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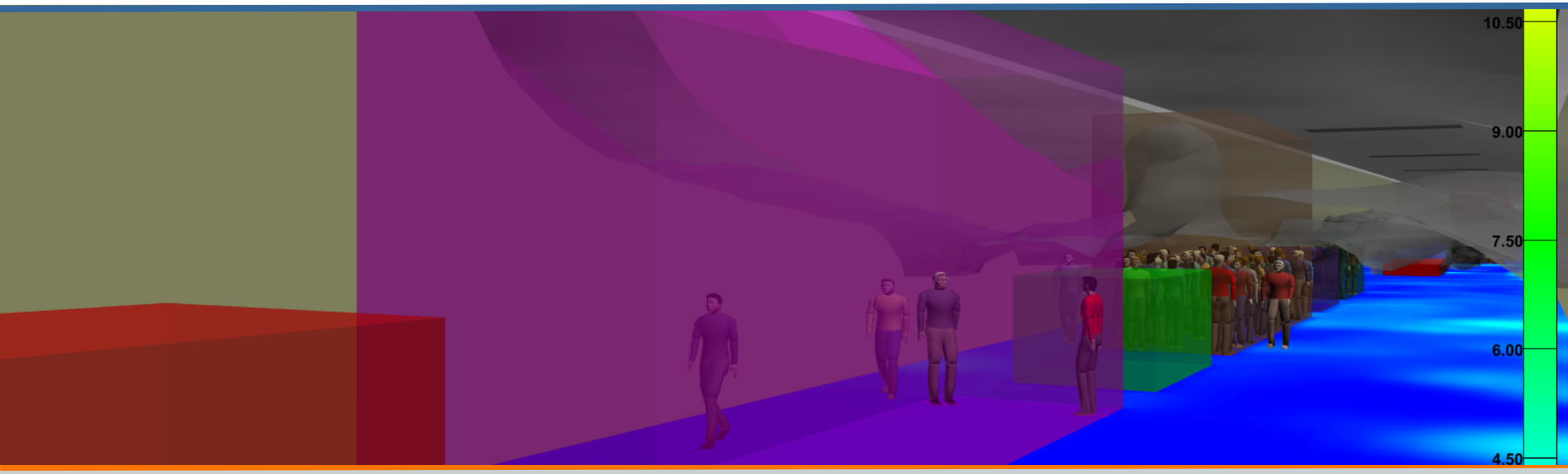

EVACUATION MODELING IN ROAD TUNNEL FIRE EVENTS, CFD INFLUENCING EVACUATION RESULTS

Fire and Evacuation Modeling Technical Conference (FEMTC) 2014

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Purpose →

- Explore benefits of integrating CFD (FDS) results into pedestrian modeling software (STEPS)
- Applicable to any situation – here road tunnel
- Consider criteria for assessment of tenability
  - Temperature
  - Heat flux
  - Carbon Monoxide Fractional Effective Dosage (FED)
  - Visibility

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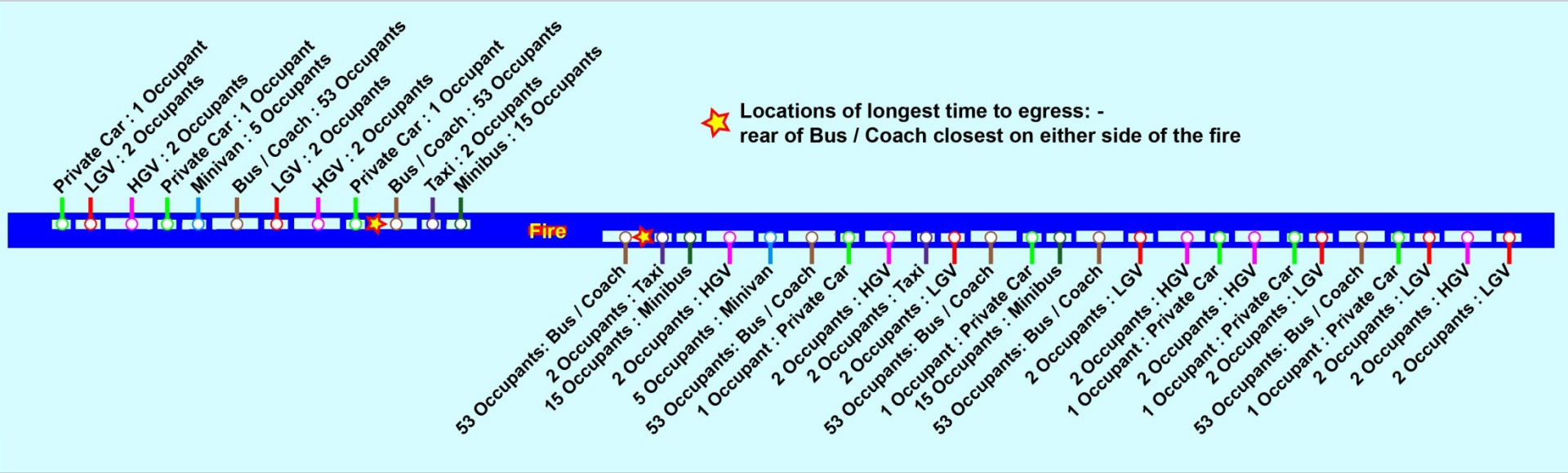
Example Scenario – Bi-directional road tunnel

Description of sample model →



- 416 meters long x 9.5 meters wide x 5.5 meters tall
- 5.6% slope up to left-hand side
- 30 MW fire positioned 140 meters from LHS

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Description of model →

- The tunnel ventilation system is a point extract system
- 4.5 x 2 meter openings at 25 meter intervals in the ceiling – 3 open in vicinity of fire

Two fan cases:

- Case 1: 120 m^3/second (3 openings @ 40 m^3/second)
- Case 2: 180 m^3/second (3 openings @ 60 m^3/second)

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Pre-movement time / Walking Speeds

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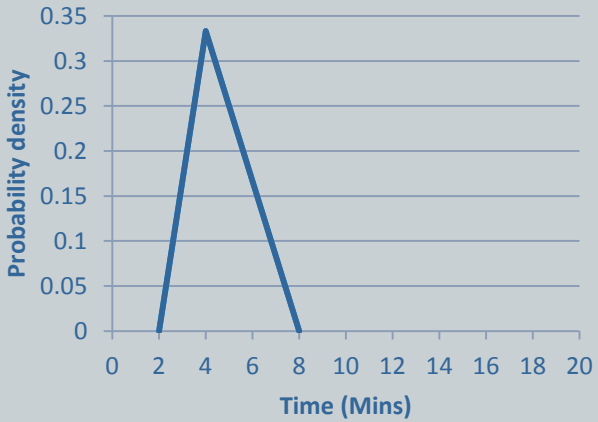
Pre-movement times →

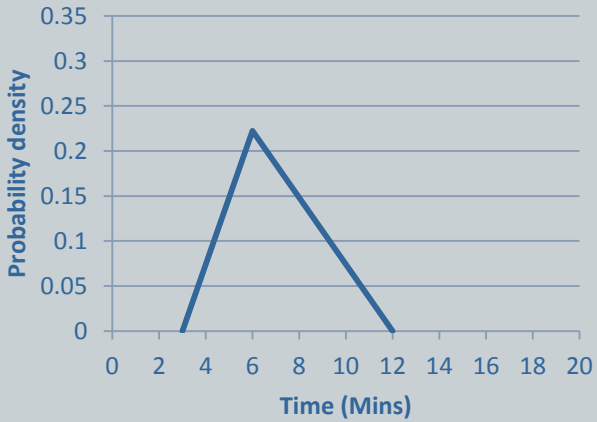
Two applications:

A. Fixed 5 minutes

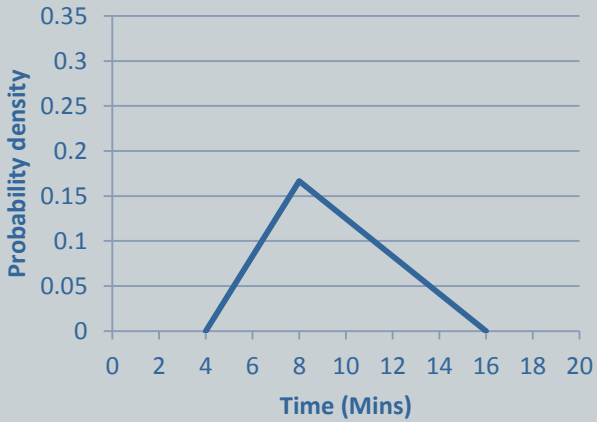
B. Variable pre-movement based on proximity to fire



