A real-time stochastic evacuation model for road tunnels

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Overview

- Introduction
- DSS (Decision Support System)
- Evactunnel®
- Comparison with other egress models
- DSS: Incident and Decision Models
- Case of application
- Conclusions

What is currently available for the tunnel operator to deal with the emergency?

A fast and effective response can mean the difference between life and death

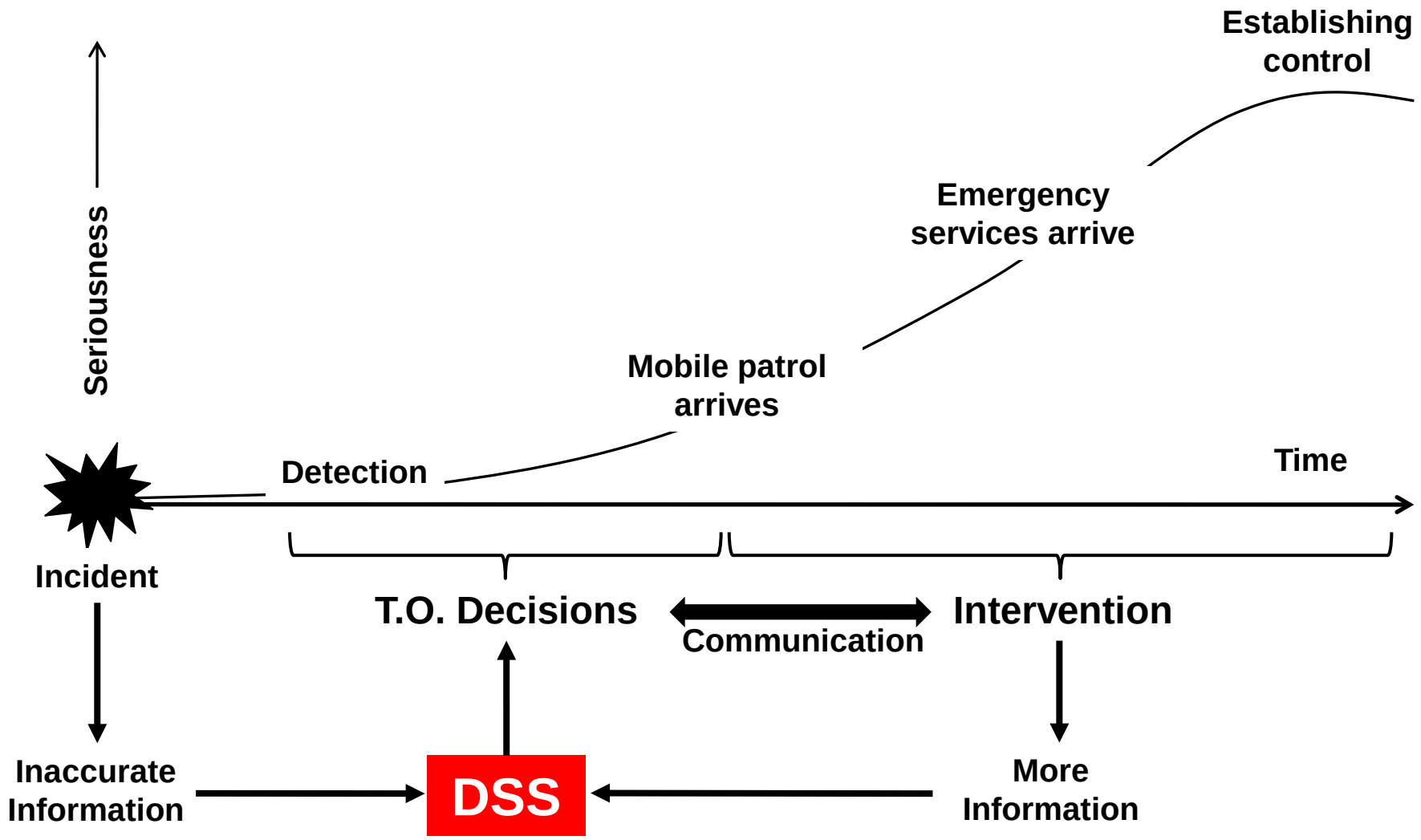
Contingency Plans:

Static Flow charts and Event trees?

