NEXT STATION 2015 Conference, 21-22 October, Marrakech (Marocco)

Modeling and simulation of pedestrian flows in railway stations

Experimental study at Noisy-Champs station, France.

S. MOKHTARI[1], Z. CHRISTOFOROU[1], F. LEURENT[1], B. KABALAN[2], P. ARGOUL[2], G. CUMUNEL[2]

[1]LVMT (IFSTTAR, ENPC, UPEM), [2]Laboratoire Navier (ENPC, IFSTTAR, CNRS)

A train station is a complex object, a sub-system shared by a global transportation system and an urban system. But it is also a system of flows, which gathers pedestrian flows, train traffic, information, energy and economic flows. Thus, the efficiency of a transportation system is an important matter, for the users, the operators and the society as a whole. To assess this efficiency, the dwell time in stations (the time a train spends in a station transferring passengers, without moving) has proved to be a relevant indicator. Indeed, longer dwell times lead to delayed trains, which cause more crowded platforms, a bunching effect and even worse delays on the train traffic, especially during peak hours. Our objective is to estimate this dwell time by simulation. We chose to study the simple case of Noisy-Champs railway station, which is located on line A of Paris' suburban railway network. This 109 kilometers-long railway line, which crosses Paris and its region from east to west, is used by over a million passengers on a typical working day. In 2011, over 300 million trips were even registered, which makes it the European railway line with the highest passenger demand! It connects 46 stations and enables for instance to reach Disneyland Paris theme park. Noisy-Champs station is a middle-size station on line A, with a yearly average passenger demand around 4.7 million. However, in the next years, it will become a significant node of *Grand Paris Express*' eastern transportation network, with the development of 3 brand new subway lines, which will induce a significant increase in passenger demand. In our study, we chose to focus on the interaction between the pedestrian flows, which are located at the platform level, and the train traffic, which is located at the line level. Indeed, in the last few years, several studies[1,2] have proved that dwell times are strongly affected by the congestion on the platform and in the train. In order to estimate this dwell time, we simulated, thanks to a crowd motion model, the pedestrian flows on Noisy-Champs' platform and the alighting/boarding phenomenon during morning peak hours.

Many tools and models have been developed in the last decades to simulate crowds' behaviors. Different modeling approaches have been studied: crowds can be described from either a macroscopic or microscopic point of view; the space in which pedestrians are moving can be either continuous[3] or discrete; pedestrian movements can be induced by forces or behavioral heuristics…Among all these approaches, we chose to use a 2D discrete pedestrian model[4], based on non-smooth mechanics and on the Discrete Element Method (DEM) used to study granular media. This model is able to simulate, with different techniques, the two main pedestrian-pedestrian and pedestrian-obstacle interactions, which are collision and avoidance[5]. However, in order to apply it to Noisy-Champs station, we had to collect all the necessary input data, such as the trains and station's geometry, the pedestrian flows in the station, the pedestrians' positions on the platform and in the train, and the train traffic on the railway line.

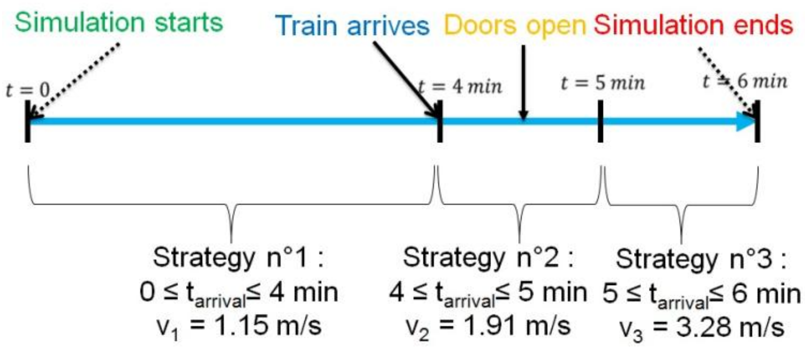
---

[1] M. S. Fritz, *Effect of crowding on light rail passenger boarding*, Transportation record 908, Ed., 1983.
[2] N. H. M. Wilson & T. Lin, *Dwell time relationships for light rail systems*, Transportation Research Record (1361), Ed., 1992.
[3] J. Bodgi, S. Erlicher, P. Argoul, 2007. *Lateral vibration of footbridges under crowd-loading: continuous crowd modeling approach*, Key Engineering Materials, Vol. 347, 2007, pp 685-690.
[4] Pecol et al, 2010, 2011.
[5] B. Kabalan. *Crowd dynamics: modeling pedestrian movement and associated generated forces*. PhD thesis, Université Paris-Est, Champs-sur-Marne, France, 2015.

Noisy-Champs station has a rather simple design: it is an open-surface station, with two main entrances (east and west) linked by two linear platforms. Stairs and elevators enable pedestrians to reach the platforms, which are located below the road level. 4 bus lines enable people to reach the station, but they can also use their own car and park on the *park and ride* area near the station. Field measurements were led to collect the necessary data and calibrate the crowd motion model's parameters (geometrical data, train traffic and pedestrians' data). We also used CapTA model[6], which is an assignment model that accounts for capacity phenomena.

To calibrate the parameters of the pedestrian flows simulation on Noisy-Champs platform, we followed a 3 layered-process:

1. **Line level**: about the train flow, we evaluated a 6 minutes average headway during morning peak hours. We added to that the passenger demand on the railway line estimated by CapTA model, and the number of people wishing to alight and board at Noisy-Champs station.
2. **Station level**: we defined a 6 minutes time window for the simulation, corresponding to the measured average headway. In our time schedule, the train arrives 4 minutes after the simulation starts. We also defined the station's geometric model (entrances, gantries, stairs, elevators…). As for the passenger demand in the station, we defined, based on our empirical observations, the pedestrian incoming flow in the station during each minute of the simulation.
3. **Platform level**: we first defined the platform and train's geometry. We then divided the platform in 3 zones and identified 3 different pedestrians' travelling strategies, with different choices for the arrival time at the station ([0, 4 min], [4, 5 min] and [5, 6 min]), for the platform's boarding zone and for the walking speed. We also explored two strategies regarding alighting and boarding, namely aggressive and polite strategy.



Once that all these input parameters have been calibrated, we then simulated, thanks to the pedestrian motion model, a 6 minutes long pedestrian flow entering the station and the platform and one alighting/boarding event when the train arrives and opens its doors. By repeating the simulation, we have thus been able to estimate 3 dwell time values and to compare them to the experimental measures: we thus obtained standard deviations between 8% and 18%. To reduce this error margin, we could refine the different pedestrians' strategies (arrival time, walking speed), for instance by taking into account their age, their gender and their motives (work, studies, holidays…). We could also refine the time subdivision of the 6 minutes simulation's time window. As further developments, we could study a bigger railway station with a more complex architecture and a significantly higher passenger demand, such as Marne-la-Vallée/Chessy station, which connects Disneyland Paris theme park to Paris, at the end of line A. We could then check whether the pedestrian motion model is still able to simulate properly the alighting/boarding event for a higher number of pedestrians, and to give good results in terms of dwell times.

[6] F. Leurent et al, 2014. *A traffic assignment model for passenger transit on a capacitated network: Bi-layer framework, line sub-models and large-scale application*, Transportation Research Part C 47, pp 3-27.