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EVACUATION MODELLING IN ROAD TUNNEL FIRES

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Outline

1. CV and Research background
2. Research objectives and methods
3. Evacuation modelling in road tunnel fires
4. The novel multi-model approach
5. Discussion

CV and Research Background

B. Eng. Civil Engineering, Polytechnic University of Bari - Italy (2003-2006)

M. Sc. Transportation Engineering, Polytechnic University of Bari - Italy (2006-2008)

Ph.D. Road and Transport Systems, Land Use and Technological Innovation, Department of Roads and Transportation, Polytechnic University of Bari – Italy (01/2009-03/2012)

Visiting Phd student at GIDAI Group of University of Cantabria - Spain (09/2009-02/2010 and 11/2010-01/2011)

Visiting Phd student at the department of Fire Safety Engineering and Systems Safety, Lund University - Sweden (2011). Involved in the METRO project, www.metroproject.se

Background

CV and Research Background

Post-doc. Department of Fire Safety Engineering and Systems Safety, Lund University – Sweden (05/2012-09/2012)

Guest Researcher. Fire Research Division, National Institute of Standards and Technology (NIST), Department of Commerce – USA (10/2012-03/2013)

Guest Researcher. Department of Psychology I, University of Würzburg (04/2013-07/2013)

Evacuation modelling in road tunnel fires

- **Performance based design: ASET vs RSET**
- **RSET can be calculated using evacuation modelling**
- **Evacuation modelling is a multi-disciplinary subject**
- **RSET has NOT been object of the same amount of studies as the ASET**
- **Need for a dedicated research about evacuation modelling in road tunnel fires**

Three key objectives:

1) STUDY AND TEST OF SIMULATION TOOLS

- The model impact on results (capabilities and features, model validation, default settings, single or multiple use of models, etc.)

- The modeller‘s impact on results, (the choice of the model input, modeller‘s experience, availability of experimental data)

2) COMPILATION OF DATA FROM EXPERIMENTS

- Use of data from tunnel evacuation experiments (a priori vs a posteriori modelling)

3) IDENTIFICATION OF THE MODELLING APPROACHES

- New framework, namely the multi-model approach

1) REAL EVACUATION SCENARIOS

Case studies
Evacuation experiments

2) MODELLING EVACUATION SCENARIOS

Archive analysis and surveys
Sensitivity analysis
A priori vs a posteriori modelling

