EVACUATION MODEL FOR FIRE SAFETY ENGINEERING

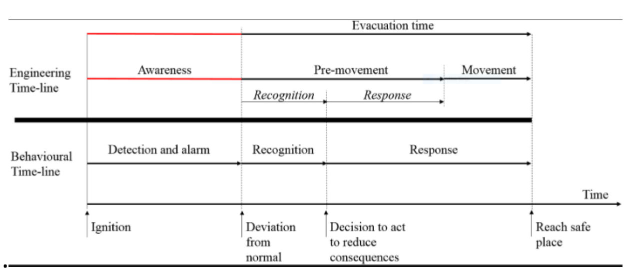
Mansura rahman
20201227

INTRODUCTION :

Evacuation models are used in fire safety engineering to investigate the safety conditions of a given building, area or infrastructure. The simulation of human behavior in fire poses several challenges from a model development perspective. Several disciplines play a fundamental role in evacuation model development, including engineering, psychology, applied mathematics, physics, computer science, sociology, etc. The pedestrian evacuation modeling market for FSE applications include over 70 models. Most evacuation models represent exit/route choice using very simple assumptions (e.g., shortest or quickest path algorithms) These methods can only partially take into account the complexity of human decision making. To the author's knowledge, there is no fully 3D evacuation simulation of people movement. Survey identifies most commonly used evacuation models for FSE applications. None of the top three most used models adopt a movement modeling method developed in the last twenty years. Analysis poses an outstanding question: why have the modeling approaches developed over the past twenty years not become mainstream in pedestrian evacuation models? A review identified 22 evacuation models which could potentially be used for such scenarios. This paper mainly focuses on pedestrian evacuation models, but many of the concepts are applicable to traffic evacuation models as well. It is hoped that it will stimulate a debate on if/which fundamental modeling assumptions should be questioned. The paper suggests the development of a common standard for evacuation model validation to reduce inconsistencies among modeling results[1].

The evacuation model development process : A model is a condensed version of reality that can take many different shapes. To establish a hypothesis about how human behavior is represented in fire, two methods can be applied. Both have advantages and disadvantages, but they share a logical basis in common. The engineering time-line model is typically used to illustrate the actions that evacuation models simulate[2].

Modeling human behavior using a time-line : Two different time-lines can be used to represent the evacuation process, namely an engineering and behavioral timeline (see Fig. 1). The engineering time-line includes the awareness phase (corresponding to detection and alarm in the behavioral time line) and the pre-movement phase (time from deviation from normal until purposive evacuation movement) [3]. For this reason, the following sections focus only on the movements of people towards a safe place



EVACUATION MODEL FOR FIRE SAFETY ENGINEERING

Mansura rahman
20201227

The use of pseudo-random sampling techniques is the method most frequently used to portray the pre-movement period. This strategy doesn't seem to accurately reflect how people actually behave. The ability to explicitly express the actions that might take place as a result of behavioral itineraries may also be provided by evacuation models[4]. The main problem with these methods is that user assumptions are used to represent behavior rather than actual model predictions. Using a pre-movement predictive sub-model that explicitly takes the factors influencing the choice to evacuate into account is an alternate strategy. Such a model is predicated on the random utility theory's description of important internal and external elements (such as risk perception). Its primary drawback is the requirement for numerous dedicated data sets for calibration.

Evacuation models typically consider the movement of agents at a number of levels, including tactical/strategic/global (i.e. route/exit choice), and local level (e.g. representing local movement and collision avoidance with obstacles/other agents). An additional locomotion level at a more refined degree of resolution may be considered (intended here as the detailed representation of components of an agent, e.g., legs or shoulders of a pedestrian or wheels of a car)[5]. In the context of FSE, fire smoke can have a significant impact on evacuation movement, so this aspect has been addressed in a dedicated sub-section.

Exit choice modeling: Most evacuation models are based on optimization algorithms aimed at obtaining paths which resemble the shortest (i.e., reaching the closest exit) or quickest path. More sophisticated approaches include the representation of conditions which may affect the chosen route, e.g., lines of sight, the presence of smoke, social influence, etc. The use of specified routes can also be useful to model assisted evacuation scenarios[6].

The choice of an individual agent in a room with two exits can be modeled in several manners. Fig shows that varying levels of sophistication can be adopted to represent route choice in which different factors can be implicitly or explicitly taken into consideration[7]. Assessing the impact of different assumptions gets more difficult with the increasing complexity of a building.

