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A research roadmap for evacuation models used in fire safety engineering

ENRICO RONCHI, Ph.D.

Department of Fire Safety Engineering

Lund University, Sweden

enrico.ronchi@brand.lth.se

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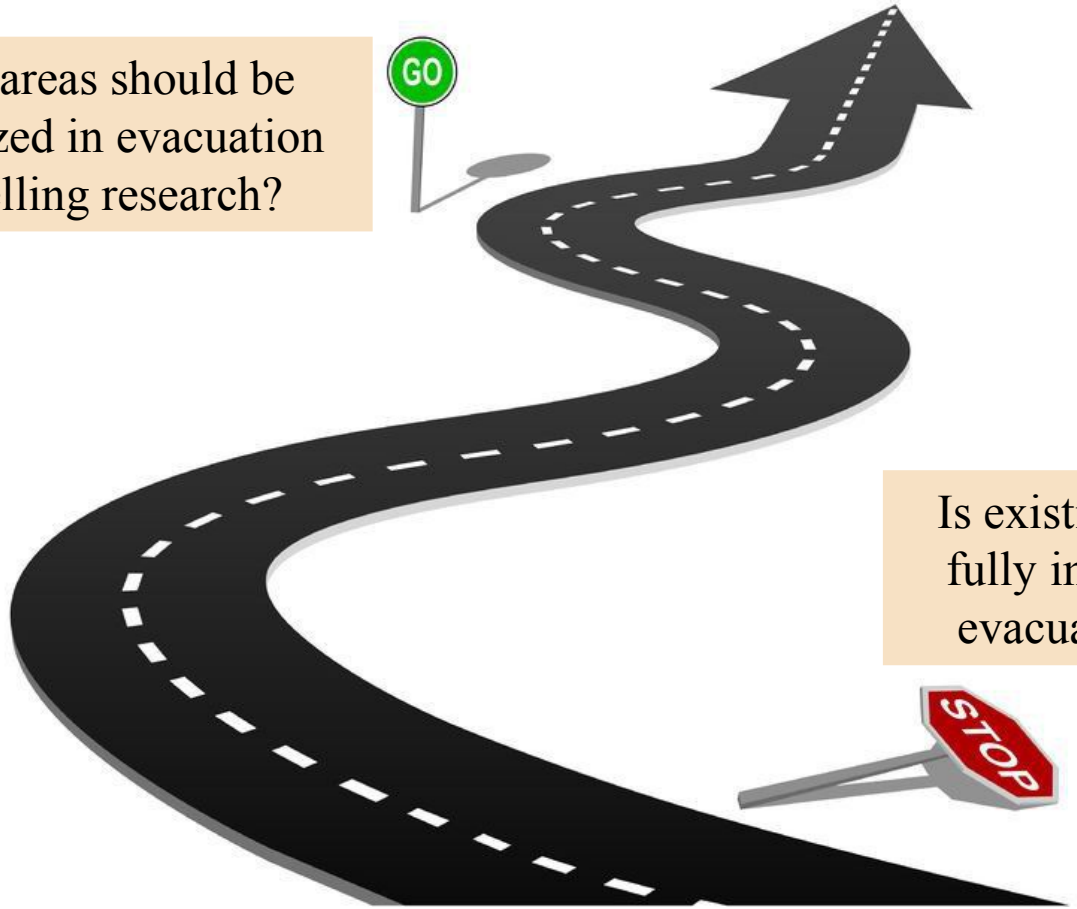
Outline

- Why a research roadmap?
- Factors affecting people movement
- Route choice modelling
- Behavioural uncertainty
- Integration with other models
- Validation methods
- Conclusions

Why a research roadmap?

FUTURE EVACUATION MODELS

What areas should be prioritized in evacuation modelling research?



Is existing knowledge fully implemented in evacuation models?

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Why a research roadmap?