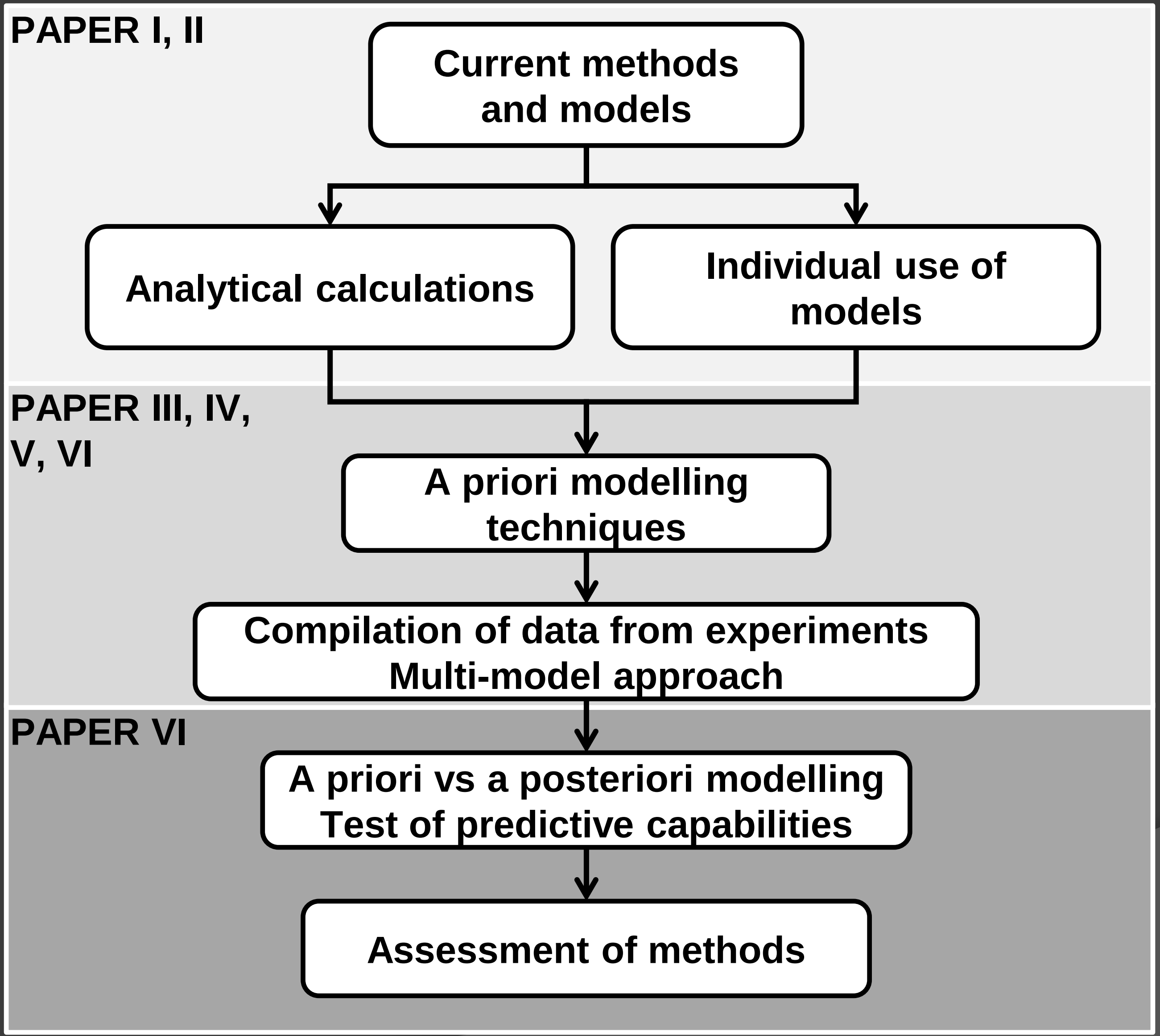
Research methods

STRATEGY

Identify problem:

Solve problem:

Test system:



Current methods and models

SURVEY about evacuation models at www.Evacmod.net

Evacmod.net
Evacuation Modelling Portal

Ronchi E & Kinsey M (2011). *Evacuation models of the future. Insights from an online survey on user's experiences and needs.* In Capote J (ed) et al: Advanced Research Workshop Evacuation and Human Behaviour in Emergency Situations EVAC11, Santander, pp. 145-155.

Current methods and models

-**Most used models have been identified**

- **V & V is the most important factor (93.9% of participants having some knowledge of V&V)**

- **Immature field, inexpert users**

- **Many model users are UNAWARE of other models**

- **Reviews need to be constantly updated. A MODEL DIRECTORY has been built on www.Evacmod.net**

Current methods and models

EVACUATION MODEL COMPARISON (FDS+Evac, STEPS, Pathfinder, SFPE hydraulic model)

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Analysis of the Lantueno tunnel

Ronchi E, Colonna P, Capote J, Alvear D, Berloco N, Cuesta A (2012). ***The evaluation of different evacuation models for assessing road tunnel safety analysis.*** **Tunnelling and Underground Space Technology Vol. 30, pp.74-84**

Ronchi E, Colonna P, Berloco N (2013). ***Reviewing Italian fire safety codes for the analysis of road tunnel evacuations: advantages and limitations of using evacuation models*. Safety Science, Special Issue from the 1st CoSaCM. Vol 52, pp. 28-36.**

Current methods and models

- **Models may employ different modelling assumptions**

- **Smoke-occupant interaction is one of the key factors causing differences in road tunnel evacuation scenarios (e.g., walking speed in smoke, exit choice)**

- **Need for further experimental data for model input calibration**

- **Need for the assessment of the appropriate modelling approach in relation to the scenario complexity**

Smoke-occupant interaction: Walking speeds

SENSITIVITY ANALYSIS of a hypothetical evacuation scenario (six evacuation models: FDS+Evac, buildingEXODUS, Gridflow, STEPS, Pathfinder, Simulex)

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VISIBILITY CONDITIONS vs WALKING SPEEDS

Ronchi E, Gwynne SMV, Purser DA, Colonna P (2013). ***Representation of the impact of smoke on agent movement speeds in evacuation models. Fire Technology. Volume 49, Issue 2, pp 411-431***

