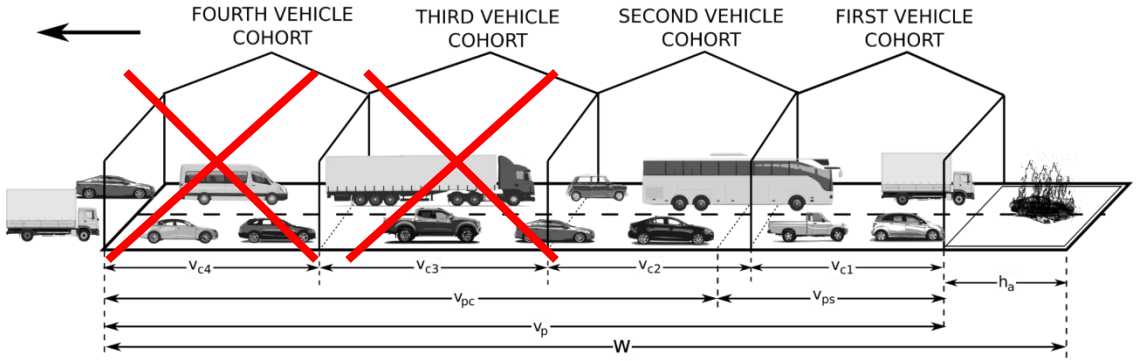
Detect scenario



Fast intervention



Avoid scenarios



25% 25% 25% 25% = 100%

25% 25% 25% = 75%

25% 25% = 50%

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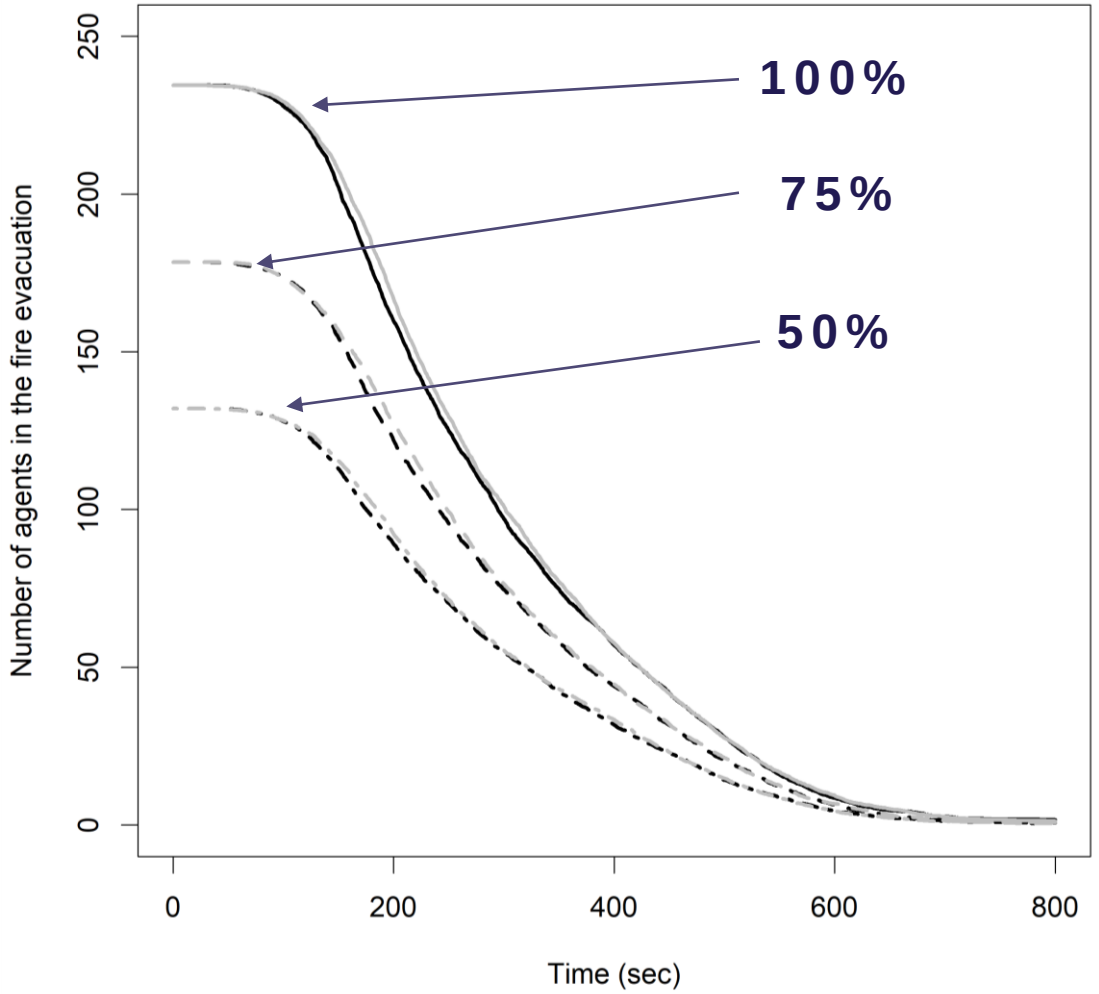