- 0 to 50 meters from fire



- 50 to 100 meters from fire



- Greater than 100 meters from fire

Walking speeds →

Two applications:

A. Fixed
   - 1 m/s able bodied
   - 0.5 m/s PRM

B. Distribution using NFPA 502 values
   - 0.5 m/s minimum
   - 1 m/s mode
   - 1.5 m/s maximum

National Fire Protection Association 502 “Standard for Road Tunnels, Bridge and other Limited Access Highways”

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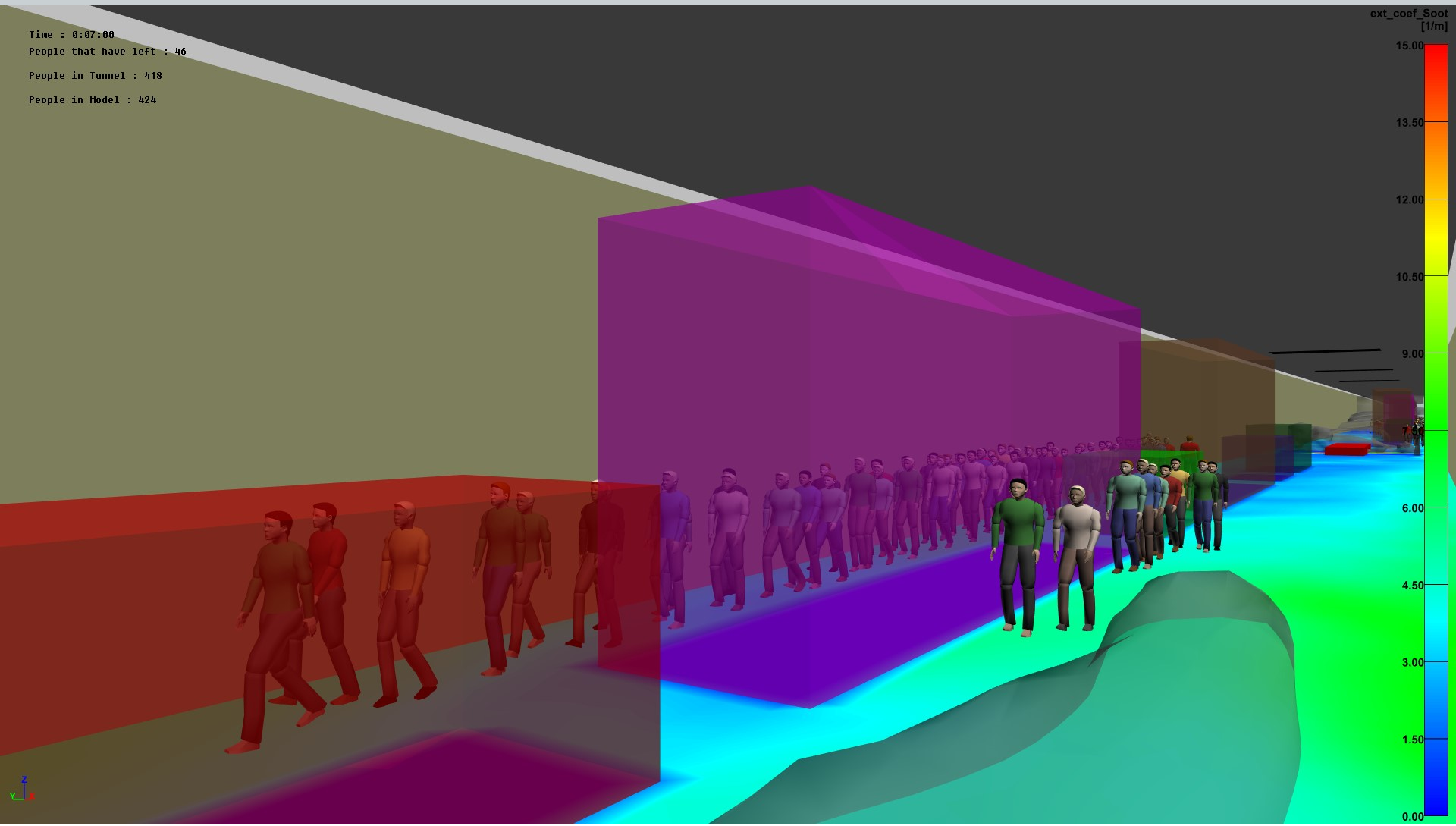
Fixed pre-movement & walking speed →



- 10 meter iso-surface visible: time = 7:00 : Fan case 120 m3/second

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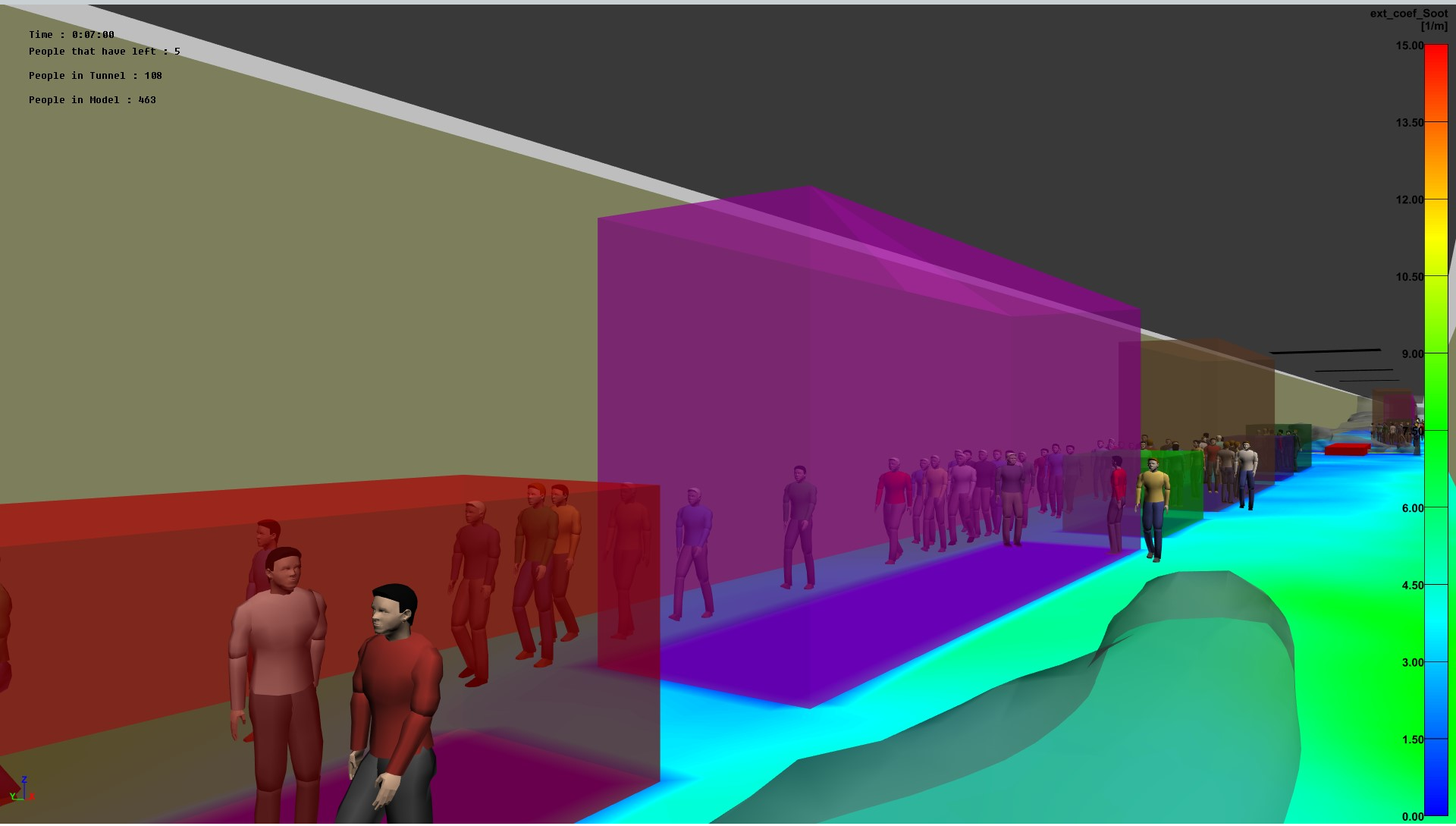
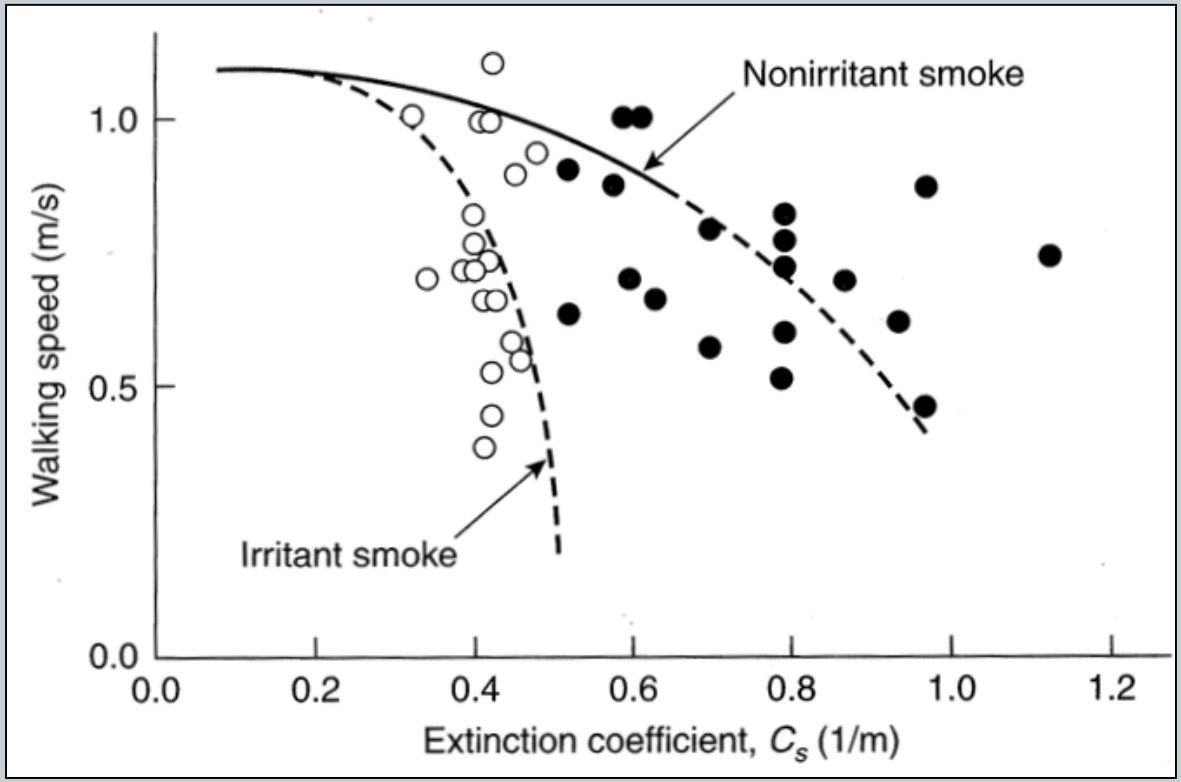
Distributed pre-movement & walking speed →