Smoke-occupant interaction: Walking speeds

- Two main experimental data-sets (Jin vs Frantzich & Nilsson) used by the models

-Five possible interpretations of the impact of smoke on walking speeds

$$v_i^s = v_i^0 c(K_s) \quad (1)$$

$$v_i^s = Max\{v_{i,min}, v_i^0 c(K_s)\} \quad (2)$$

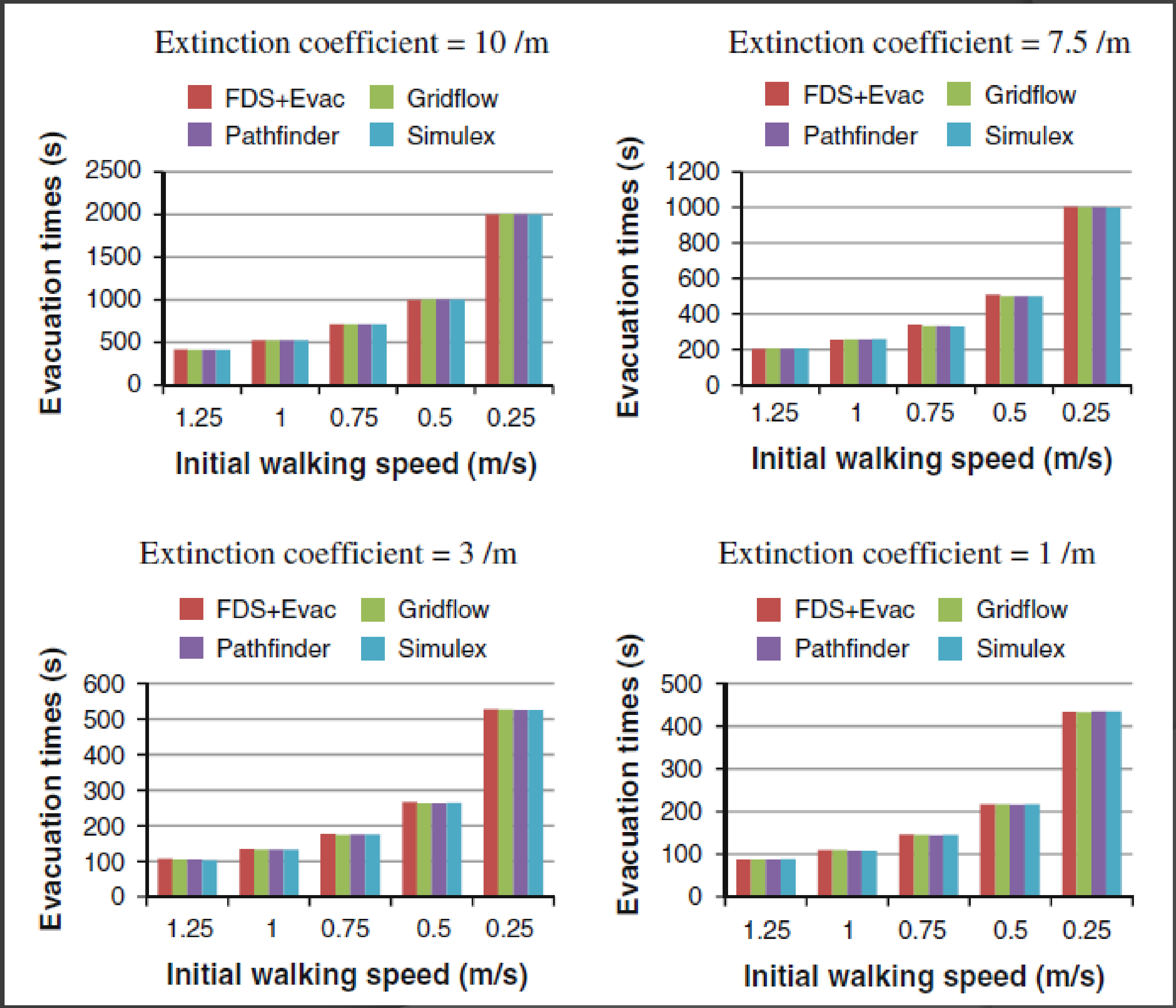
$$v_i^s = Max\{v_{i,min}(i), v_i^0 c(K_s)\} \quad (3)$$