BENEFITS

Researchers

- Implementation of research findings

Model users

- Improved features
- Increased credibility

Model developers

- Increasing model capabilities
- More users

AHJ

- Increased trust in results

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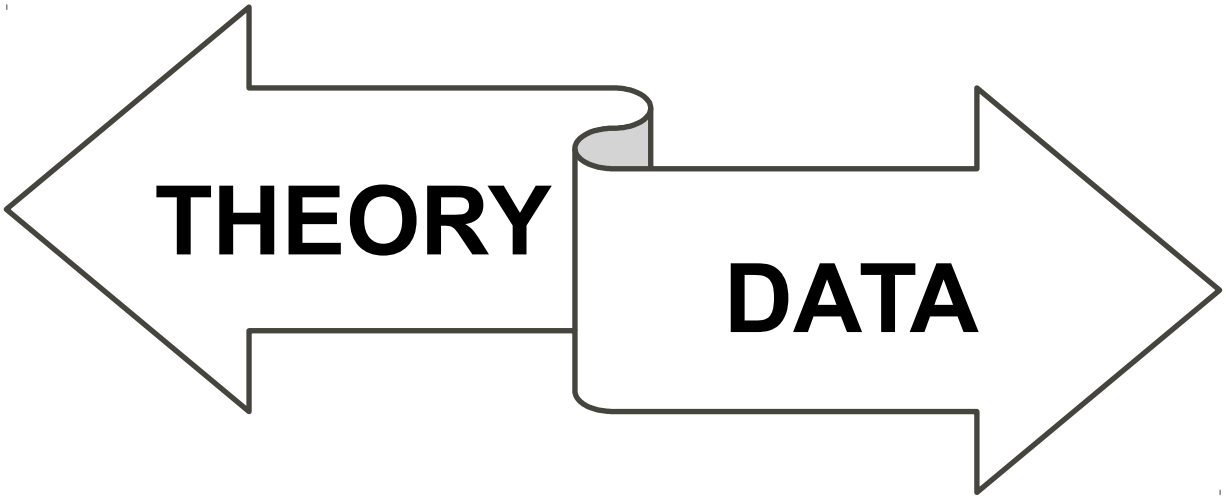
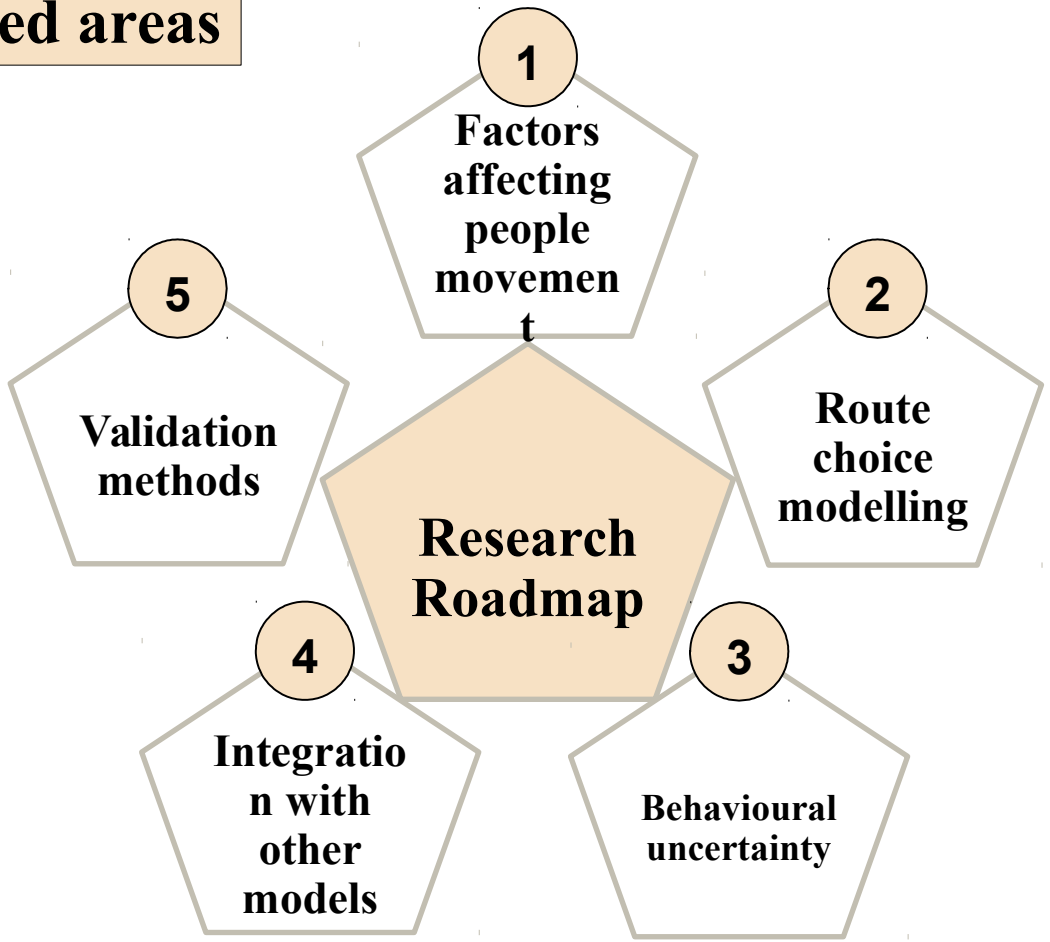
Why a research roadmap?

MODEL VALIDATION IS PRIORITY 1!



Why a research roadmap?

