Case Studies in Fire Safety 5 (2016) 11–19

Contents lists available at ScienceDirect

Case Studies in Fire Safety

journal homepage: www.elsevier.com/locate/csfs

Modelling large-scale evacuation of music festivals

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ARTICLE INFO

Article history:
Received 28 October 2015
Received in revised form 7 December 2015
Accepted 8 December 2015
Available online 30 December 2015

Keywords:
Emergency evacuation
Evacuation modelling
Crowd management
Music festival
Cascading effects

ABSTRACT

This paper explores the use of multi-agent continuous evacuation modelling for representing large-scale evacuation scenarios at music festivals. A 65,000 people capacity music festival area was simulated using the model Pathfinder. Three evacuation scenarios were developed in order to explore the capabilities of evacuation modelling during such incidents, namely (1) a preventive evacuation of a section of the festival area containing approximately 15,000 people due to a fire breaking out on a ship, (2) an escalating scenario involving the total evacuation of the entire festival area (65,000 people) due to a bomb threat, and (3) a cascading scenario involving the total evacuation of the entire festival area (65,000 people) due to the threat of an explosion caused by a ship engine overheating. This study suggests that the analysis of the people-evacuation time curves produced by evacuation models, coupled with a visual analysis of the simulated evacuation scenarios, allows for the identification of the main factors affecting the evacuation process (e.g., delay times, overcrowding at exits in relation to exit widths, etc.) and potential measures that could improve safety.

1. Introduction

Music festivals present a set of challenges from the perspective of evacuation safety. For instance, very high people densities can be reached in proximity of the stages, thus creating potential issues associated with crushing and trampling [9,26]. Attendees are often unfamiliar with the evacuation routes, thus potentially increasing the time needed for way-finding during such incidents. Pre-evacuation behaviour itself (which can be defined as the time needed to start the purposive movement towards a safe place [19]) may be affected by several variables such as the impact of social media [5,18] or levels of alcohol consumption [6].

Today evacuation safety measures for music festivals are mostly based on guidelines (rules of thumb) discussing variables such as the width of available exit space depending on the number of people, maximum number of people per m^2, etc. [10]. Evacuation exercises to test festival evacuation plans are rarely done. Evacuation modelling to test festival evacuation plans and procedures are an easier way to evaluate and improve the safety of music festivals. However this technique is seldom used as organisers and local authorities rely on the current practice of evacuation guidelines.

Evacuation models can be used to obtain qualitative and quantitative information on evacuation times and space usage in different evacuation scenarios [7]. The behaviour of festival goers and members of staff can also be explored [16,28].

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http://dx.doi.org/10.1016/j.csfs.2015.12.002

A model study was developed in order to explore the potential of evacuation modelling for the simulation of music festival evacuation scenarios. In particular, the paper discusses the insights provided by the use of evacuation simulations tools, including what type of results can be obtained and how they can be used by event safety and public emergency response managers. A fictional music festival was created, the characteristics of which were informed by a review of several real ones by the researchers. The music festival area is able to host up to 65,000 people and includes eleven stages. Three evacuation scenarios were devised, in which different threats and available evacuation routes were assumed. The connections between variables in the model (number and location of exits, delay times, exit paths) have been investigated.

2. Method

The method employed in this study was the application of evacuation modelling techniques. The initial phase of the study was therefore the selection of an appropriate evacuation model to simulate large-scale evacuation scenarios at a music festival. A review of the characteristics needed in evacuation models to simulate this type of scenarios was performed. This included the representation of large populations and high densities. Existing research on crowd modelling in cases of large-scale evacuation is mostly based on modelling assumptions aimed at low computational cost (given the large number of people involved), e.g., macroscopic simulations [3] or cellular automata [2]. The present study sets out to simulate large-scale evacuation scenarios with a higher level of sophistication, i.e., adopting a multi-agent-based model with a continuous modelling approach. The choice of the evacuation model employed in this study was made after an analysis of the characteristics of evacuation models as stated by model developers, e.g., the model inventory available at www.evacmod.net [21] or presented in scientific reviews [7,14]. A set of simulations was performed using an agent-based continuous model—Pathfinder [27].

When possible, the input of the evacuation model was calibrated using experimental data rather than the default settings of each model. This had the effect of making the evacuation scenarios as realistic as possible, while limiting the user effect [25], i.e., results affected by the choices of the modellers during the process of input calibration.

3. Model case study

The model case study was an outdoor dance festival in an area (see Fig. 1) restricted by fences due to its close proximity to a residential area, river and main road transport infrastructure (highway and secondary roads). The area was used for music performances at different stages (eleven). The maximum number of attendees was 65,000 people, most of whom were likely to be aged between 16 and 35 years old. In case of evacuation, fences close to the exits used for the delimitation of the festival are usually open. External exits have a width in the range of 7.5–9 m, except the main entrance of the festival area (Fin_Ex2 in Fig. 1 has a width of 45 m).

Three evacuation scenarios were taken into consideration, in which different threats and available evacuation routes are assumed. The evacuation scenarios were developed in order to explore the predictive capabilities of evacuation models during such incidents:

1. A preventive evacuation of a section of the festival area containing 15,309 people due to a fire breaking out on a ship close to the festival site;
2. While the preventive evacuation is ongoing, an escalating scenario involving the total evacuation of the entire festival area (65,000 people) due to a bomb threat;
3. While the preventive evacuation is ongoing, a cascading scenario involving the total evacuation of the entire festival area (65,000 people) due to the threat of an explosion caused by the overheating of the ship engine.

Based on discussions with festival organizers, the starting average people density is assumed to be equivalent of 2 people/m^2 at the outdoor stages and 3 people/m^2 for the indoor stages. This could be due to high density in close proximity to the stages (even higher than 4 people/m^2) and a lower density in areas situated further away from them (approximately 1 people/m^2). The population placement is then adjusted in order to consider 10% of the population that is not on the stages and that the upper limit of the population allowed in the festival area is 65000 people. This results in densities lower than 1 people/m^2 in those festival areas situated far away from the stages.

Scenario 1 involved the partial preventive evacuation of a section of a festival area due to a hypothetical fire on a nearby ship. Assuming the fire occurring on a vessel on the river close to the north/north-west part of the festival area, a total of 15,309 attendees would need to be evacuated from the areas in close proximity to stages 4, 7, 10, and 11. In Fig. 1, Fin_Ex1 is the only available exit for the evacuation (the exits on the north/north-west part, i.e., Fin_Ex2, Fin_Ex3B and Fin_Ex3A are assumed not to be available due to toxic smoke from the fire) and attendees are also relocated to the central part of the festival area.

In order to provide insight into the impact of the blocked exits upon the evacuation process, a benchmark case was also considered (Scenario 1a) in which the preventive evacuation scenario was simulated again but with all exits considered available (i.e., including the exits in the north/north-east part of the festival). In addition a Scenario 1b is also considered where the exits on the north/north-east part, i.e., Fin_Ex2, Fin_Ex3B and Fin_Ex3A are assumed to be unavailable (as in Scenario 1), but an additional provisional 9 m wide exit is created in the proximity of Fin_Ex1 by removing fences.