$$v_i^s = Max\{v_{i,min}, v_i(K_s) \pm \Delta\} \quad (4)$$

$$v_i^s = Max\{v_{i,min}(i), v_i(K_s) \pm \Delta\} \quad (5)$$

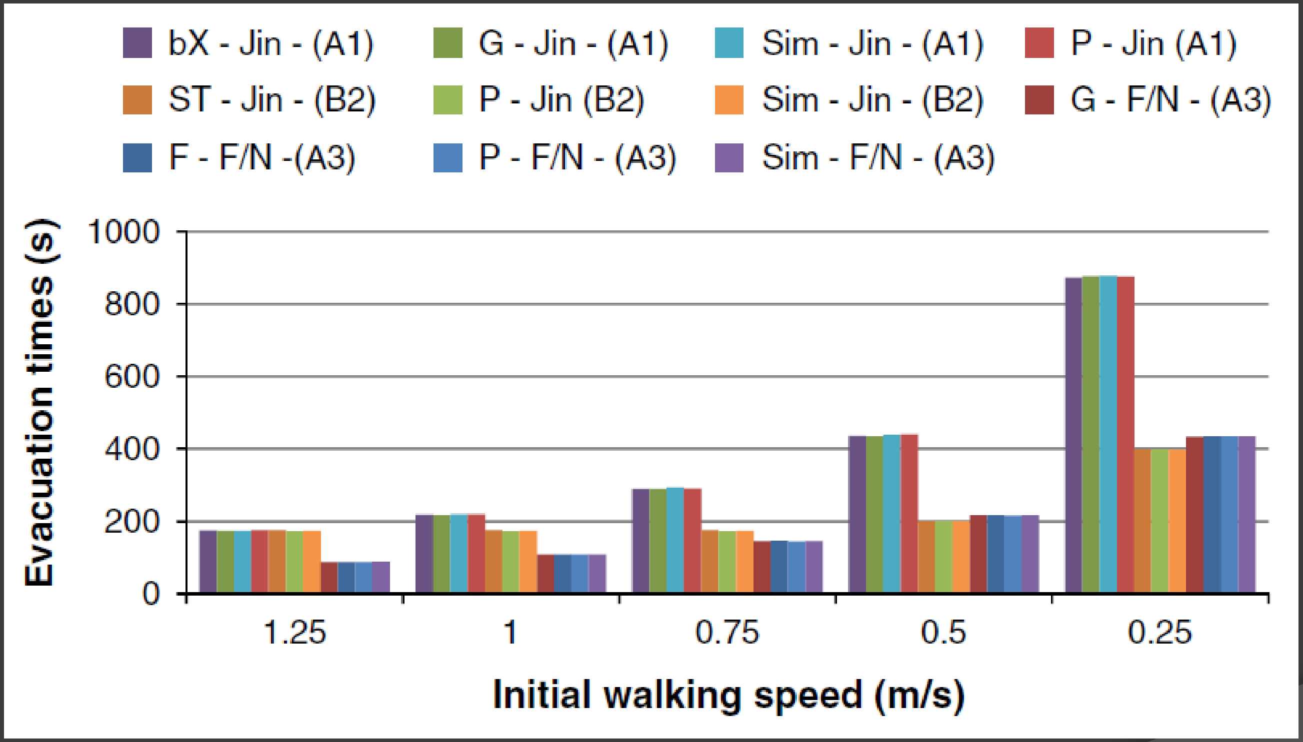
Smoke-occupant interaction: Walking speeds

Model results are **consistent** if employing the same correlation speed vs smoke and the same data-set



Smoke-occupant interaction: Walking speeds

Significant differences arise if applying indiscriminately default settings



Smoke-occupant interaction: Exit choice

Superset of tunnel evacuation trials (a priori modelling using two evacuation models: FDS+Evac, buildingEXODUS)

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Behavioural modelling: Agent-sign interaction

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Laboratory experiments (data from Lund University) for the simulation of the impact of three types of exit signs

Ronchi E, Nilsson D, Gwynne SMV (2012). ***Modelling the impact of emergency exit signs in tunnels. Fire Technology, Vol 48:4 pp. 861-988.***

Smoke-occupant interaction: Exit choice

The impact of exit signs in smoke-filled tunnels

The physical area from which a sign can be seen and the interactions with the agents

(can occupants see the sign?)

