Large scale multi-modal simulation of pedestrian traffic

Hubert Klüpfel a,*

aTraffGo HT GmbH, Bismarckstr. 142a, 47057 Duisburg, Germany

Abstract

For the planning of large events the crowd management is of key importance. This comprises the direction, management, and guidance of pedestrian movement. This contribution deals with the planning of the “Eidgenössisches Schwinger- and Älplerfest” (ESAF) that took place in Burgdorf, Emmental, Switzerland in 2013. To this end, simulations were performed to identify congestion and potential “hot spots”, to estimate the time it takes to evacuate the arena, to estimate the time it takes for the visitors to leave the festival and to get onto their train home.

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1. Introduction

For the ESAF 2013†, different simulations were performed prior to the event. The festival itself took place on August 31st and September 1st 2013 in Burgdorf, Switzerland. Burgdorf itself is a small town with approximately 15,000 inhabitants. Consequently, the infrastructure, especially the public transport system is not dimensioned for such a large event. The overall number of visitors was estimated to be 250,000 for three days and 120,000 on Sunday. The athletic part of the festival, the national Swiss wrestling tournament, ends on Sunday evening with the final and most visitors are assumed to leave immediately afterwards. Three scenarios were investigated by means of capacity analysis in combination with pedestrian flow simulations:

- Evacuation of the Arena
- End of the festival and departing traffic (pedestrian flow)

* Corresponding author. Tel.: +49-203-87833601; fax: +49-203-87833609.
E-mail address: kluepfel@traffgo-ht.com
† Information on the festival can be found at http://de.wikipedia.org/wiki/ESAF (in German, also available in French and Dutch).
Capacity of the train station

The capacity of the public transport system, i.e. the train station and the train schedules in combination with the capacities of the cars, was compared to the estimated demand. A similar investigation was performed for car traffic but is not the focus of this contribution, apart from the fact that it of course influences the modal mix. The traffic demand was initially estimated to be 48,000 for public transport. Since the festival ended on Sunday evening and the next day was a working day, the visitors were assumed to leave immediately after the final round. Based on those assumptions, simulations were performed for the departing pedestrian flow. These simulations showed considerable congestion, especially at the entry points to the trains station and on the platforms. The considerations and suggestions derived from the simulations were implemented on spot. This lead to a considerable decrease of congestion in reality compared to the prognosis based on the simulation. Furthermore, the traffic demand was overestimated and the reaction time span for leaving the festival underestimated prior to the event. In addition to the ex-ante simulations used for crowd management planning, an ex-post analysis and simulation was performed in order to reflect the observed parameters (reaction time-span, route choice, modal mix). The simulation results for the calibrated parameters were in good agreement with the observations. For the ex-ante analysis, the number of persons leaving by train was decreased to 30,000 and the reaction time span was increased to a range from 0 to 1.5 hours (the ex-ante simulations were based on immediate reaction, i.e. 0 to 10 seconds, which is the worst case in the sense that it leads to the highest demand and most severe congestion, compared to a longer reaction time span.

The outline of the remaining part of this paper is as follows: the assumptions made for the simulations and calculations are presented in the next section. The results of these calculations and simulations are presented in section 3. Section 4 deals with the observations made in Burgdorf during the festival on Sunday, September 1st 2013. These were used to adapt the parameters and the ex-ante simulation results are shown in section 5. Section 6 summarizes the results and concludes with the major findings, lessons learned and an outlook into their future use.

2. Assumptions concerning Traffic Demand

The traffic demand estimation was based on the overall number of visitors, the modal split, and the visitors behavior. The capacity of the train station used in Table 1 is based on the minimum of the capacity of the pedestrian path elements (stairs, ramps, tunnels, etc.) of the train station and the capacities and schedules of trains. The latter was the decisive limitation in our case. In summary, a total number of 15,000 persons could leave the train station at maximum per hour. The total capacity of the train station is based on the total number of trains per hour. However, for an uneven distribution of the traffic demand (e.g., if certain directions of travel are more frequent) the capacity will be lower than that. This is illustrated in the following table, where 70% of the visitors are assigned to platform 2/3 (which serves the trains to Basel). The train station has 5 tracks in total. The departure time is 5.5 hours for the public transport based on the assumptions made for this calculation. The bottleneck in this case is the capacity of the train system, i.e. the number of trains that can leave certain tracks per hour.