- 10 meter iso-surface visible: time = 7:00 : Fan case 120 m3/second

Walking speed affected by Extinction Coefficient

- Used non-irritant smoke, Jin and Yamada curve



Effect of extinction coefficient on walking speed – Jin & Yamada 1985
N.B. C_s in image indicates extinction coefficient

Assessing tenability

Assessment of tenability →

Temperature

- NFPA 502 air temperature not to exceed 60°C (140°F)

Heat Flux

- NFPA 502 tenability limit to radiant heat is 2.5kW/m²

Visibility

- Effect of smoke on visibility effects walking speed in STEPS and therefore evacuation time

Assessment of tenability →

Carbon Monoxide

- ISO/TS 13571:2012(E)

$$FED_{CO} = \sum_{t1}^{t2} \left(\frac{\varphi_{CO}}{35000} \right) \Delta t$$

- Where φco = average carbon monoxide exposure in ppm over time Δt in minutes
- Effect is cumulative

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Results

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Fixed pre-movement, time = 7:00 →
Fan case 120 m^3/second

- 10 meter iso-surface visible

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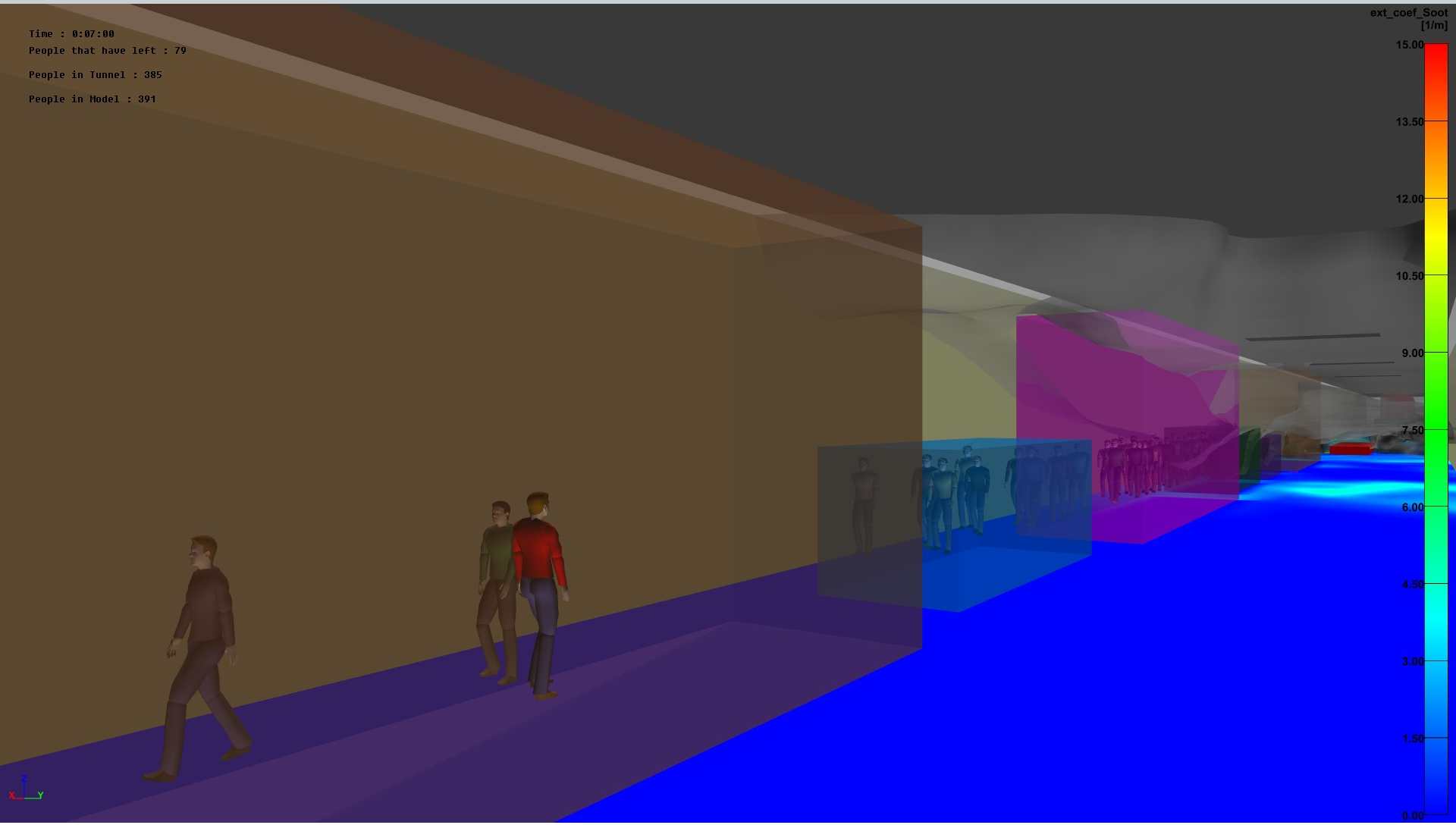
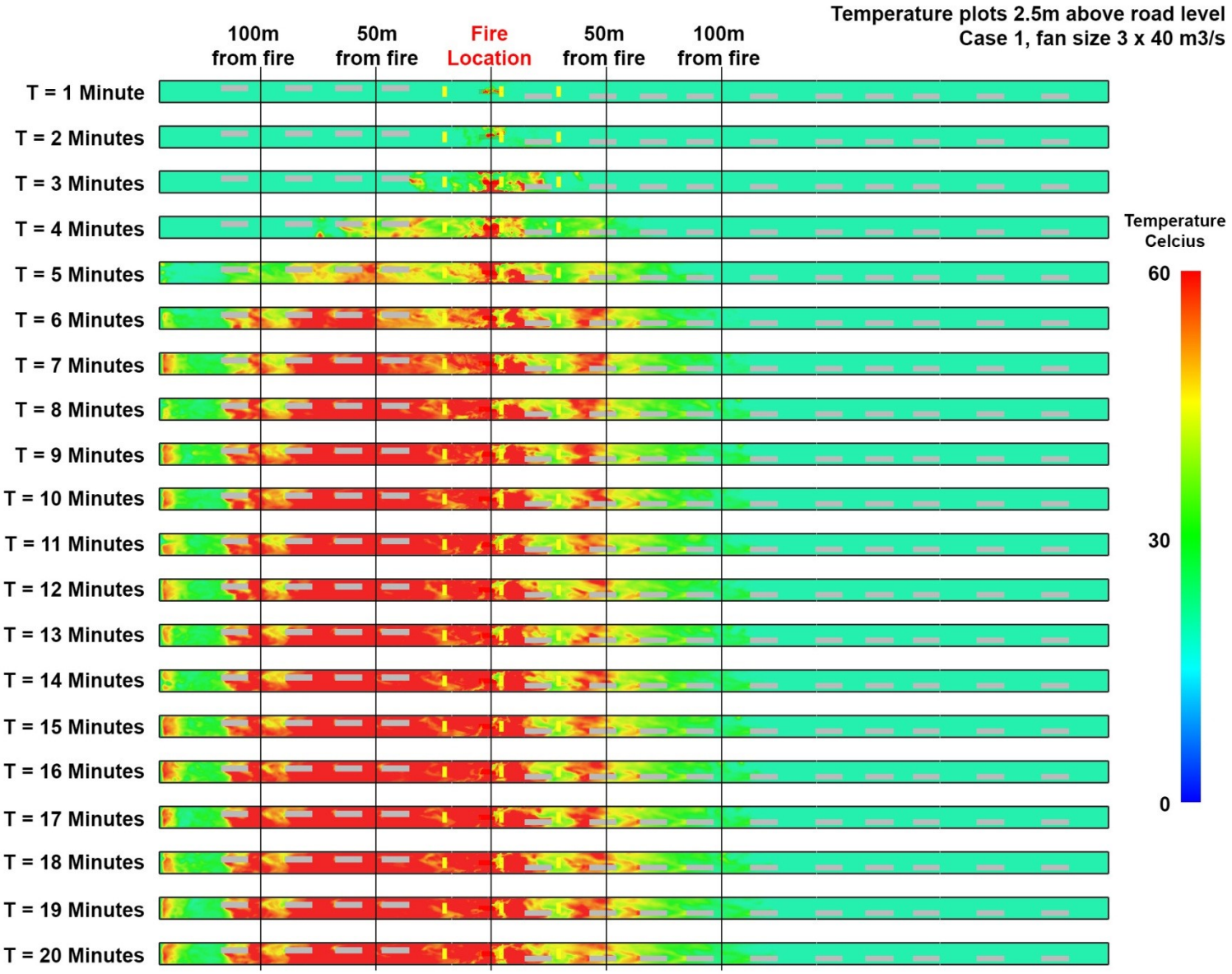
Fixed pre-movement, time = 7:00 →
Fan case 180 m^3/second

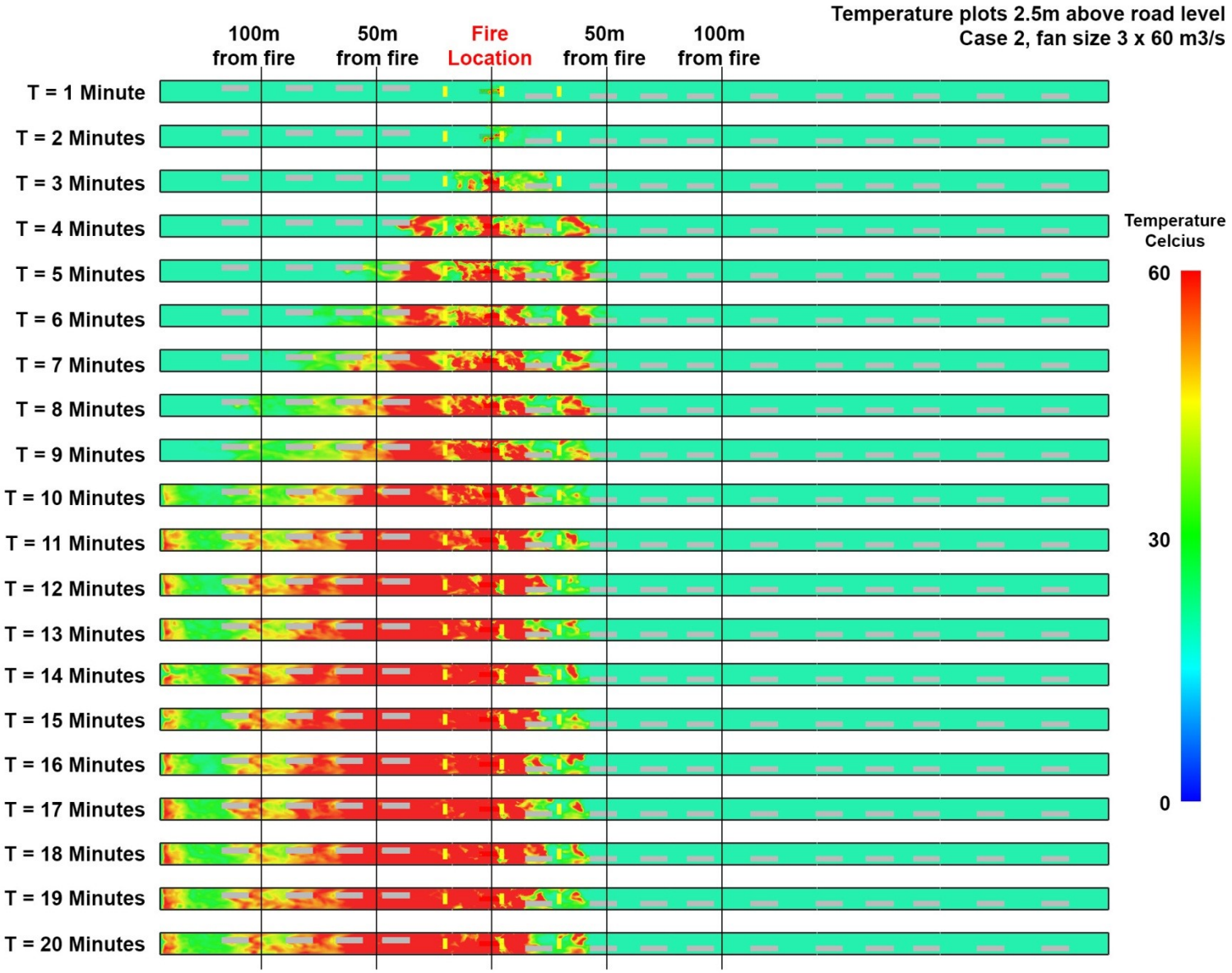


- 10 meter iso-surface visible

Results – Temperature Plan →



Results – Temperature Plan →



Results – Heat Flux →

- **Left of Fire**

Fan Case	Maximum heat flux to left of fire (kW/m2)		
	0 to 50 m from fire	50 to 100m from fire	Greater than 100m from fire
120 m^3/sec	1.11	0.36	0.21
180 m^3/sec	1.01	0.27	0.14