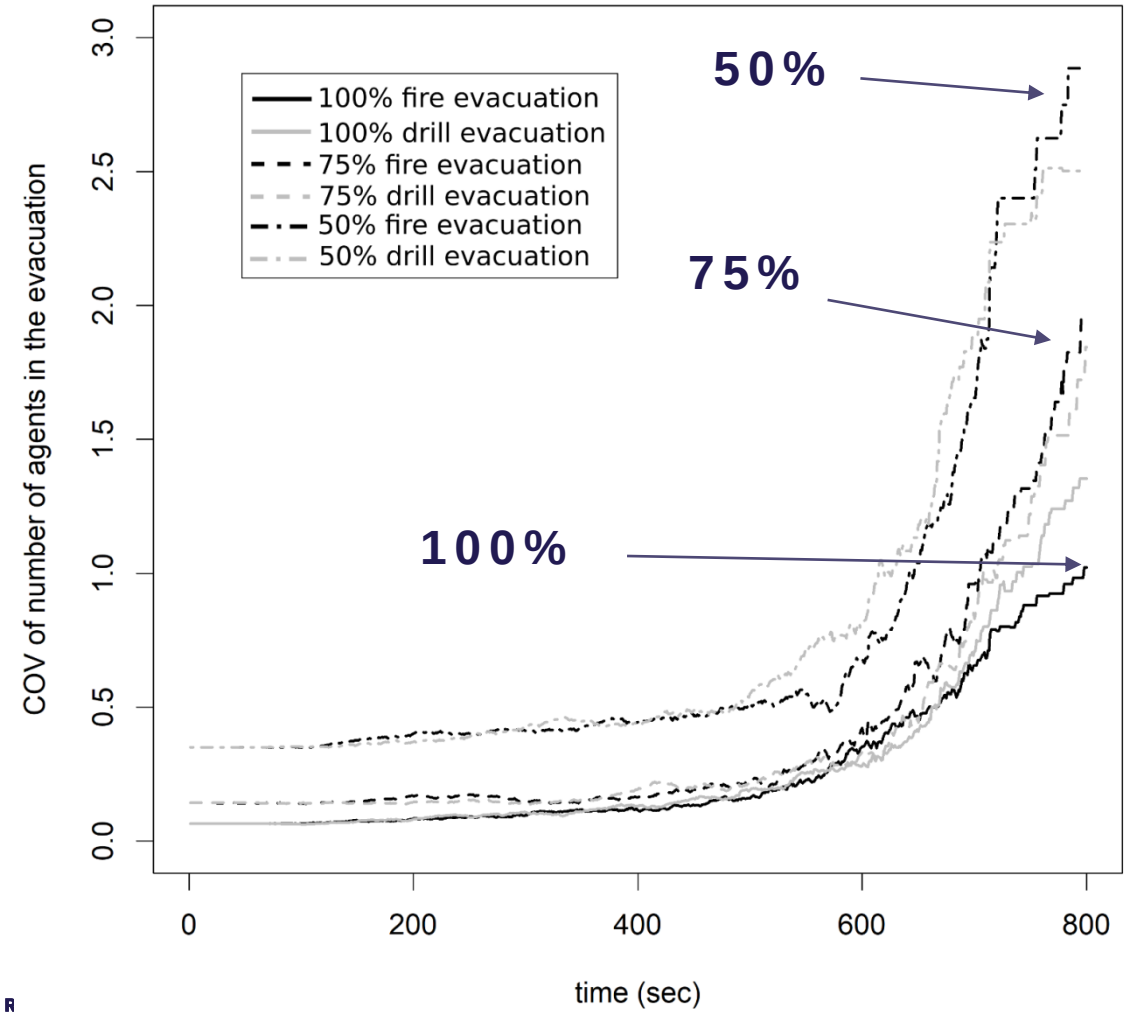
Agent-based modeling

Real-Time informatio vs Effectiveness-Efficiency





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Thanks for your attention

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