Table 1. Traffic demand for the festival.

| Arrival | Departure |
|---------|-----------|
| **Sunday** | **Total** | **MIT** | **PT/SBB** | **Bus** | **Other** | **Total** | **MIT** | **PT/SBB** | **Bus** |
| 6 hrs | 35,000 | 16,000 | 14,000 | 5,000 |
| 7 hrs | 40,000 | 24,000 | 16,000 |
| 8 hrs | 10,000 | 6,000 | 4,000 |
| 9 hrs | 10,000 | 6,000 | 4,000 |
| 10 hrs | 10,000 | 6,000 | 4,000 |
| 11 hrs | 5,000 | 3,000 | 2,000 |
| 12 hrs | 5,000 | 3,000 | 2,000 |
| 13 hrs | 5,000 | 3,000 | 2,000 |
| 18 hrs | | | | | 120,000 | 67,000 | 48,000 | 5,000 |
| Sum | 120,000 | 67,000 | 48,000 | 5,000 |
The distribution of the departing visitors to the tracks depends on their intended direction of travel. The capacity of the train station is 15,000 per hour.

Table 2. Capacity of the public transport system.

| Capacity of train station | 4.5 Minutes distance |
|---------------------------|----------------------|
| Trains per hour per track | 6.6                  |
| Tracks                    | 5                    |
| Persons per train         | 455                  |
| Sum P/h                   | 15,015               |

Table 3. Departure time for the public transport.

| Trains per hour platform 2/3 | 13.3 |
|-------------------------------|------|
| Traffic demand PT total       | 48,000 |
| Share of platform 2/3         | 70%  |
|                               | 33,600 |
| Capacity track 2 and 3        | 6,067 |
| Departure time / hours        | 5.5  |

3. Simulation Results

Based on the results of the previous section, considerable congestion was expected for the departing flows. At the same time, the expected congestion for the arriving flow in the morning was by far less severe. There are two reasons for that: the first reason is the fact that the capacity of the pedestrian walkways (and stairs, ramps, etc.) in the station and from the station to the festival area exceed the capacity of the public transport system by factor of two. Therefore, congestion was expected for the departure phase, not for the arrival phase (Fig. 1).

Fig. 1. Congestion simulated for 48,000 agents (left). The scale is from 0 to 1561 seconds (red) of local density larger than 3.5 p/sqm.
The simulation results for the departure phase are shown in the previous figures. The results are based on the software PedGo which has been calibrated, verified, and validated extensively (Rogsch (2014); Klüpfel (2003); Forell et al. (2014)). The plot for the congestion is based on the local density. Details are given in (Klüpfel (2010)). The parameters used for the (ex-ante) simulation are: N=48,000, react=0, Ost=28%.

4. Observations at the Event

4.1. Arrival on Sunday Morning

The observations made on Sunday, September 1st 2013 in the morning show a very relaxed situation. This was expected, since the capacity of the station itself (i.e., the platforms, ramps, stairs, etc.) was higher than that of the train system (i.e., schedules, train capacity, capacities of doors and passenger exchange times). The basis for the observations presented here is a trip coming from Basel via Olten to Burgdorf.

Fig. 2. Arriving traffic (9:08 hrs, left) and service road north of the arena at 10:21.

The way from the station to Kirchbergstraße took approximately three minutes, which is a distance of 300m, i.e. the movement was unhampered. It was also possible at that time to pass the pedestrian tunnel at the train station in both directions without any congestion. All those observations show that the prognosis of congestion free arrival flows (for pedestrians) was correct. The only place, where some congestion might have been expected was on the platforms, especially at the upper stair landings.