- **Right of Fire**

Fan Case	Maximum heat flux to right of fire (kW/m2)		
	0 to 50 m from fire	50 to 100m from fire	Greater than 100m from fire
120 m^3/sec	1.14	0.10	0.03
180 m^3/sec	1.14	0.02	0.00

- NB – these represent radiant heat flux values only where people are present
- Recorded on a plane 2.5m above road level facing up towards hot gas

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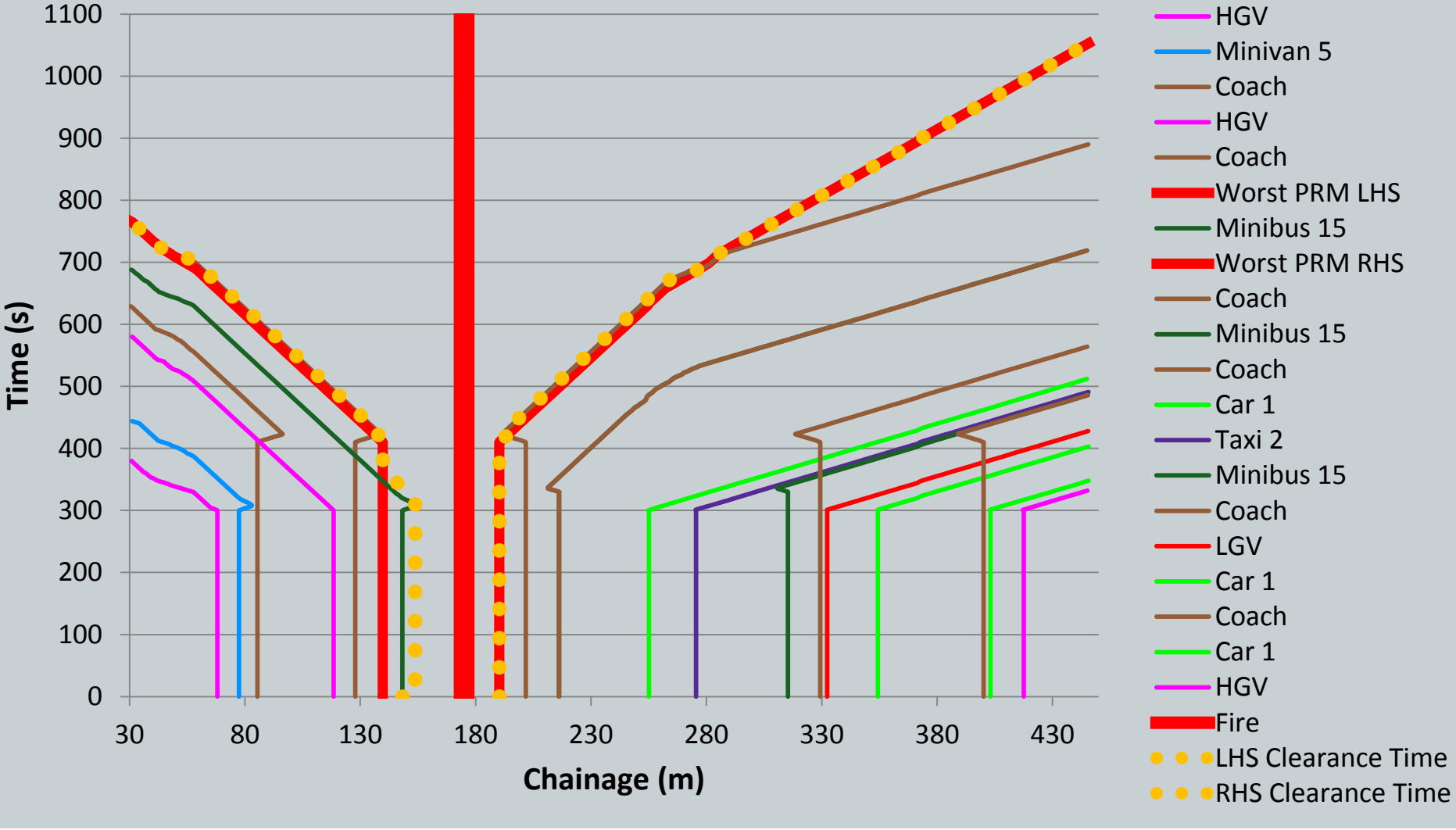
Results - Visibility →

- **Total overall evacuation time**

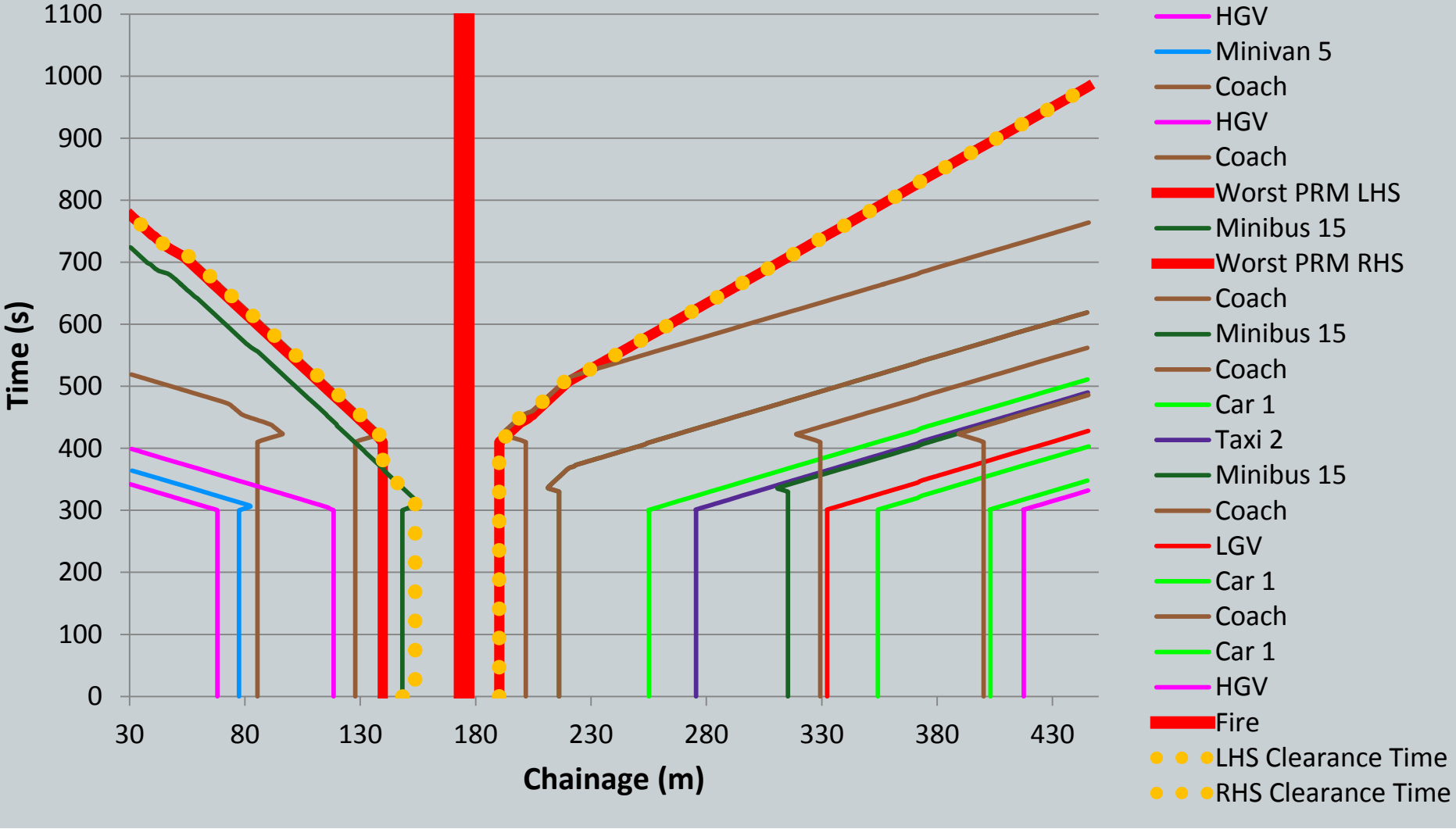
Scenario	Total evacuation time (mins:secs)	% increase over static calculation
Static Calculation	15:30	-
120 m^3/sec Fixed	17:34	+13%
120 m^3/sec Distribution	18:50	+22%
180 m^3/sec Fixed	16:24	+6%
180 m^3/sec Distribution	18:43	+21%