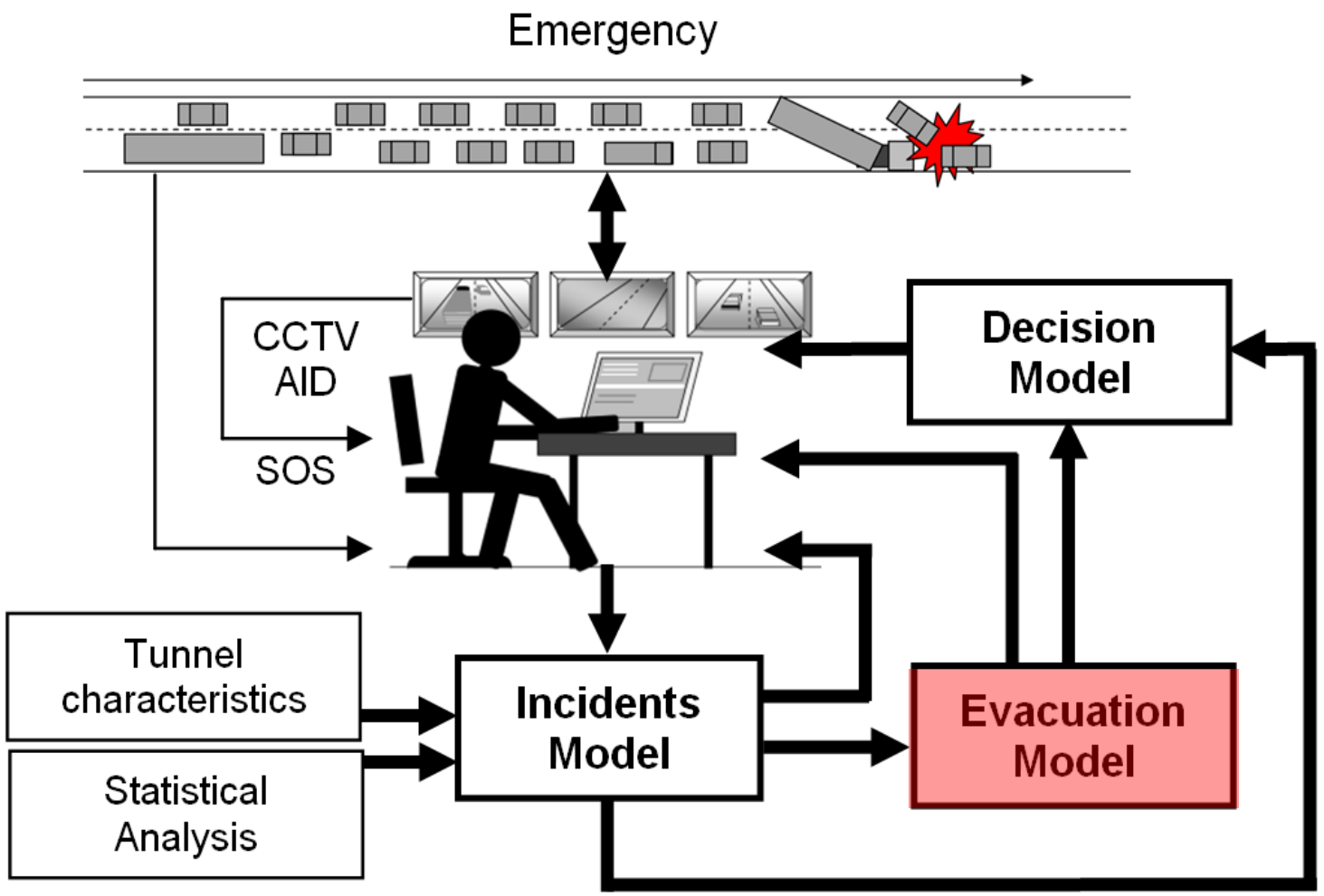
Personal Skills:

Training, Experience, etc.?

Decision Support System



Decision Support System

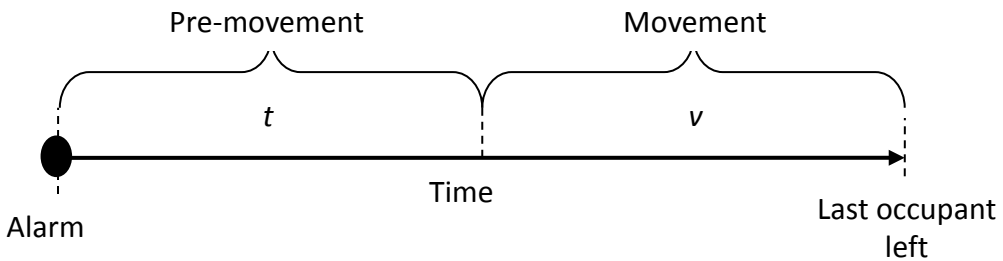


Evacuation Models

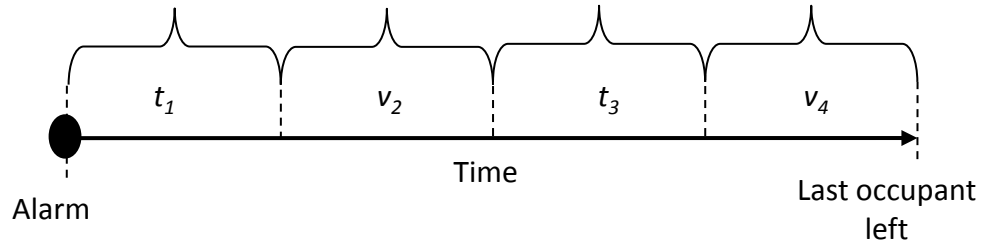
Particular scenarios

t = times variables
v = movement variables

Traditional approach



Real scenario observation



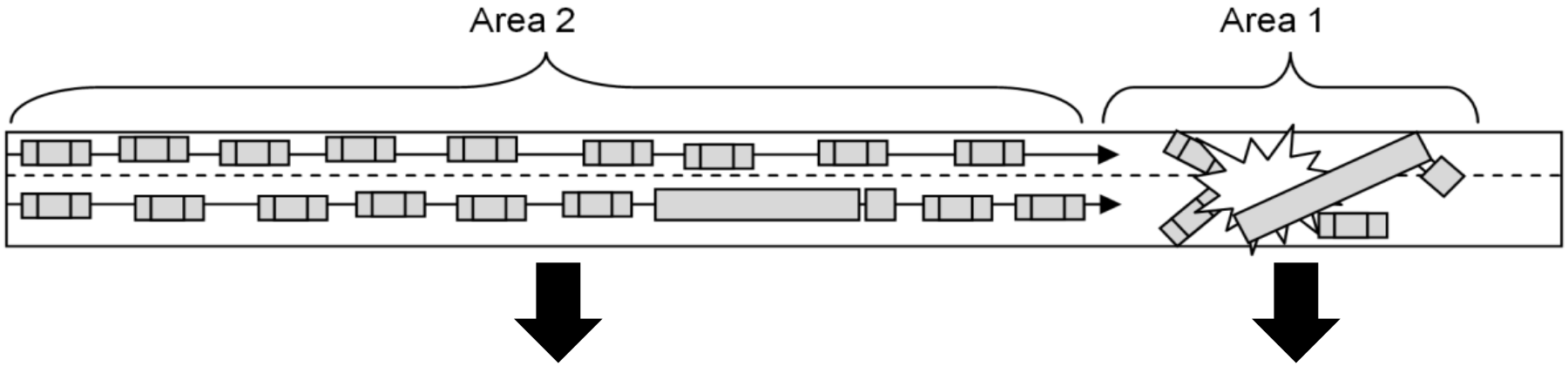
¿Pre-movement = t_1 + t_3?

$$\bar{t} = \bar{t}_1 + \bar{t}_3$$

$$\sigma_t = \sqrt{\sigma_{t_1}^2 + \sigma_{t_3}^2}$$

¿Not consider t_3?