The likelihood of the agents paying attention to the sign and absorbing the information

(do occupants notice the sign and understand what it is?)

The likelihood of the agents using the information provided

(do occupants use the exit?)

-Three modelling approaches

1. Implicit/Imposed – 2. Explicit/Blind – 3. Explicit/Informed

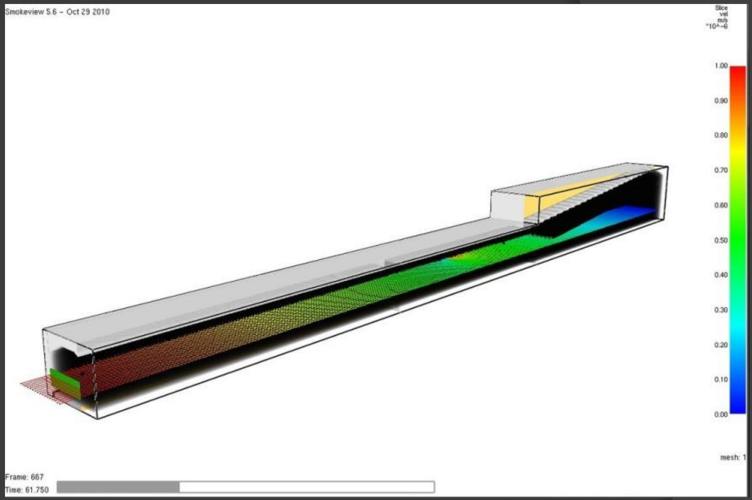
Smoke-occupant interaction: Exit choice

- **The use of Approach 2 (Explicit/Blind) causes differences in model results**

- **Exit choice sub-models may be predictive or based on deterministic user-defined assumptions**

- **Model results are consistent if experimental data are available for input calibration, i.e. model results are not affected by the modelling assumptions/sub-algorithms**

Compilation of data from tunnel evacuation experiments



Tunnel evacuation experiments in Stockholm, Sweden (METRO project)

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1) Movement speeds in a smoke-filled tunnel (including different surfaces/inclinations)
2) The impact of smoke on exit choice

Fridolf K, Ronchi E, Nilsson D, Frantzich H (2013). ***Movement speed and exit choice in smoke-filled rail tunnels.*** **Fire Safety Journal Volume 59, pp. 8–21.**

Compilation of data from tunnel evacuation experiments

- Smoke is the most important factor (no significant impact of inclination/surface materials)

- Occupants use the wall to orientate themselves

- Loudspeakers are the most effective systems, followed by green flashing lights

- Tunnel occupants mis-interpret white and green lights (when used together)

A priori vs a posteriori modelling

Recommendation on the assessment of the modelling approach in relation to scenario complexity

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- *A priori* vs *a posteriori* modelling of tunnel evacuations

- Six evacuation models (FDS+Evac, Gridflow, buildingEXODUS, STEPS, Pathfinder, Simulex) and analytical calculations are tested (largest model comparison and validation effort ever made for road tunnel evacuation scenarios)

Ronchi E (2013). *Testing the predictive capabilities of evacuation models for tunnel safety analyses.* Safety Science. In Press.

A priori vs a posteriori modelling

Results highlight the impact of different modelling assumptions: models may be suitable for the simulation of different aspects of the evacuation process.