Results - Visibility →



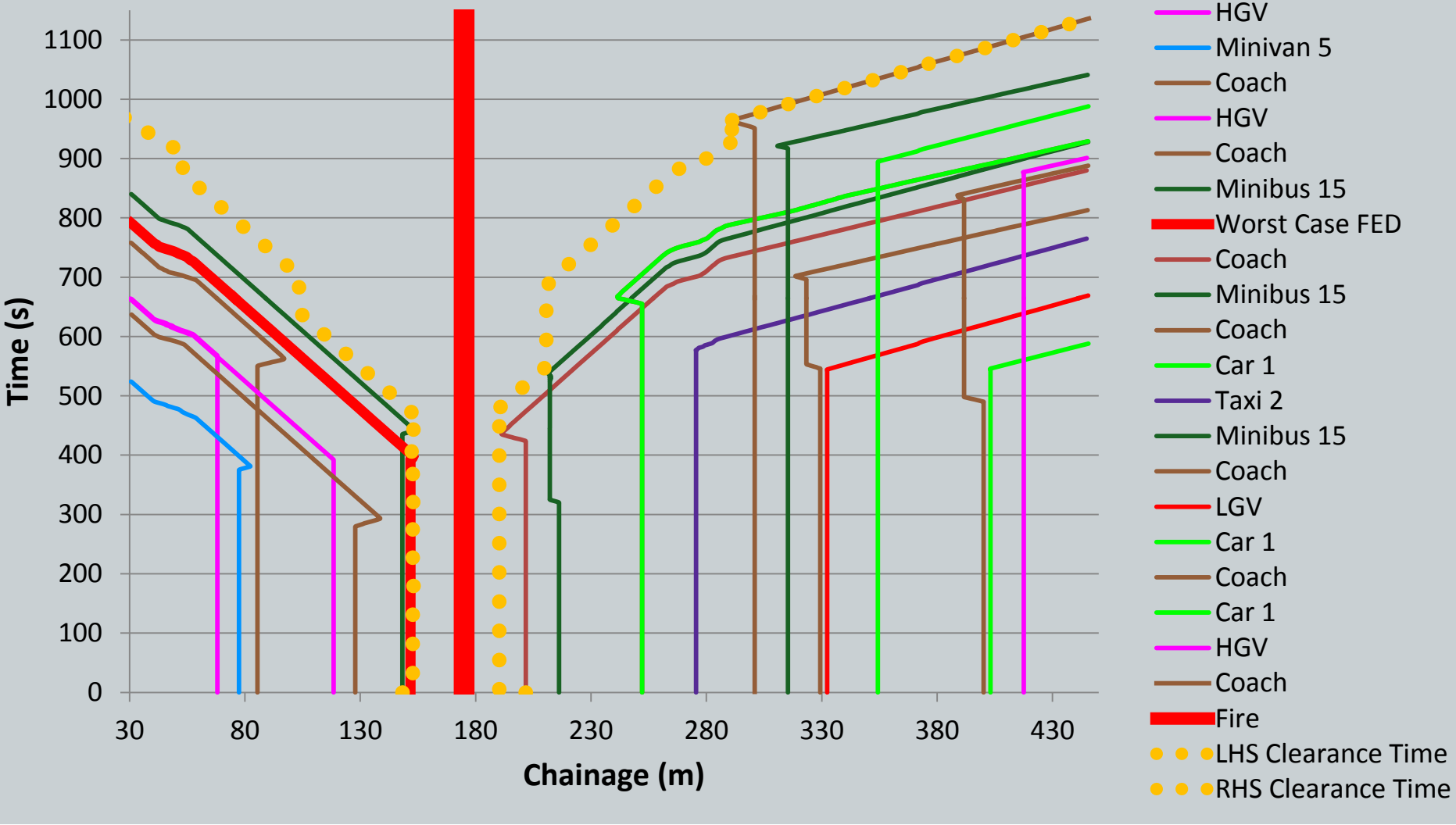
- 120 m^3/second – fixed scenario

Results - Visibility →



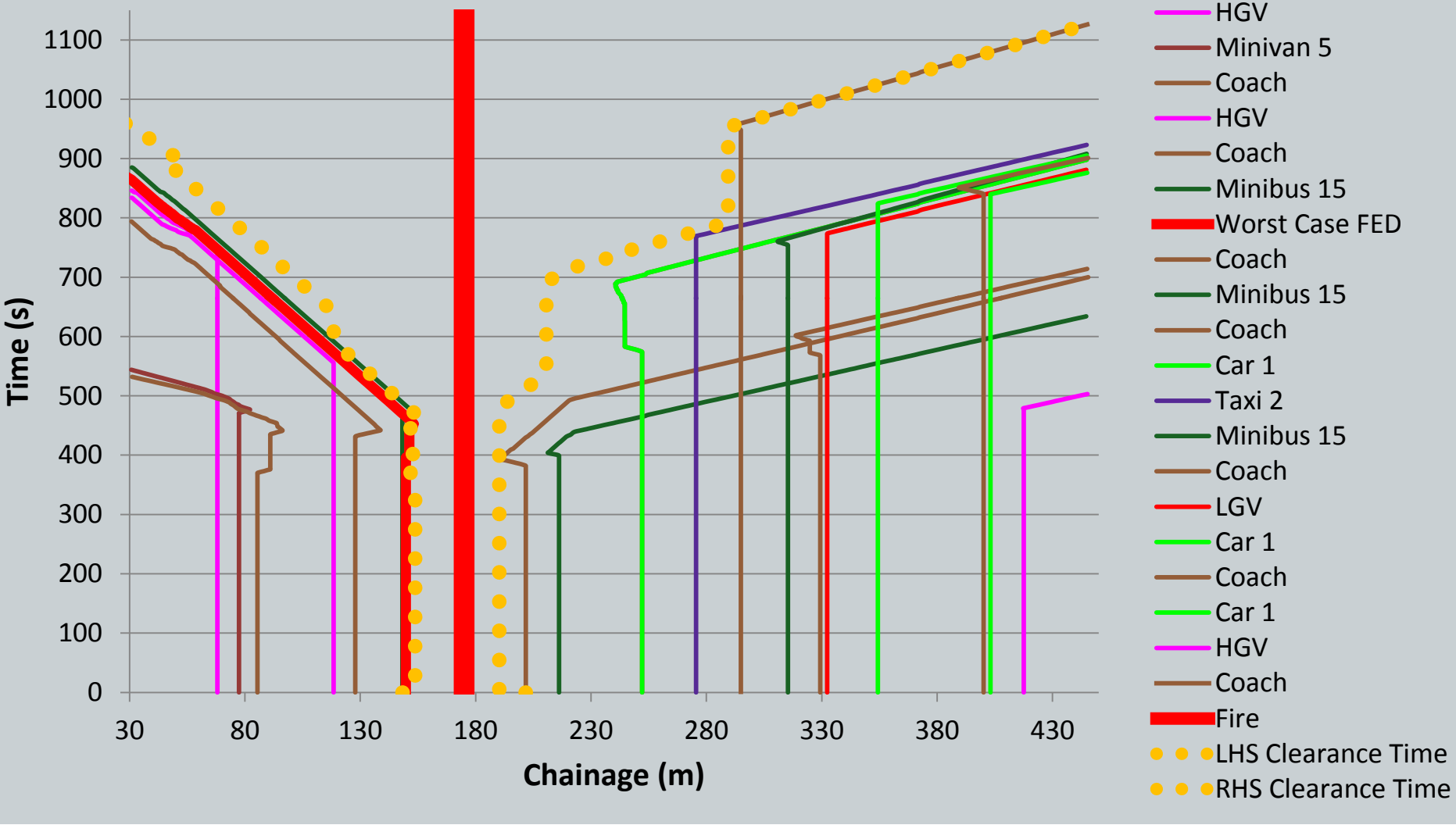
- 180 m^3/second – fixed scenario

Results - Visibility →



- 120 m^3/second – distributions

Results - Visibility →



- 180 m^3/second – distributions

Results – Carbon Monoxide FED →

Scenario	Maximum Carbon Monoxide FED
Case 1 Fixed	0.0312
Case 1 Distribution	0.0246
Case 2 Fixed	0.0248
Case 2 Distribution	0.0220