Five suggested areas



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Factors affecting people movement

PRESENT

- Distribution of **unimpeded** walking speeds

constant value for each person

- **Impeded** speeds

*Explicitly affected by the impact of **obstacles** and **other people***

FUTURE

- Distribution of **unimpeded** walking speeds

*Affected by **risk perception** and **motivation***

- **Impeded** speeds

Explicitly affected by the impact of many variables (e.g., physical exertion, smoke, deference and merging flows, etc.)

PARADIGM SHIFT?

Cognitive heuristics?
Biomechanics?

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Factors affecting people movement

Physical exertion

Ronchi, E., Norén, J., Delin, M., Kuklane, K., Halder, A., Arias, S., Fridolf, K., 2015b. Ascending evacuation in long stairways: Physical exertion, walking speed and behaviour (Report 3192). Department of Fire Safety Engineering, Lund University, Lund, Sweden.

How can evacuation models represent explicitly the impact of physical exertion? (e.g. long distances and ascending evacuation)

Project lead by Lund University and two Swedish companies (Briab and DeBrand) on ascending stair evacuation investigated experimentally the impact of physical exertion on evacuation.

- Continuous climbing at high pace may lead to **exhaustion** to a time as little as 3 minutes
- People taking **rests** can affect the whole flow (is fundamental diagram just a "snapshot"?)
- **Model** for maximum vertical displacement vs oxygen consumption

Factors affecting people movement

Motivation and Risk perception

Ronchi, E., Reneke, P.A., Peacock, R.D., 2016. A conceptual fatigue-motivation model to represent pedestrian movement during stair evacuation. Appl. Math. Model. 40, 4380–4396. doi:10.1016/j.apm.2015.11.040

Is a constant desired unimpeded walking speed a correct assumption?

Collaboration between Lund University (Sweden) and NIST (USA)

- Motivation can play a role (known in sport science, often ignored in evacuation modelling)
- Experiments show that people speed up when close to reach the target (Ronchi et al., 2015b)
- Should risk perception be considered explicitly in evacuation models? (Kinateder et al., 2014)

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Factors affecting people movement

Smoke impact

Fridolf, K., Nilsson, D., Frantzich, H., Ronchi, E., Arias, S., 2016. Människors gånghastighet i rök: Förslag till representation vid brandteknisk projektering [Human walking speed in smoke: recommendations for representation in fire engineering design]. SP Sverige, Sweden.

How should the impact of smoke on walking speed be represented?

Ongoing project on the impact of smoke on walking speed (SP and Lund University)

- Review data-sets available (mostly in Sweden and Japan)
- A recommended correlation is produced
- What other variables should be considered in evacuation models? (e.g., irritancy, interpretation of data-sets, etc.)

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Factors affecting people movement

Deference and merging flows

Sano, T., Ronchi, E., Minegishi, Y., Nilsson, D., 2016. A pedestrian merging flow model for stair evacuation.

Should the impact of deference behaviour and merging flows be represented explicitly?

Collaboration between Lund University (Sweden) and Waseda University (Japan)

- A simplified mathematical **sub-model** for merging flows is developed (merging ratio vs evacuation time at each floor)
- Need to conduct further **experimental research** to understand merging and deference and study their impact on evacuation