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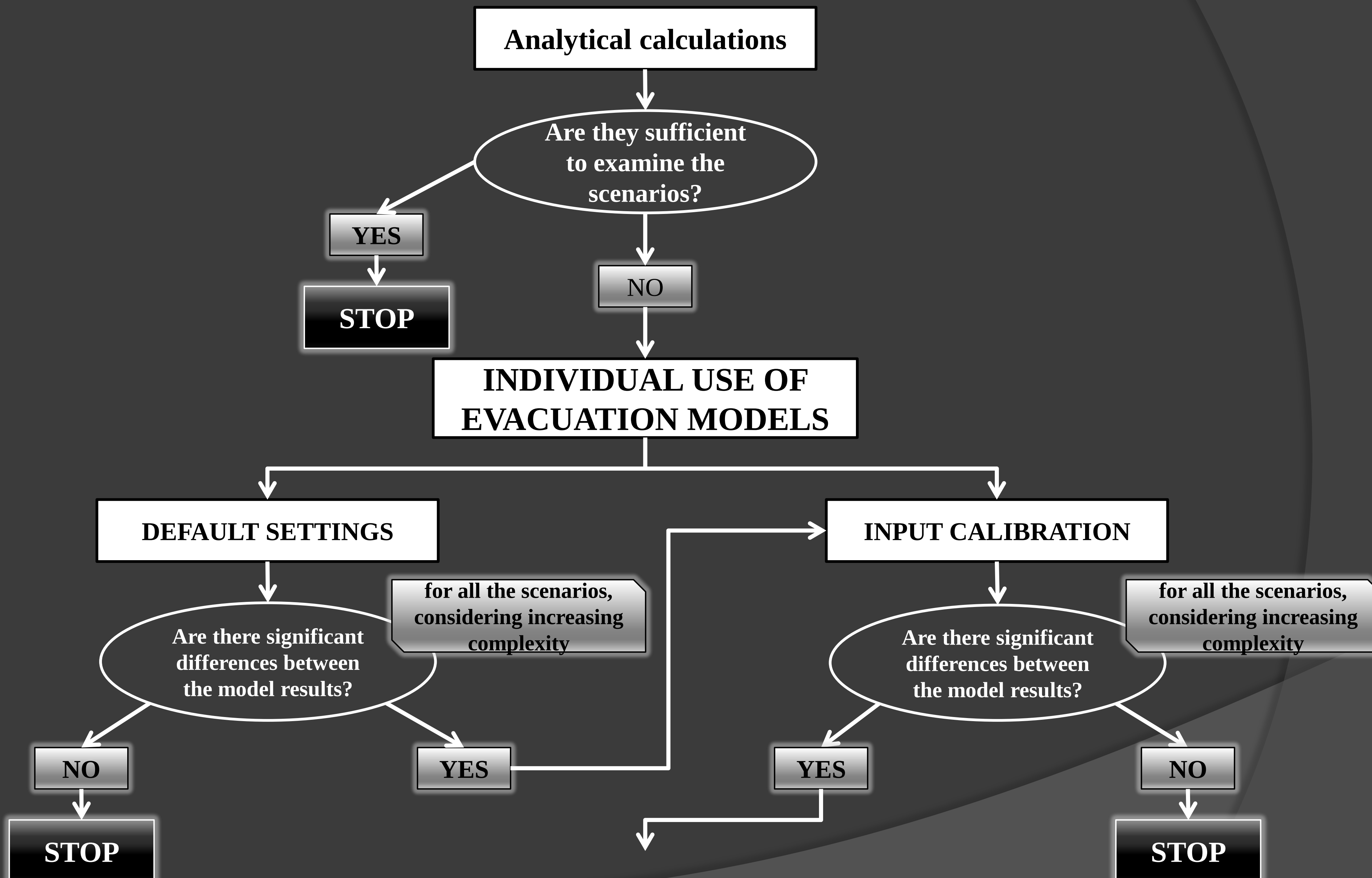
MULTI-MODEL APPROACH