- Case 2 fixed vs Case 1 fixed:
  - max CO FED reduced by 20%
- Case 2 dist vs Case 1 dist:
  - max CO FED reduced by 10%

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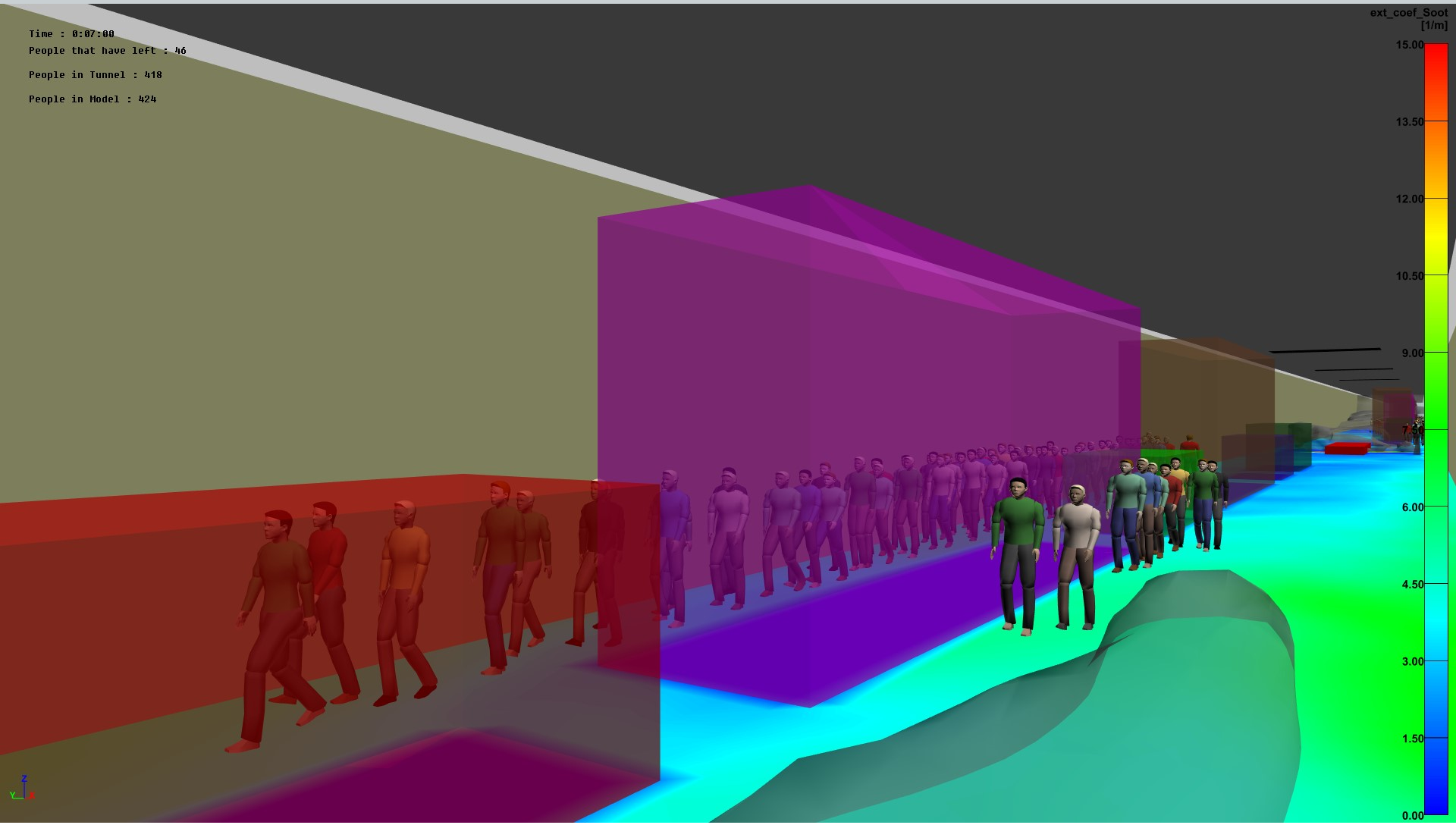
Fixed pre-movement, time = 7:00 →
Fan case 120 m^3/second



- 10 meter iso-surface visible

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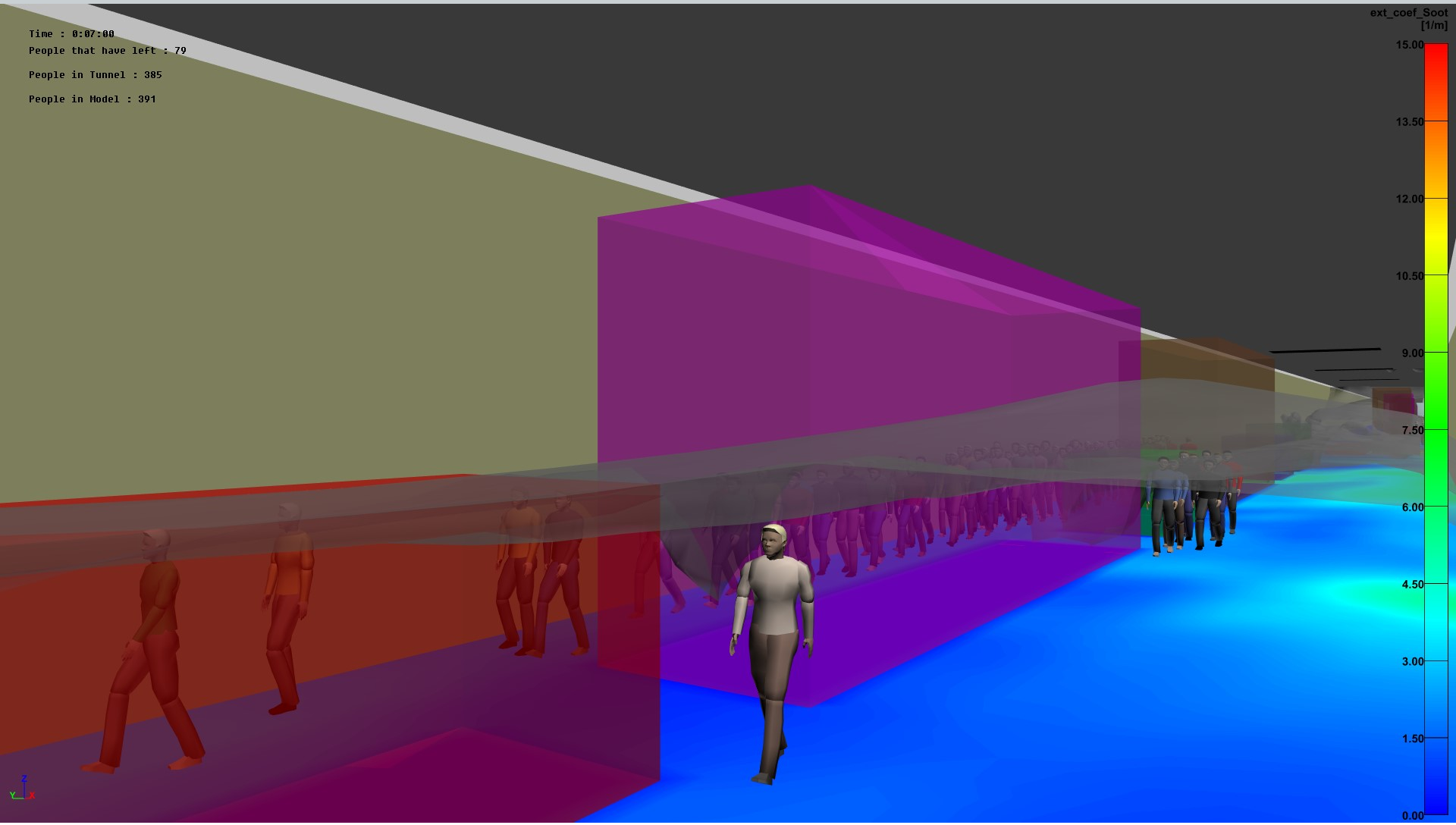
Fixed pre-movement, time = 7:00 →
Fan case 180 m^3/second