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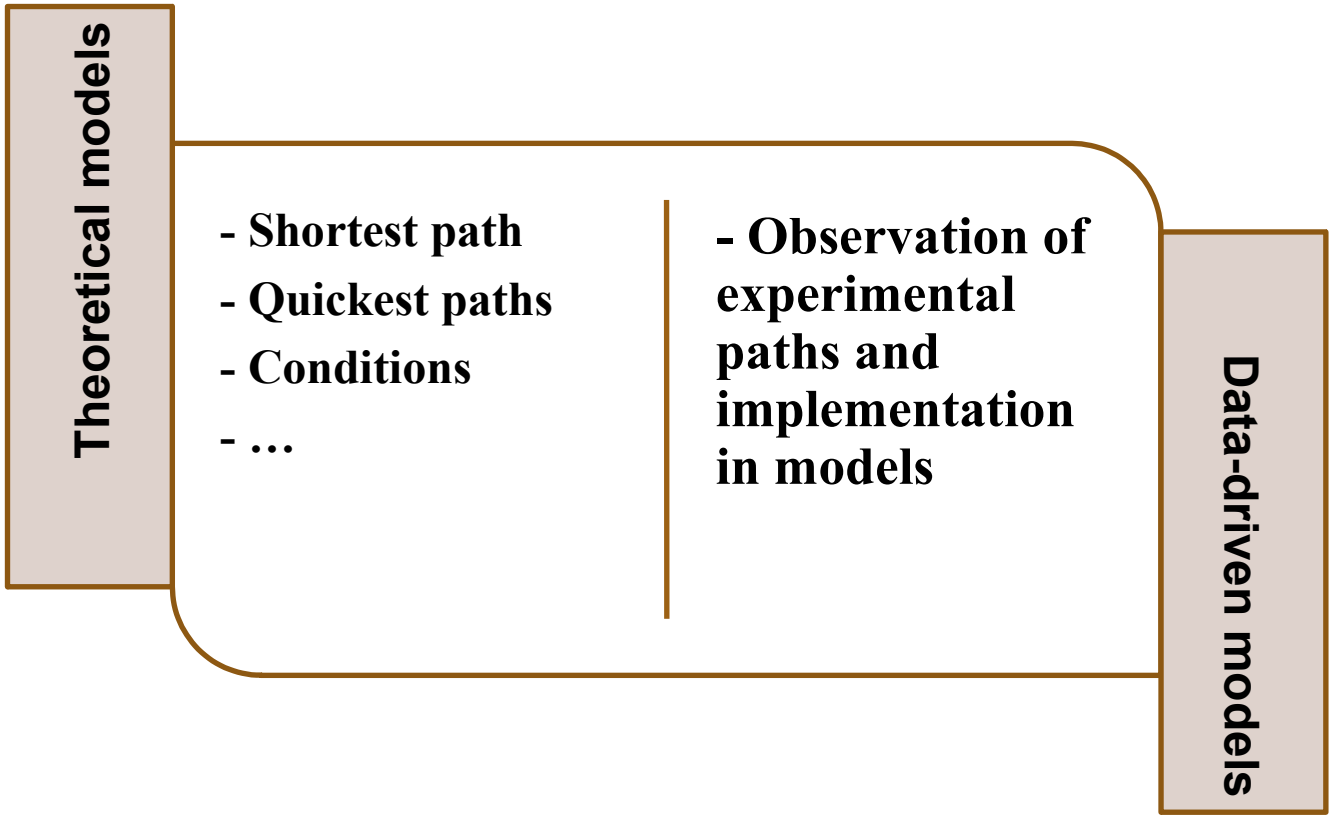
Route choice modelling

Are current route choice sub-models a reasonable approximation?

Lovreglio, R., Ronchi, E., Nilsson, D., 2015a. Calibrating floor field cellular automaton models for pedestrian dynamics by using likelihood function optimization. Phys. Stat. Mech. Its Appl. 438, 308–320. doi:10.1016/j.physa.2015.06.040



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Route choice modelling

Are current route choice sub-models a reasonable approximation?

Olander, J., Ronchi, E., Lovreglio, R., Nilsson, D., 2017. Dissuasive exit signage for building fire evacuation. Appl. Ergon. 59, 84–93. doi:10.1016/j.apergo.2016.08.029

- Route choice modelling is generally based today on the evolution of the behaviour of the agents in space (e.g. queuing time, etc.)
- It should consider the evolution of the **environment** (i.e., dynamic information given to the building occupants) and the **interactions among agents**.

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Behvioural uncertainty

How many repeated runs should be done in a probabilistic simulation?

Ronchi, Enrico, Paul A. Reneke, and Richard D. Peacock. "A Method for the Analysis of Behavioural Uncertainty in Evacuation Modelling." *Fire Technology* 50, no. 6 (November 2014): 1545–71. doi:10.1007/s10694-013-0352-7.

Evacuation models use a **probabilistic approach** (e.g. pseudo-random number sampling from distributions) for the simulation of human behaviour

Different **methods** have been proposed in the literature for the analysis of the uncertainty associated with the use of distribution laws.

Collaboration between Lund University (Sweden) and NIST (USA)

Need to implement a method to automatically optimize the number of runs.

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Integration with other models

How should evacuation model be integrated with other models?

Evacuation model uses for **large disasters** (wildfires) and **BIM**

Future model developments should **expand integration** with other tools (e.g., fire modelling, traffic modelling, structural modelling, lighting modelling, etc.)

NEED FOR A DATA TRANSFER INTERFACE

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Validation methods

Which methods should be used in model validation studies?

Cuesta, Arturo, Enrico Ronchi, Steven M. V. Gwynne, Michael J. Kinsey, Aoife L. E. Hunt, and Daniel Alvear. "School Egress Data: Comparing the Configuration and Validation of Five Egress Modelling Tools: School Egress Data." Fire and Materials, 2016. doi:10.1002/fam.2405.

A variety of methods are used in the literature

Need for the **assessment of methods** for the validation of evacuation models

ISO TC92/SC4/WG7 is working on a document on evacuation models V&V

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Conclusions

More **data** on human behaviour for validation is the known number one priority in the field

Five suggested priority areas for future research in evacuation modelling were presented

THIS IS NOT THE FINAL ANSWER!

A BROAD DEBATE ON THE RESEARCH ROADMAP IS THE "REAL" PRIORITY!

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THANK YOU!

Email: enrico.ronchi@brand.lth.se
Department of Fire Safety Engineering: www.brand.lth.se

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