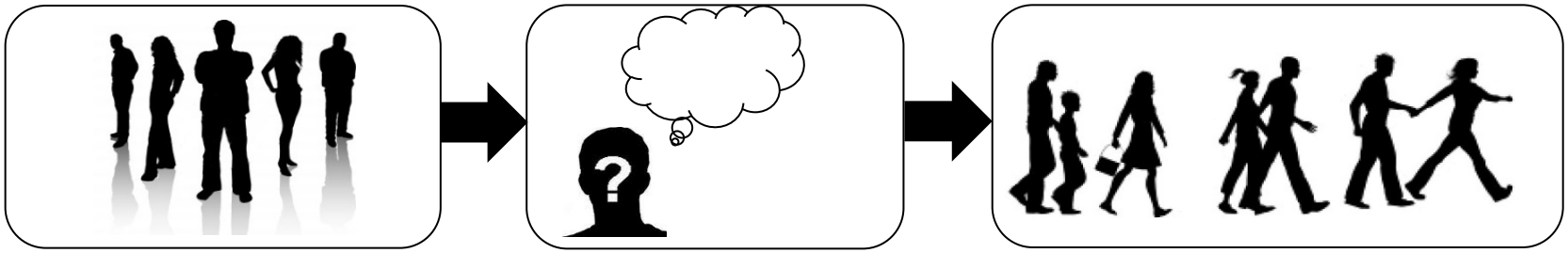
t_3 has influence on the rest of variables



Evacuation Model of Area 2 (self-rescue)

Evacuation Model of Area 1 (rescue and self-rescue)

Uncertainty = Stochastic Approach



Capote, J. Alvear, D., et al. A real-time stochastic evacuation model for road tunnels, Safety Science, 52 (2013), 73-80

Evacuation Model of Area 1

Incidents Model

Normal Mobility (NM)
Reduced Mobility (RM)
Assisted Mobility (AM)

$$t_{E1_i} = t_{pm_i} + \frac{d_{mov_i}}{v_{mov_i}}$$

Total evacuation time for *j th* simulation:

$$T_{t_{E1_i}} = \max \left\{ t_{E1_{ij}}^{(NM)} \Big|_{i=1,n'_{INM}}, t_{E1_{ij}}^{(RM)} \Big|_{i=1,n'_{IRM}}, t_{E1_{ij}}^{(AM)} \Big|_{i=1,n'_{IAM}} \right\} \Big|_{j=1,n_{iter}}$$

Evacuation Model of Area 2

Nº of people trapped:

$$q_j = \tilde{k}_{LV_j} \cdot n'_{IILV} + \tilde{k}_{HV_j} \cdot n'_{IIHV} + \tilde{k}_{BV_j} \cdot n'_{IIBV}$$

Where:

$\tilde{k}$ = Occupation coefficient on each vehicle type (random between max. and min.)

Distribution of people trapped (start position):

$$d_{mov_{ij}} = i \cdot \frac{d'_{I1}}{q_j}\Bigg|_{i=1,q_j}$$

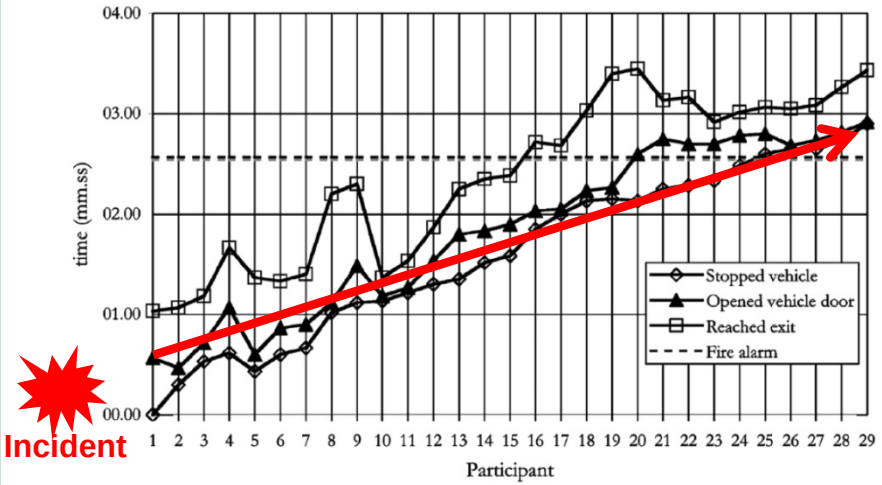
Where:

$d_{mov_{ij}}$ = Distance to the exit for i th user on j th simulation

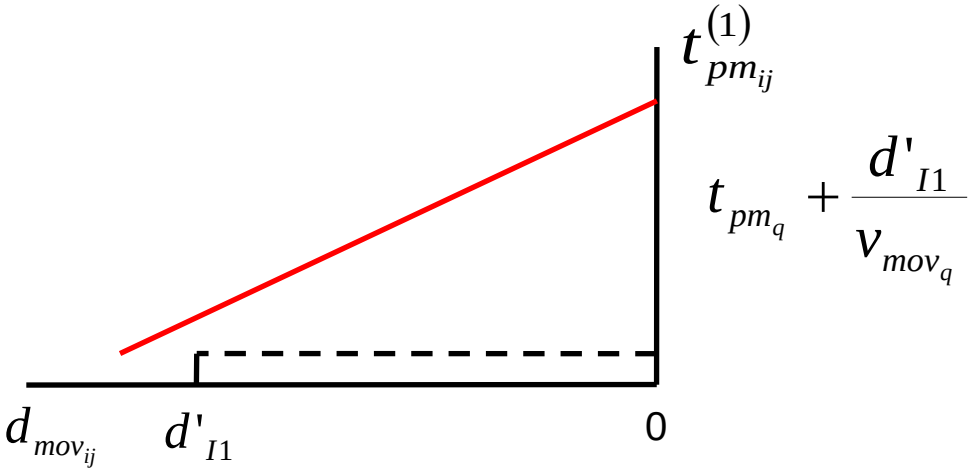
d'_{I1} = Maximum travelling distance in Area 2

Evacuation Model of Area 2

$$\text{Pre}-\text{movement time}\,(t_{pm_{ij}}) = \text{Recognition}\,(t^{(1)}_{pm_{ij}}) + \text{Response}\,(t^{(2)}_{pm_{ij}})$$



Source: Daniel Nilsson, Maria Johansson and Hakan Frantzich: Evacuation experiment in a road tunnel: A study of human behaviour and technical installations**.**
Fire safety Journal 44 (2009).



$$t^{(1)}_{pm_{ij}} = t_{pm_q} + \frac{d'_{I1} - d_{mov_{ij}}}{v_{mov_q}}$$

Advantages

1. Quick and easy to set up

2. It is possible to represent how different human behavoiur affects evacuation times

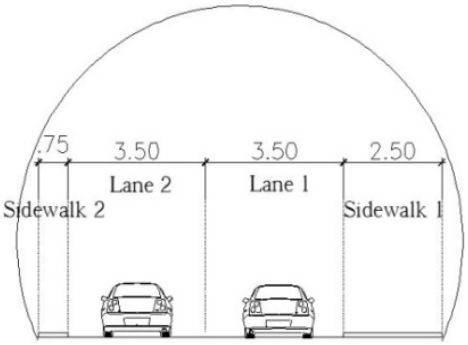
3. We can simulate thousands of potential outcomes in less than 5 seconds (results faster than Real-Time)

Demostration

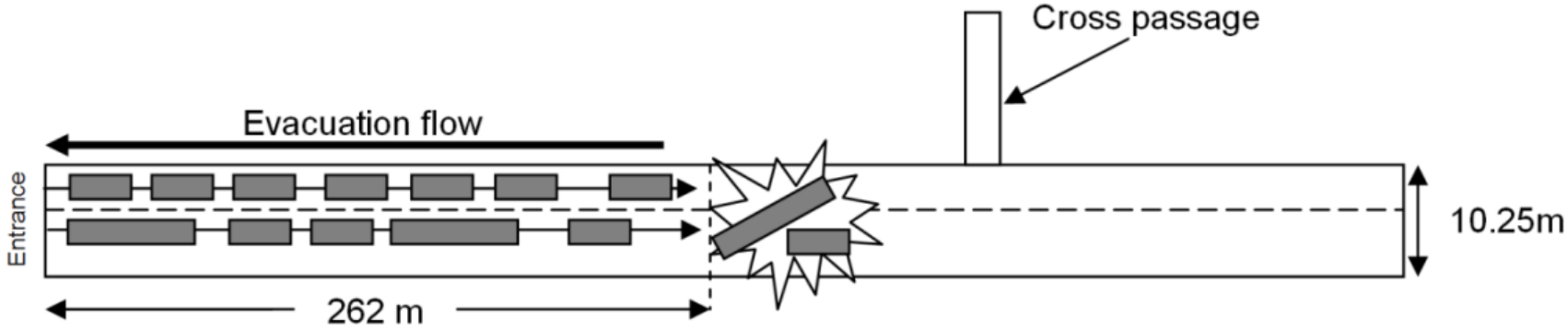
Comparison with other models

The tunnel

Name = Lantueno Tunnel
Location = La Meseta Highway (A-67)
two-bore uni-directional road tunnel
Length = 670 m
Cross passage at 390 m



The scenario



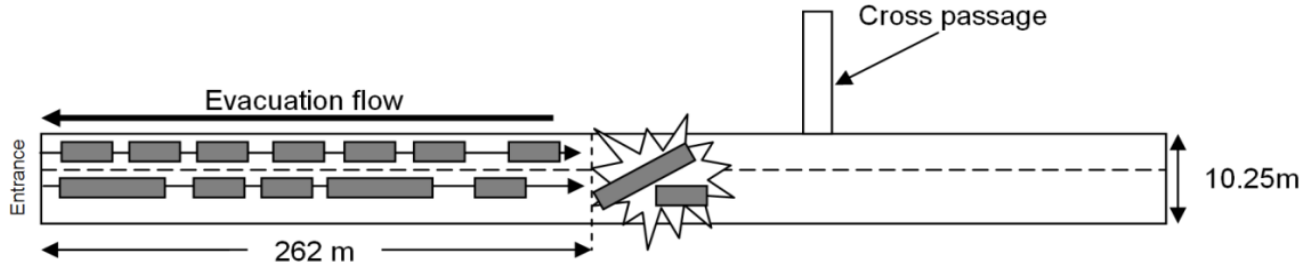
The Egress Models

GridFlow, Pathfinder and STEPS

Ronchi, E., Colonna, P., Capote, J., Alvear, D., et al. The evaluation of different evacuation models for assessing road tunnel safety analysis, Tunnelling and Underground Space Technology, 30 (2012) 74-84