- 10 meter iso-surface visible

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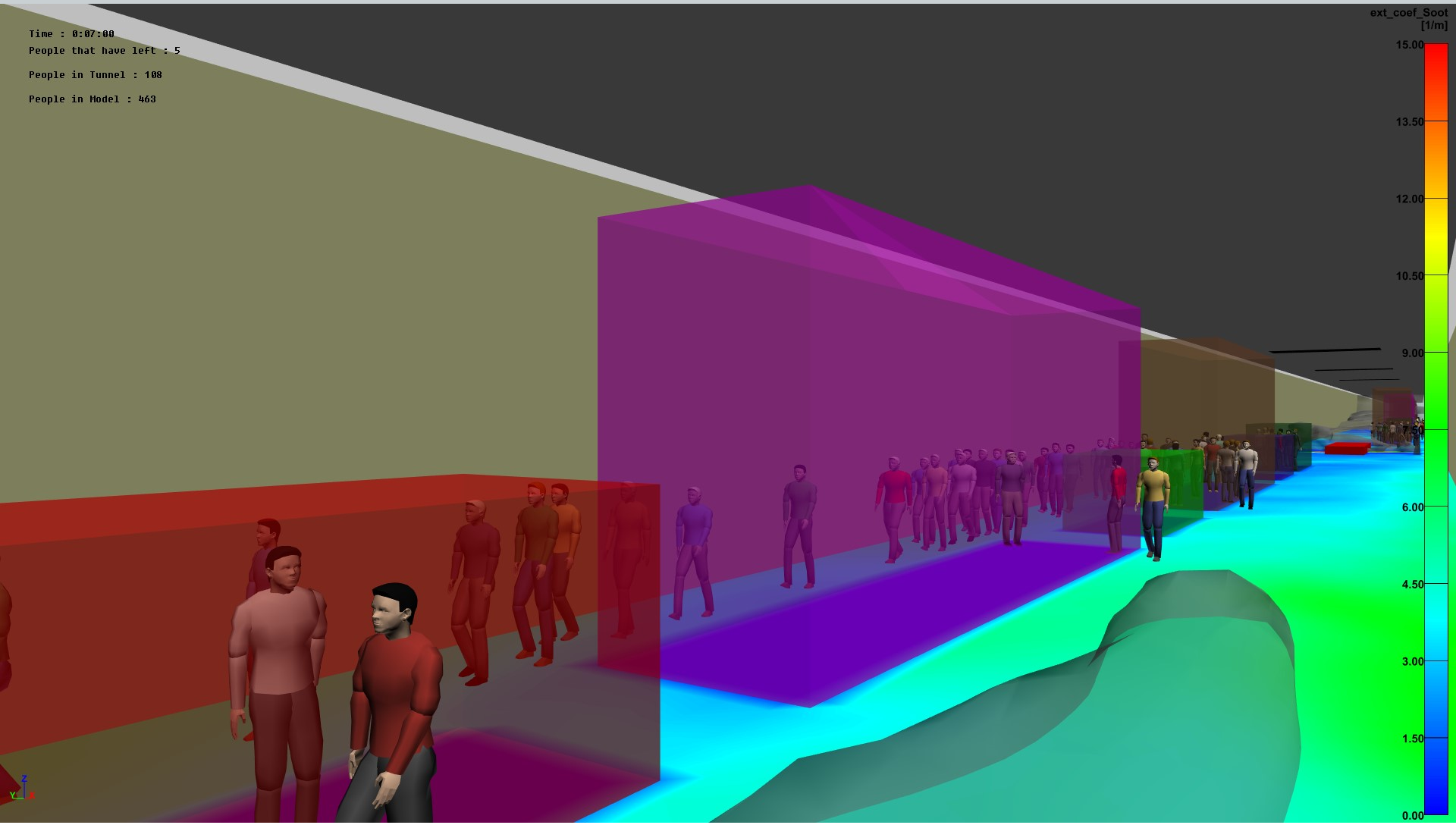
Distribution pre-movement, time = 7:00 →
Fan case 120 m^3/second



- 10 meter iso-surface visible

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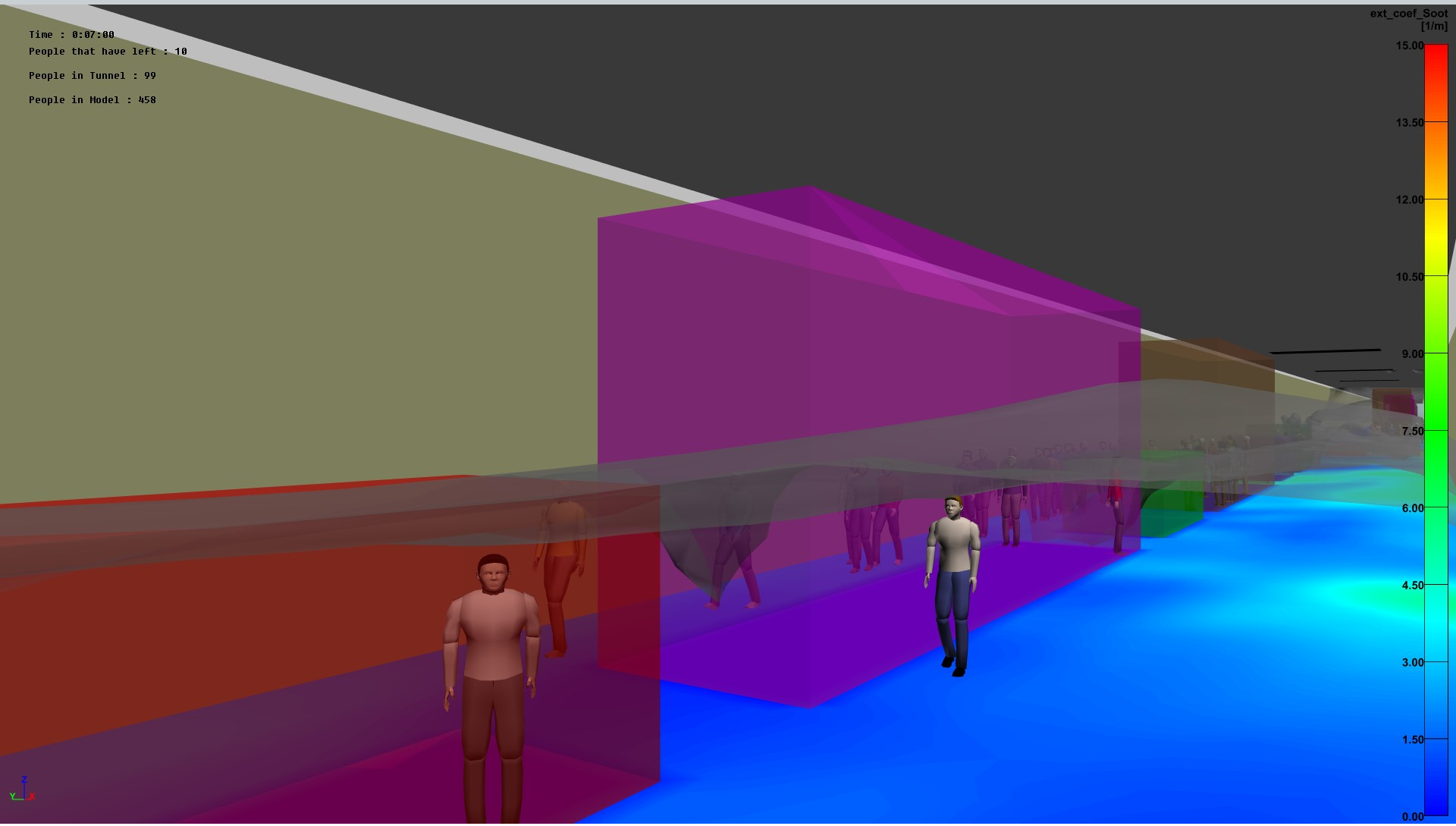
Distribution pre-movement, time = 7:00
Fan case 180 m^3/second



- 10 meter iso-surface visible

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Conclusions →

Specific case study

- Temperature is limiting factor for tenability
- Larger fan provides better overall conditions

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Conclusions →

General

- Combining FDS and STEPS allows assessment of
  - FED
  - Impact of extinction coefficient
- Global parameters do not indicate whole picture
- The use of distributions can mask the effects of changes in ventilation strategy

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Thank you for listening.

Questions?

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