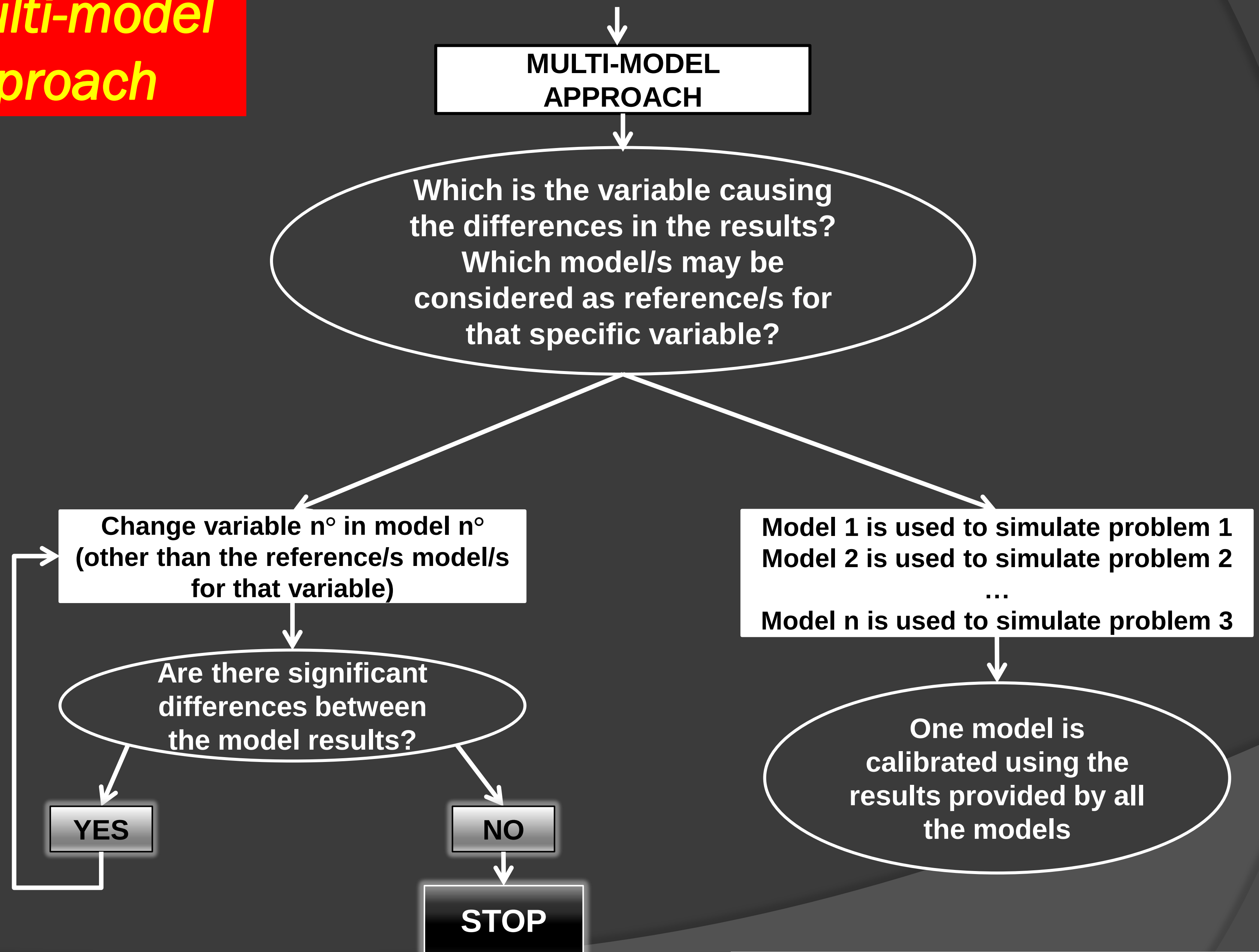
Synergistic use of models (adopting different modelling assumptions) so that the strengths of each model can compensate each others' weaknesses.

The multi-model approach



The multi-model approach

Multi-model approach



Assessment of the modelling approach

Evacuation route and layout
Single evacuation route [S]
Multiple evacuation routes [M]
Complex layout and evacuation routes [C]

Way-finding installations
Standard [S]
Not Standard [NS]

Occupant density
Low [L]
High [H]

Assessment of the modelling approaches

Evacuation routes - way-finding installations - occupant density	Recommended modelling approach
S-S-L	Analytical calculations
S-S-H	Analytical calculation
S-NS-L	Individual use of models
S-NS-H	Individual use of models
M-S-L	Individual use of models
M-NS-L	Individual use of models
M-S-H	Individual use of models
M-NS-H	Individual use of models
C-S-L	Multi-model approach
C-NS-L	Multi-model approach
C-S-H	Multi-model approach
C-NS-H	Multi-model approach

Discussion

Three key objectives achieved:

1) STUDY AND TEST OF SIMULATION TOOLS

- The model impact on results (capabilities and features, default settings, single or multiple use of models, etc.)

- The modeller‘s impact on results, (the choice of the model input, modeller‘s experience, availability of experimental data)

- Largest model comparison for road tunnel fire evacuations (a priori vs a posteriori modelling)

2) COMPILATION OF DATA FROM EXPERIMENTS

- Use of Tunnel evacuation experiments made by Lund University

3) IDENTIFICATION OF THE MODELLING APPROACHES

- New framework, namely the multi-model approach

- Classification of road tunnels in relation to the modelling approach to employ

THANK YOU

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