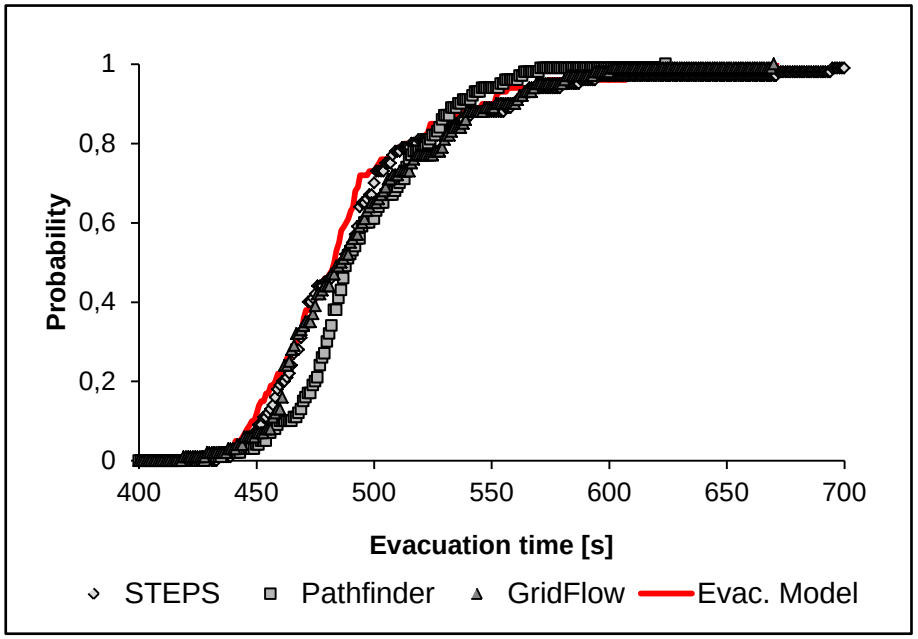
Comparison with other models

Validation for Evacuation Area II



49 LVs
5 HGVs
119 Tunnel users

100 runs with each egress model

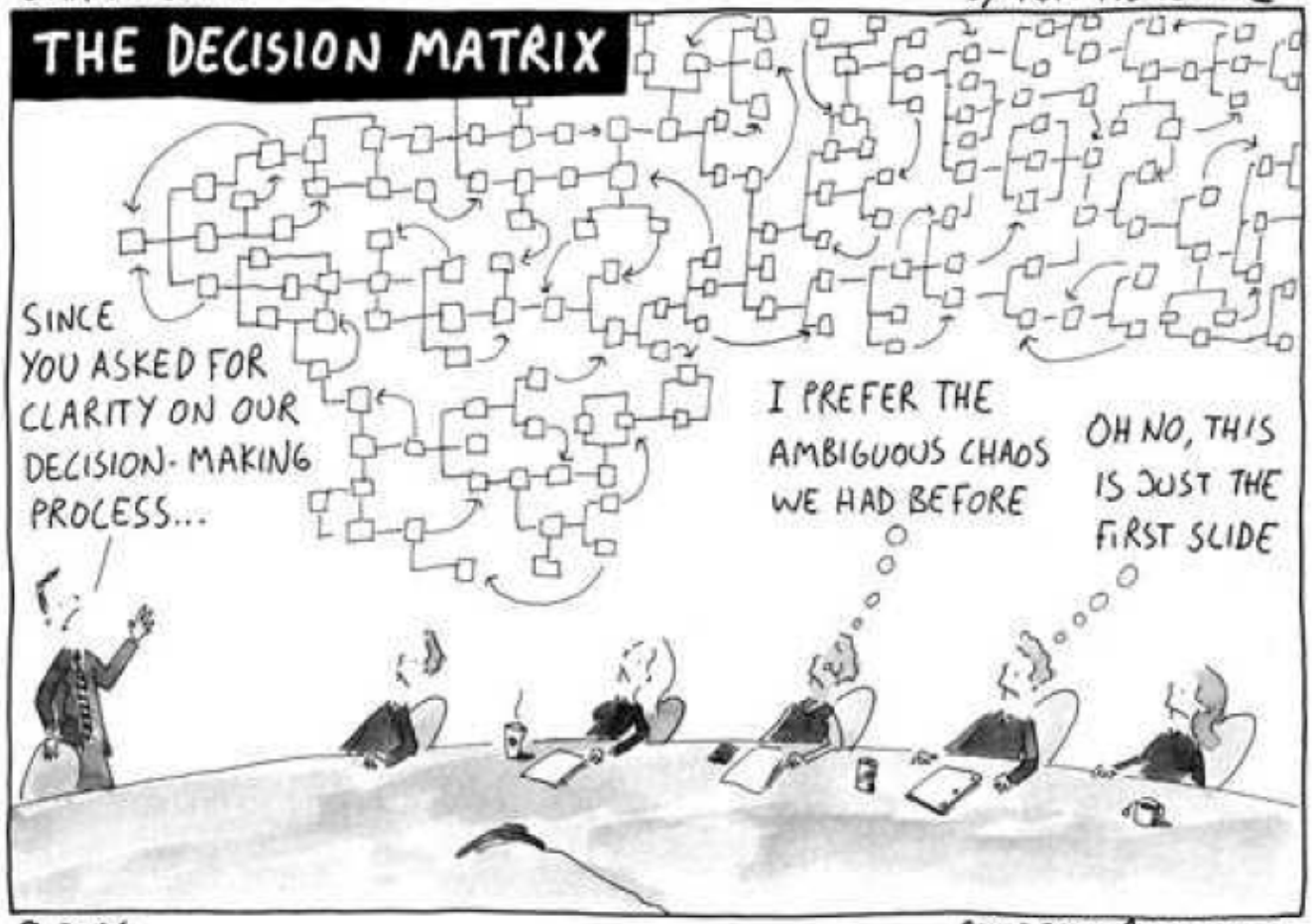


Potential outcomes in less than 5 s

	Pathfinder	STEPS	GridFlow	Evacuation Model
Mean	497	496	495	**491**
S. D.	31	50	42	**44**
Maximum	624	698	670	**671**
Minimum	429	434	419	**434**
95th Percentile	554	580	570	**587**

