Comparison of an Evacuation Exercise in a Primary School to Simulation Results

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Abstract. The modeling of pedestrian movement has received growing interest over the last decades. This is due to the potential applications in facility design and especially evacuation simulation as well as the fascination of its fundamental properties. Empirical data plays a particular role with respect to both aspects. The key challenge in modeling and simulating crowd movement is to validate the model assumptions on the one hand and the simulation results on the other hand. In this paper we present empirical data on an evacuation exercise in a primary school. About two hundred pupils (and their teachers) took part in the drill. Three drills were carried out. The premises are divided into two separate buildings, the larger one containing 6 classrooms with about 120 pupils. The results of the exercise are reported. Additionally, the time measured is compared to the time distribution gained from simulations.

1 Modeling and Simulating Evacuation Processes

Pedestrian dynamics is a vital and growing interdisciplinary field of research [18, 19]. Especially the subject of evacuation simulation has attracted increasing interest. Overviews over the different simulation and optimization methods available can be found in [9, 10, 14]. They can be roughly classified into:

1. regression models (hydraulic/hydrodynamic),
2. queuing models,
3. route-choice models (mesoscopic), and
4. microscopic models (social force model) [11] and Cellular-Automaton-Models (CA-Models) [2, 3, 5, 16].

Regardless of the type of model used, calibration of the parameters and validation of simulation results is of major concern. This holds for normal crowd movement as well as for the evacuation or emergency case. This distinction is in a sense reflected in the one between empirical observations and experiments (active preparation of the conditions). Experiments are usually not carried out for a large number of persons and do therefore rather investigate individual behavior and movement than the characteristics of crowd motion. The latter has mainly been accessed via observations. Calibration of input

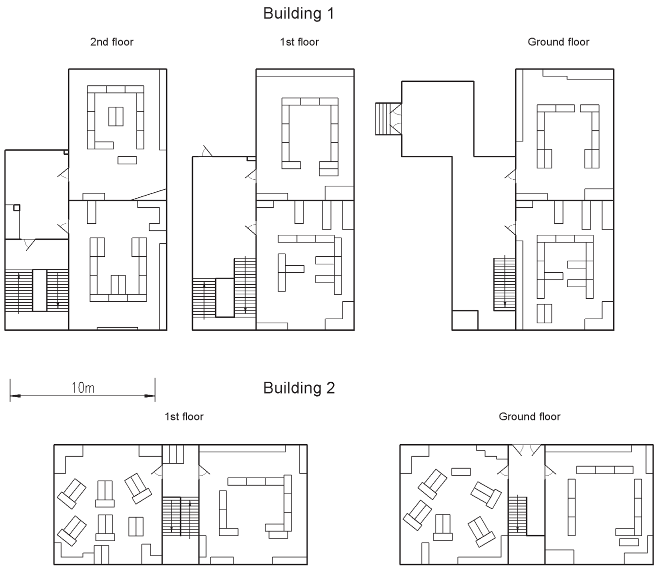

Fig. 1. Layout of the school building. It is separated into two independent parts, building 1 (top) and building 2 (bottom). Building 1 has three floors (from right to left), building 2 two floors. The students gather on the playground just in front of each building. The drawing is in scale: the doors of the rooms are 1m wide, the main exit on the ground floor is 2.2m wide.

parameters can therefore be based on experimental results, the validation of full scale simulations is mainly done via observations or data from fire drills.

The data presented in this paper are not truly experimental, since they are based on an evacuation exercise and not on laboratory experiments. However, there is a well defined scenario and the situation is controlled to some extent. Therefore, it mainly addresses the question of evacuation time and whether it can be predicted by the simulation. Please note that the case described should be considered ideal (optimal movement and behavior), since there are no hazards present and the participants were aware of the fact that it was an exercise.

Phenomena like lane formation and oscillation at bottlenecks [12], flow-density relationships [13, 17, 20], or the level of service concept [7] provide further methods for checking and calibrating simulation results. However, they can usually not be observed in this type of scenario, since there is no movement into the building (no counterflow), which is characteristic for most of these phenomena but not for evacuation drills.

The model that is used here to simulate the egress time (cf. eq. 1) is described in [16, 21]. Du to the limited space, we do not describe the model here in detail. It is a CA model (floor-plan=square grid, cell=0.4m$\times$0.4m)

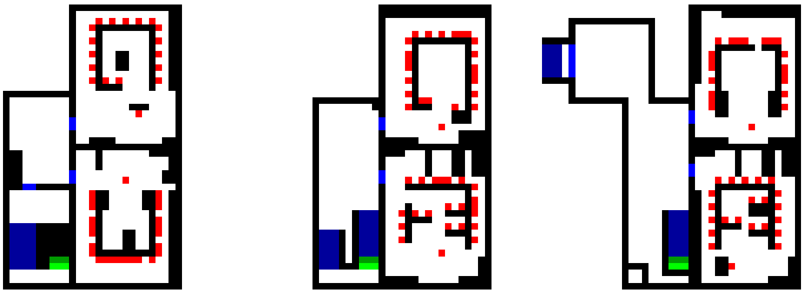

Fig. 2. Initial distribution (grey cells) in the simulation for the three floors of building 1 (cf. fig. 1, same order). Each small grey square corresponds to one person. The initial number of persons is therefore (from top left to right, top to bottom): 21, 21, 22, 22, 18, 25.