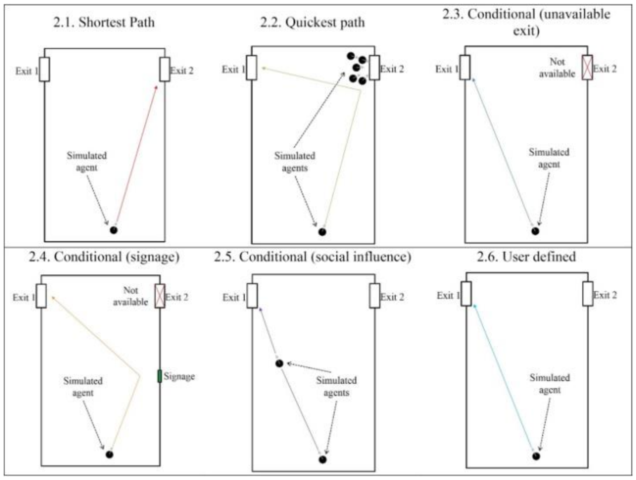


Fig. 2. Example of chosen routes based on the assumptions adopted for a simple choice between two exits

Evacuation models assume that the simulated agents are fully aware of the space from the beginning of the simulation and have an initial target to reach. This approach can be considered applicable for evacuation scenarios in which people are fully familiar with the environment. Developing and testing appropriate criteria for dynamic re-routing could significantly improve the predictive capabilities of evacuation models. It appears evident the need to further investigate how people perceive the surroundings and respond to the cues along their evacuation path[8].

Movement modeling : Cellular automata (CA) can be employed to represent evacuation movement. CA models consist of a uniform lattice made of cells, which can be either occupied (by an agent or an obstacle) or available. A time-based or event-based approach can be used to update the state of the cells and the movement takes place in accordance to a given set of rules. The movement of the agents can also be obtained as a property based on a set of global/local rules (i.e. using an agent-based modeling approach) or differential equations (generally based on Newtonian forces)[16]. These approaches allow the representation of the interactions between agents and the space. Examples of such methods are the social force model [9] and the steering model [10]. The use of a constant value of desired/unimpeded speed is an established assumption in evacuation modeling literature. This assumption is inspired by self-driven particle models, which assume that agents are self-propelled particles with a constant speed. An alternative approach for representing the desired speed would therefore consider a variable speed[9]. This approach could also be adopted to represent additional behavioral factors affecting the selection of the desired walking speed. Evacuation models adopt similar assumptions as if the movement would happen on an incline or a projected plane. Of particular interest is the case of representing merging flows coming from different egress components (e.g. stairs and floors), as they can affect the order in which floors are evacuated. The most used alternative to stairs in case of fire emergencies is the use of Occupant Evacuation Elevators (OEE)[17].

EVACUATION MODEL FOR FIRE SAFETY ENGINEERING

Mansura rahman
20201227

Modeling the impact of smoke :Smoke from wildfires can affect both the pre-movement and evacuation phases of a human's journey away from a site[10]. The impact of smoke on walking speed and route selection has been shown in experimental studies. Different empirical correlations have been built and implemented in evacuation models to represent the impact of fire smoke on evacuation[18].

Validation: Two surveys among model users showed that verification and validation (V&V) are the main contributing factors for selecting an evacuation model .Verification is intended as the process of determining that a calculation method implementation accurately represents the developer's conceptual description of the calculation method. Table 1 presents a summary of the tests included in the three main existing V&V documents[11]. IMO has provided a list of tests for the V&V of evacuation model capabilities within a set of guidelines on the assessment of new and existing passenger ships. A key objective is to assess the ability of evacuation models to reproduce a range of key egress components (defined as component testing). A qualitative analysis of the predicted human behavior is also recommended. The Tester is required to present the full range of capabilities of the model under consideration and provide instructions for its correct use[12].