BRAND CAMP

by Tom Fishburne



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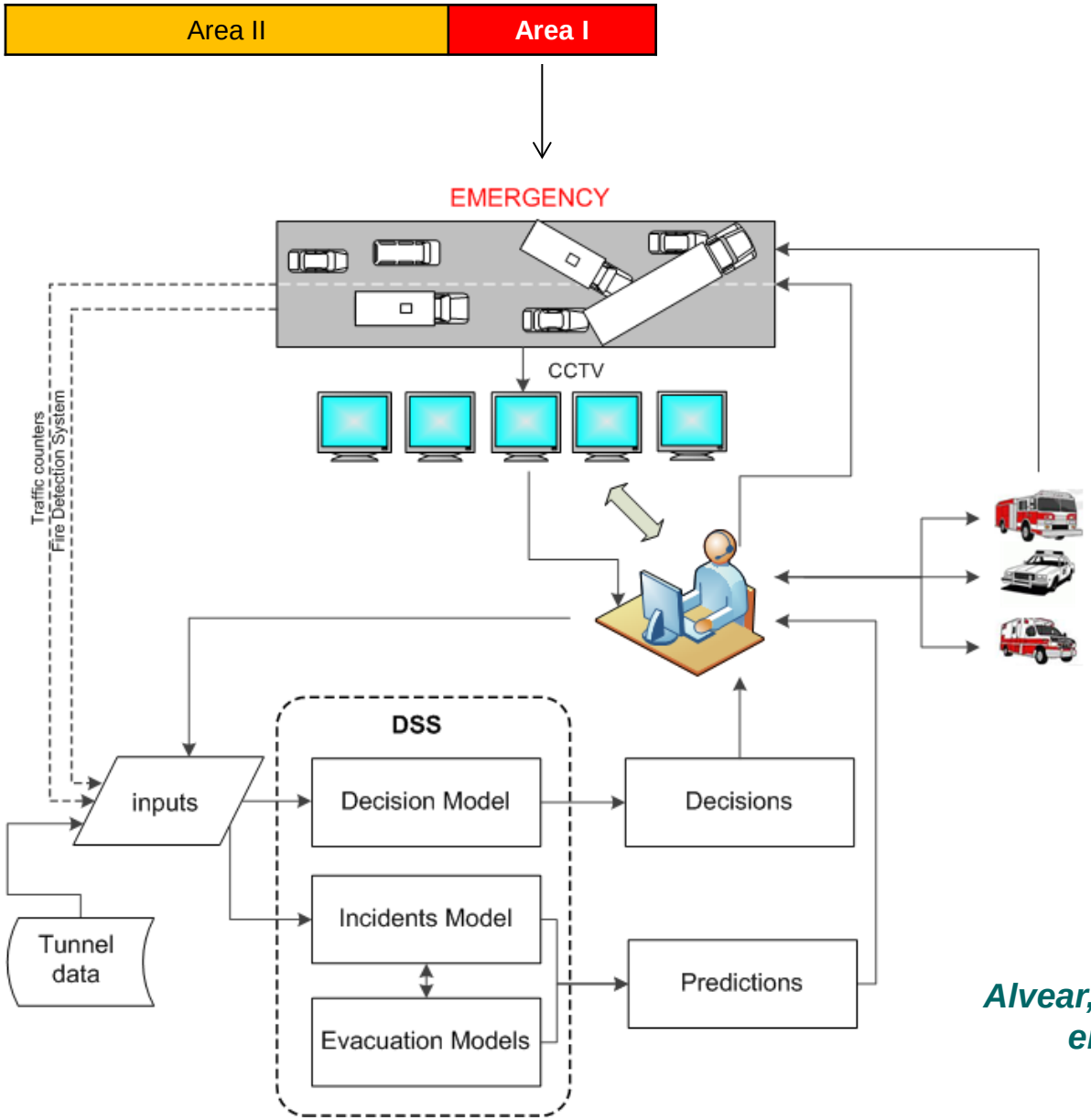
Decision Support System