with $v_{\max} = 5\text{cells}/\Delta t$, $\Delta t = 1s$, and each cell being occupied by at most one person. The total evacuation time is obtained by the following equation [8]:

$$t_{\text{evac}} = t_{\text{process}} + t_{\text{react}} + t_{\text{egress}}, \tag{1}$$

where t_{process} is the time for realizing the situation (e.g., the time it takes to trigger the alarm), t_{react} is the reaction time, and t_{egress} the time for the movement out of the building. t_{process} can be set to zero, since in an exercise the time starts with triggering the alarm. What is then measured is $t_{\text{react}} + t_{\text{egress}}$. Those two could be distinguished by recording information about the events within the classroom. This was not done, however. This is justified by the fact that the time until the first person reached the door of the room was in the order of a few seconds, e.g., only t_{egress} is relevant and $t_{\text{evac}} \approx t_{\text{egress}}$. A more detailed report about the exercise can be found in [15].

2 The Evacuation Exercise

The building consists of two separated parts. It houses a primary school with about 200 pupils. The geometrical details are shown in fig. 1.

The procedure for the evacuation exercise was the following:

1. The alarm siren was triggered.
2. The persons started evacuating.
3. A person was considered evacuated when she reached the outside, e.g., had left the building via its main exit.

The initial distribution for the simulation is taken from the statistical records of the headmaster (class sizes and rooms, not taking into account absences). It is shown in fig. 2. Therefore, there might be slight deviations in the number of persons between the simulation and the exercise (see figs. 2 and 3).

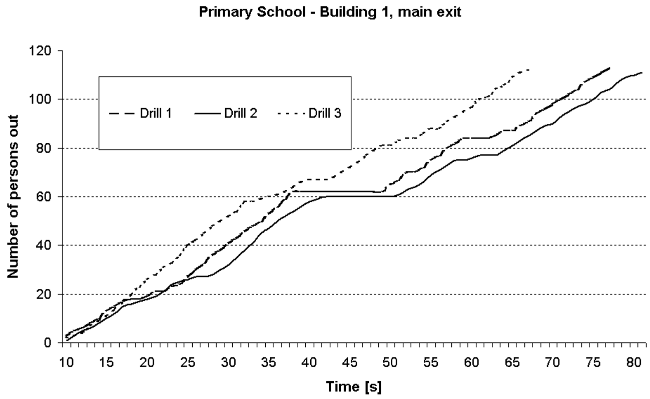

Fig. 3. Number of persons out vs. time for building 1 (cf. fig. 1). Drill 1 to 3 are three different runs of the same scenario, with the same population and initial conditions. Drill 3 proceeded slightly faster due to learning effects.

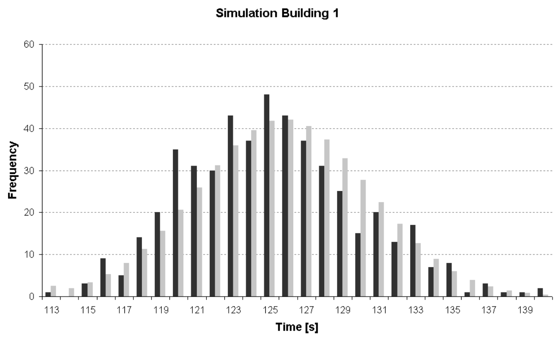

Fig. 4. Distribution of the simulated evacuation times for building 1 (500 simulation runs). The different times result from two factors: the statistical distribution of the personal parameters to the persons and the influence of stochastic parameters.

The participants were all children of the age 6 to 10 (first to fourth grade). Demographic data can be taken into account by the parameter settings. One aim of this endeavor was to check the validity of the parameter settings for such a population (cf. the next section).

3 Results

The evaluation is based on the videotapes taken during the exercise. Three different drills with the same initial conditions were performed. Figure 3 shows the number of persons having left building 1 via the main exit on the ground floor vs. time (evacuation or egress curve). It can be seen that there is a small learning effect which leads to a smaller egress time for the repeated drills.

The simulated egress times (for 500 simulation runs in each case) are:

	Exercise	Simulation
Building 1:	(125 ± 4.7)s	80s
Building 2:	(80 ± 4.7)s	58s

Due to lack of space, the egress curve is only shown for building 1. However, the detailed analysis of building 2 is comparable and would not provide new insights.

4 Summary and Conclusion

We have reported results on an evacuation exercise performed in a primary school. There is a deviation between the egress time predicted by the simulation and the actual time it took to evacuate the building. Actually, the simulated time is too high by a factor of 1.6 (building 1), resp. 1.4 (building 2). This is mainly due to the fact that the movement was extremely orderly and organized by well-trained teachers. This fact corresponds the absence of route choice or orientation problems. The population is naturally divided into groups (classes). And the pupils are physically fit, probably even more than adults, very familiar with the building, and used to follow the advice of their teachers. The simulation was based on a standard scenario which corresponds to a less optimal situation. It can therefore be concluded that it gives a more conservative estimate of the egress time than the drill. E.g., walking speed was set to 1.2–2m/s in the simulation; in the drill walking speeds up to 5m/s were observed. Another remarkable result is the reduction of the evacuation time for a repeated drill, even though the motivation decreased. However, this influence was more than compensated by harmonization of the flow.

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