Tested component	IMO	RiMEA	NIST
Pre-movement time assignment	Test 5	Test 5	Test.1.1
Walking speed in a corridor	Test 1	Test 1	Test 2.1
Walking speed on stairs	Tests 2 &3	Tests 2 & 3	Test 2.2
Movement around a corner	Test 6	Tests 6 & 15	Test 2.3
Assigned demographics	Test 7	Tests 7 & 8	Test 2.4
Horizontal counter-flows	Test 8	No	Test 2.8
People with movement disabilities	No	No	Test 2.10
Group behaviour	No	No	Test 2.9
Reduced visibility vs walking speed	No	No	Test 2.5
Occupant incapacitation	No	No	Test 2.6
Lift usage	No	No	Test 2.7
Exit route allocation	Test 10	Test 10	Test 3.1
Dynamic availability of exit	No	No	Test 4.1
Social Influence on exit choice	No	No	Test 3.2
Affiliation to familiar exits	No	No	Test 3.3

EVACUATION MODEL FOR FIRE SAFETY ENGINEERING

Mansura rahman
20201227

Tested component	IMO	RiMEA	NIST
Route choice	No	Tests 11 & 14	No
Congestion in front of a flight of stairs	Test 11	Test 13	Test 5.1
Maximum flows	Test 4	Test 12	Test 5.2
Stair flow rates	No	No	No
Relationship between walking speed, uni-directional flows and densities	Test 12	Test 4	No
Crowd of people leaving a large public space	Test 9	Test 9	No

Table 1. Summary of the verification tests presented within the IMO[20] , RiMEA[21] and NIST [22] documents. The word "no" indicates that a given component is not evaluated with a dedicated test in the corresponding document.

Tests were grouped based on the main core behavioral components they belong to (i.e. pre-movement, movement and navigation, route/exit usage, route availability and selection and flow constraints) The document also provided references to data-sets which have been considered potentially suitable for validation. A key aspect to consider is the assessment of the uncertainties associated with the results produced.

Discussion : A common application of evacuation models in the FSE domain is performance-based design. Many models and sub-models used in FSE have been originally designed for other applications. This paper is not necessarily advocating for a drastic change in the core assumptions adopted by evacuation models. Instead, it wants to encourage a debate on reviewing their suitability for FSE applications. In general terms, evacuation models are generally addressing a punctual evacuation scenario in a given condition of the building and with a given (set of) population(s).An alternative approach may include the simulation of the lifetime of a building, placing fire evacuation safety in a larger picture. This may allow considering the implications of real fire threats and false alarms (along with other variables) on evacuation decision making[13]. An important issue to consider is the trade-off between reductionism and parsimony in evacuation models. This paper wants to encourage a debate on the need for the representation of very detailed behavior at the individual level versus the use of simplified assumptions. Despite many research efforts that have been conducted over the years to define suitable V&V tests and procedures, a standardized document which can be used by all interested parties does not exist yet. An international task group has been created to develop a standardized protocol for the verification and validation of evacuation models used in buildings. The task group involves evacuation modeling experts from the industry, model developers and researchers. This document is currently under development and is deemed to represent a significant milestone towards

Mansura rahman
20201227

the assessment of the key requirements that evacuation models need to meet[19]. Issues concerning the default configuration of evacuation model should also be considered. Future areas of development of evacuation models might come from other, fast growing, areas of research, such as pattern recognition, machine learning, big data, etc. It is hoped that research advancements in these fields will allow the collection and treatment of more and more data which can be implemented into evacuation models[14].

Conclusion :The aim of this paper is to encourage a broad debate on the need for challenging well-established assumptions. The state-of-the-art of the methods used for the verification and validation (V&V) of evacuation models is also presented[15]. Given the inconsistencies among testing methods for V&V, there is a need for a standardized protocol to address this issue.

References :

1)M. Kinateder, E. Ronchi
Letter to the editor
Burning Down the Silos in a Multidisciplinary Field. Towards Unified Quality Criteria in Human Behaviour in Fire," *Fire Technol* (May 2019)
10694-019-00867-z
Google Scholar
2) R. Lovreglio, E. Ronchi, M.J. Kinsey

An Online Survey of Pedestrian Evacuation Model Usage and Users
56, Fire Technology (2020), pp. 1133-1153
In this issue
https://doi.org/10.1007/s10694-019-00923-8
View PDF
CrossRefView Record in ScopusGoogle Scholar

3) D. Helbing, P. Molnár

Social force model for pedestrian dynamics
Phys. Rev. E, 51 (5) (May 1995), pp. 4282-4286
View Record in ScopusGoogle Scholar
4) A. Rigos, E. Mohlin, E. Ronchi

The cry wolf effect in evacuation: a game-theoretic approach
Phys. Stat. Mech. Its Appl., 526 (Jul. 2019), p. 120890
ArticleDownload PDFView Record in ScopusGoogle Scholar

5) M. J. Seitz, A. Templeton, J. Drury, G. Köster, and A. Philippides, "Parsimony versus reductionism: how can crowd psychology be introduced into computer simulation?," Rev. Gen. Psychol., vol. 21, no. 1, pp. 95–102, Mar. 2017.