Tunnel Parameters

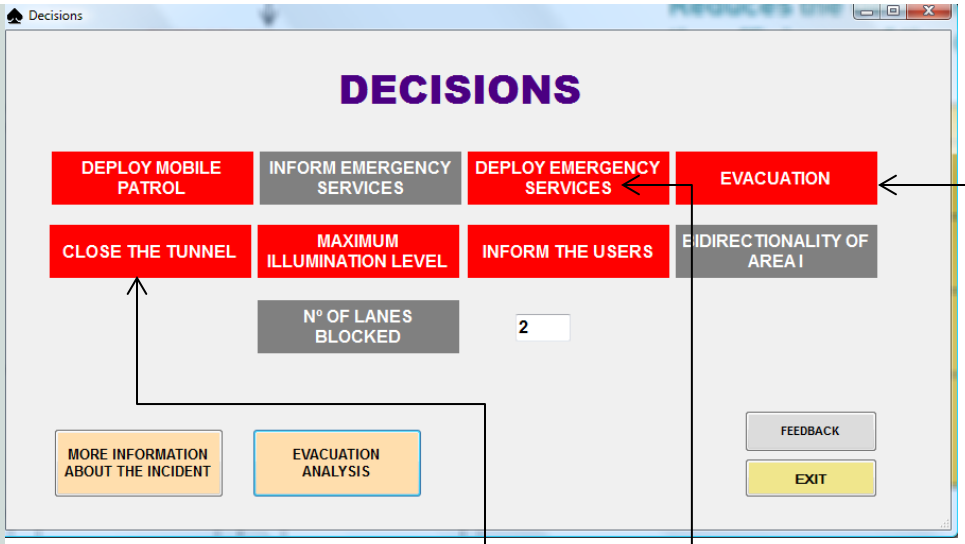
Demostration

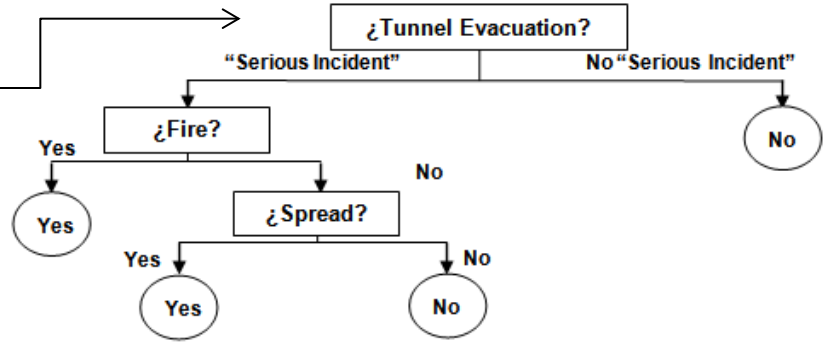
Alvear, D., et al., Decision support system for emergency management: Road tunnels, Tunnelling and Underground Space Technology, 34 (2013), 13-21

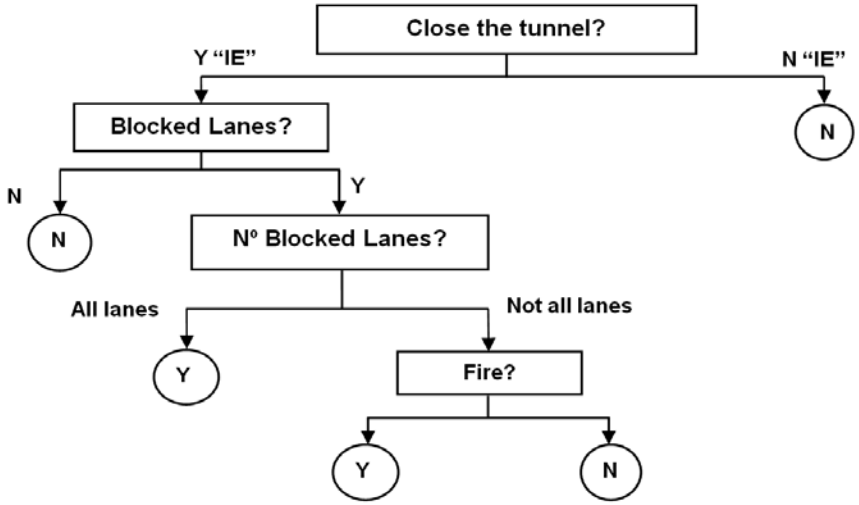
Incident Model

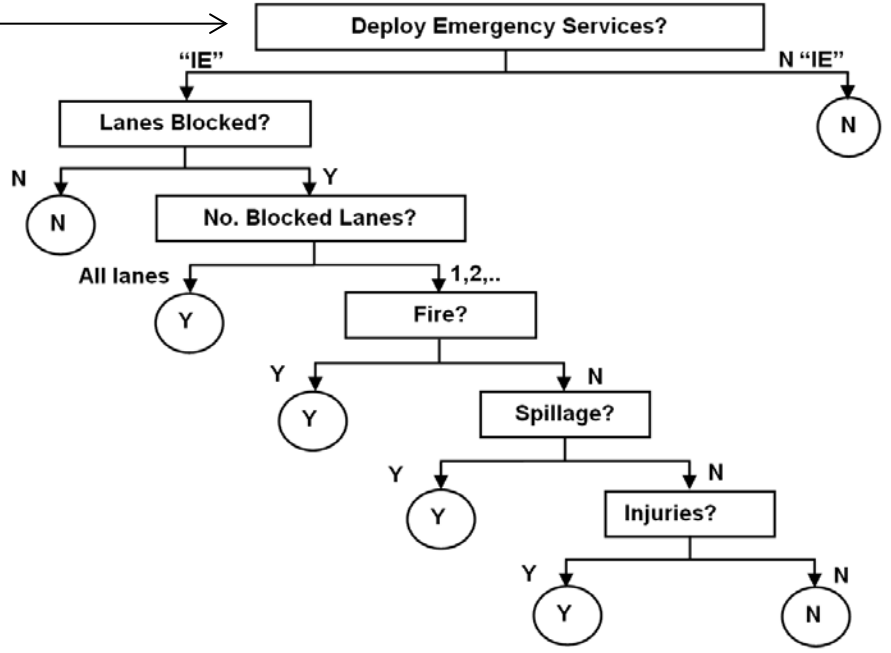
Capote, J., Alvear, D., et al. Infrecuent events model for road tunnels, Revista Internacional de Métodos Numéricos para Cálculo y Diseño en Ingeniería, 27 (1), 43-57, 2011.