4.2. Circulation on the festival area

Circulation on the festival area was not part of the simulations or calculations in the planning phase. There are some conclusions from the observations made on the day of the festival, though, based on the comparison of the circulation around the arena with the simulation its evacuation. Fig. 2 (right) shows a service road north of the arena (behind the fence). It also shows the circulation path north of the arena (inside the area, before the fence, also serving the toilets east of the arena). Security staff reported repeated congestion due to insufficient width of the path. The fence was moved outward in this case and the congestion alleviated. This could have been identified in the evacuation simulation, since the circulation path is also an evacuation path. This was not the case, though, since the movement in the evacuation simulation was only to the assembly stations which were assumed to be right outside the arena. It would have been better to place the assembly stations further away in the simulation.

4.3. Departing flows on Sunday evening

The departing flows on Sunday evening are illustrated in the following figures. Immediately after the event, only part of the population left. This is also due to the fact that there was a gap of 40 minutes between the final match and the award ceremony. Therefore, the reaction time span was larger than estimated.
Fig. 3. Sunday, 17.05 hrs (immediately after final).

Fig. 4. Sunday, 17.20 hrs (crowd management south of bridge).

Fig. 5. Sunday, 19.45 hrs (congestion, lasting five minutes at PT west).

The movement on the festival area to the exit was also quite relaxed (cf. Fig. 6). The festival area would be north west of the area depicted in Fig. 4, right). Fig. 4 shows the situation south of the bridge at 17:20 hrs, i.e. approximately 15 minutes after the wrestling ended. Therefore, the distance of approximately 1.2 km could be covered at free walking speed. There were several measures of traffic guidance and crowd management. The only spot where some congestion was observed was at the entry to the train station (Fig. 5) at 19:20 hrs. This congestion lasted only a few minutes. Next to the crowd management, the main reasons for the smaller than expected congestion was the longer reaction time span and number of persons. This will be detailed in the next section.
5. Adapted Calculations and Simulations

The observations at the festival were different from the expectations based on the calculations and simulations. Therefore, an ex-post analysis was performed based on different parameters sets and compared to the observations. The initial simulation (ex-ante) was performed for 48,000 agents, where 28% used the eastern entry to the train station (cf. Fig. 6, right) and all left immediately (react=0). The adapted parameters for the simulation in Fig. 6, left, are: N=30,000, east=50% (i.e. equal distribution due to traffic management), and react=2.5 hrs.

Fig. 6. Simulation with N=30,000, east=50%, react=2.5hrs (left) and map of the station (right). The scale (left) is from 0 (green) to 1251 seconds (red). The density plot (left) shows local densities higher than 3.5 p/sqm for the same area as in Fig. 1.

6. Summary, conclusion, and outlook

For the ESAF 2013 in Burgdorf, Switzerland, a wrestling festival with 250,000 visitors on three days, analyses and simulations were performed for the train station, the departing flow, and the evacuation of the arena. The focus lay on the departing flow during the planning phase, since this scenario was expected to lead to the highest congestion and waiting times. Observations were made at the festival on Sunday, September 1st for arrival and departure traffic. Both were relaxed (arrival traffic as expected, departure traffic other than previously expected). Ex-post simulations were performed and compared to the observations. For a reduced share of persons using public transport (number of agents reduced from 48,000 to 30,000), a more equal distribution of the route choice (50% using east entrance to the train station instead of 28%), and a longer reaction time span (2.5 hours instead of immediate reaction), a good agreement between the ex-post simulation results and the empirical observations was found.

References

Klüpfel, H., 2003. A Cellular Automaton Model for Crowd Movement and Egress Simulation. Dissertation, Universität Duisburg-Essen.
Klüpfel: H., 2014. “Large Scale Outdoor Events. Specific Requirements concerning Evacuation Analysis,” in Proceedings of the International Conference on Pedestrian and Evacuation Dynamics. In: Weidmann, U., Kirsch, U., Schreckenberg, M. (Ed.). Springer, Berlin, pp. 501-508.
Forell, B., Klüpfel, H., Schneider, V., and Schelter, S., 2014. “Comparison of Evacuation Simulation Models,” in Proceedings of the International Conference on Pedestrian and Evacuation Dynamics. In: Weidmann, U., Kirsch, U., Schreckenberg, M. (Ed.). Springer, Berlin, pp. 189-196.