EVACUATION MODEL FOR FIRE SAFETY ENGINEERING

Mansura rahman
20201227

Google Scholar
6) E.R. Galea, S. Deere, R. Brown, L. Filippidis

"An Evacuation Validation Data Set for Large Passenger Ships," Presented at the Pedestrian and Evacuation Dynamics 2012 Conference
ETH, Zurich (Switzerland) (2012)
Google Scholar
7) E. Ronchi, E.D. Kuligowski, D. Nilsson, R.D. Peacock, P.A. Reneke

Assessing the verification and validation of building fire evacuation models
Fire Technol., 52 (Sep. 2014), pp. 197-219
Google Scholar
8) International Maritime Organization

Revised Guidelines on Evacuation Analysis for New and Existing Passenger Ships, MSC.1/Circ.1533
International Maritime Organization (2016)
Google Scholar
9) S. Gwynne, E.R. Galea, P.J. Lawrence, L. Filippidis

Modelling occupant interaction with fire conditions using the buildingEXODUS evacuation model
Fire Saf. J., 36 (4) (Jun. 2001), pp. 327-357
ArticleDownload PDFView Record in ScopusGoogle Scholar

10) E. Ronchi, "Testing the predictive capabilities of evacuation models for tunnel fire safety analysis," Saf. Sci., vol. 59, no. 0, pp. 141–153, Nov. 2013.

Google Scholar
11) R. Machado Tavares, E. Ronchi

"Uncertainties in Evacuation Modelling: Current Flaws and Future Improvements," Presented at the 6th Human Behaviour in Fire Symposium 2015
Downing College, Cambridge, UK (2015), pp. 185-196
Google Scholar
12) E. D. Kuligowski et al., "Movement on Stairs during Building Evacuations," National Institute of Standards and Technology, NIST TN 1839, Sep. 2014.
Google Scholar
13) M. Moussaïd, D. Helbing, G. Theraulaz
How simple rules determine pedestrian behavior and crowd disasters
Proc. Natl. Acad. Sci. Unit. States Am., 108 (17) (Apr. 2011), pp. 6884-6888
CrossRefView Record in ScopusGoogle Scholar
14) E. Galea, J.P. Galparsoro
Exodus: an evacuation model for mass transport vehicles
Civil Aviation Authority (1993)
15) E. Ronchi, S.M.V. Gwynne, G. Rein, P. Intini, R. Wadhwani

EVACUATION MODEL FOR FIRE SAFETY ENGINEERING

Mansura rahman
20201227

An open multi-physics framework for modelling wildland-urban interface fire evacuations
Saf. Sci., 118 (Oct. 2019), pp. 868-880
Record in ScopusGoogle Scholar
16) E. Ronchi, D. Nilsson A. Cuesta, O. Abreu, D. Alvear (Eds.), "Basic Concepts and Modelling Methods," in *Evacuation Modeling Trends*, Springer International Publishing, Cham (2016), pp. 1-23 View PDFCrossRefView Record in ScopusGoogle Scholar

17) D. Helbing, P. Molnár Social force model for pedestrian dynamics

Phys. Rev. E, 51 (5) (May 1995), pp. 4282-4286 View Record in ScopusGoogle Scholar

18) E. Ronchi, D. Nilsson

Fire evacuation in high-rise buildings: a review of human behaviour and modelling research

Fire Sci. Rev., 2 (1) (2013), p. 7

https://doi.org/10.1186/2193-0414-2-7 Google Scholar

19) Xiaoshan Pan

Computational Modeling of Human Behavior for Emergency Egress Analysis: a Multi-Agent Based Simulation Approach Lambert Academic Publishing, Saarbrücken (2009) Google Scholar

20) International Maritime Organization

Revised Guidelines on Evacuation Analysis for New and Existing Passenger Ships, MSC.1/Circ.1533
International Maritime Organization (2016)
Google Scholar
21) G. Rimea

Richtlinie für Mikroskopische EntfluchtungsAnalysen [Guidelinefor Microscopic Evacuation Analysis] version 3.0
(2016)
www.rimea.de
Google Scholar
22) E. Ronchi, E.D. Kuligowski, P.A. Reneke, R.D. Peacock, D. Nilsson

The Process of Verification and Validation of Building Fire Evacuation Models
" National Institute of Standards and Technology (2013)
Technical Note 1822
Google Scholar

EVACUATION MODEL FOR FIRE SAFETY ENGINEERING

Mansura rahman
20201227