Decision Model



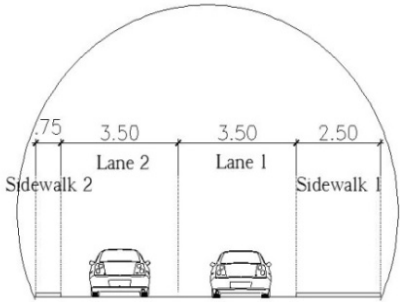


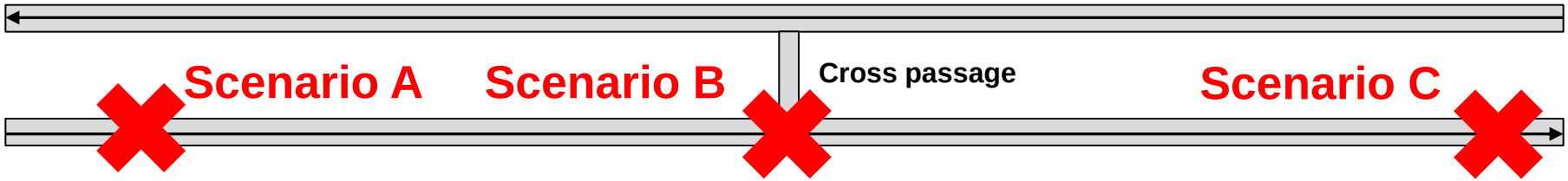




Case of Application

Lantueno Tunnel; la Meseta Highway (A-67)
Two-bore uni-directional road tunnel
670 m length; 1 cross passage at 390 m
12% HGV (no restrictions)





Case	Fire?	Injured?	Serious?	N. Blocked Lanes	LVs	HGVs
1	N	N	N	1	1	0
2	N	Y	Y	2	0	1
3	N	Y	Y	2	3	1
4	Y	Y	Y	1	1	1
5	Y	Y	Y	2	2	0
6	Y	Y	Y	2	4	2

Case of Application

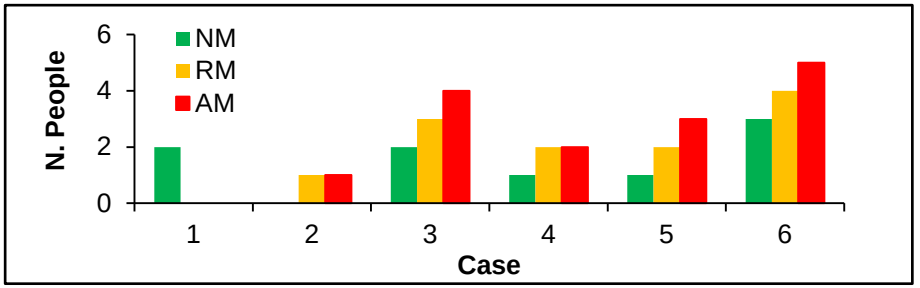
Decisions

Case	Fire?	Injured?	Lanes Blocked
1	n	n	1
2	n	y	2
3	n	y	2
4	y	y	1
5	y	y	2
6	y	y	2

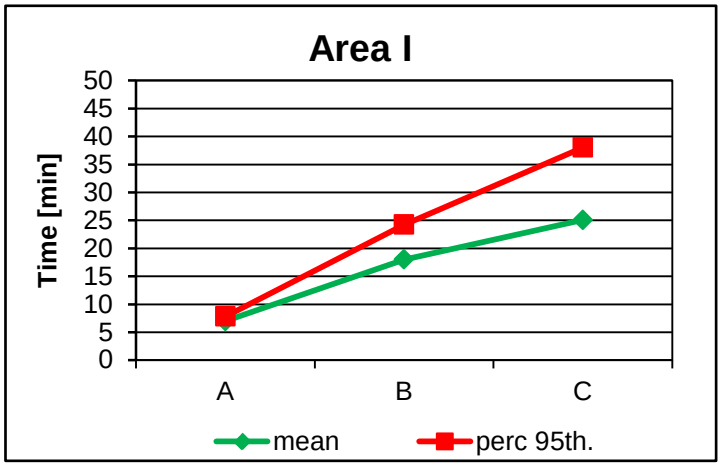
	Deploy M.P	Close Tunnel	Inform E.S	Ilumn.	Deploy E.S	Inform Users	Evac.
1	x		x			x	
2	x	x			x	x	
3	x	x			x	x	
4	x	x		x	x	x	x
5	x	x		x	x	x	x
6	x	x		x	x	x	x

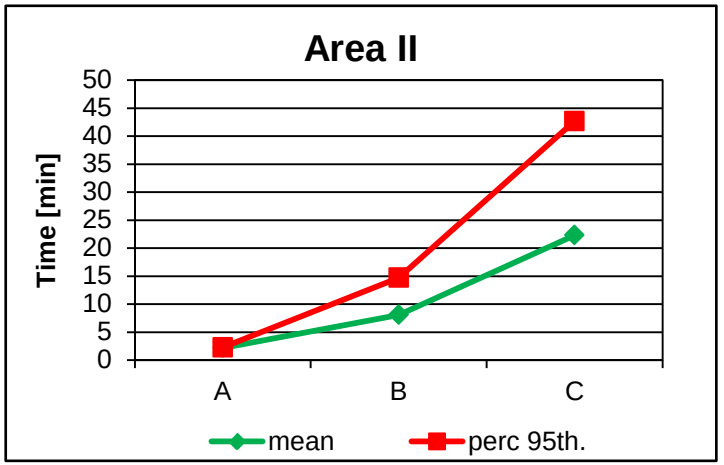
Severity

Case	LV	HGV
1	1	0
2	0	1
3	3	1
4	1	1
5	2	0
6	4	2



Rescue and evacuation times





Conclusions

1. The DSS provides **decisions in Real-Time** for the emergency management minimizing the response times. **Feedback is possible**.

Current Situation	DSS
High degree of uncertainty and stress	Additional information (predictive tools)
Decisions based on schematic models	Decisions based on dynamic alternatives
It is not possible to make certain decisions	It is possible to assume critical decisions
It is necessary to wait for the intervention teams	It is possible to perform actions minimizing the risk

2. Predictive tools offer the operator an **overview of the severity of the emergency**.
3. The stochastic evacuation model provides reasonable and consistent **results in less than 5 s**.
4. The results of the application cases have showed that **the DSS works adequately**.
5. The System is **flexible**, **adaptable** and easy to set up. Furthermore, its modular conception permits an easy development and improvement.

Contact Data

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