Macroscopic modeling of multi-directional point-like pedestrian intersections

Elhabib Moustaid, Gunnar Flötteröd*

April 10, 2015

1 Introduction

The interest in pedestrian modeling comes from the insight these models give in the design and management of pedestrian facilities and also when evaluating possible emergency evacuation plans. In this work, we start from an existing fundamental diagram (FD) and apply it for pedestrian intersections, in order to be able to use it for pedestrian network simulations. We present a macroscopic approach and hence do not treat the details of walking processes, lane generation, etc; the focus is on the aggregate pedestrian flows exchanged across interfaces and intersections.

2 Methodology

This work addresses macroscopically the problem of flow exchanged across a pedestrian intersection. It starts from an already existing FD by Flötteröd and Lämmel (2015), a simple bi-directional flow FD taking into account few measurable parameters (a maximum pedestrian velocity, a jam density and a collision avoidance parameter). The FD describes the bidirectional flows as the minimum of a sending and a receiving function representing up- and downstream flow limits. The FD provides a good fit against real data and the social force model. The work of Flötteröd and Lämmel (2015) shows particularly that a bi-directional FD can be modeled as a function of a system of uni-directional fundamental diagrams, only by taking the flow and density in the opposite direction as additional parameters. This gives a motivation to develop a multi-directional intersection FD by treating it as a system of uni-directional FDs.

Smith et al. (2015) present a family of macroscopic node models in urban road intersections with uni-directional flows. The discussion of this family of models includes the intersection model presented by Flötteröd and Rohde (2011). The incremental node model (INM) of Flötteröd and Rohde (2011) provides a way to find the flow from the upstream to the downstream links of a urban intersection. To compute these flows, it should be given the receiving (resp. sending) flow limits of down-stream (resp. up-stream) links, the turning fractions at the intersection and the intersection rules (in particular, priorities). Our work combines the approach of Flötteröd and Rohde (2011) for urban intersections with the existing pedestrian FD of Flötteröd and Lämmel (2015) to model a multi-directional pedestrian node intersection.

The essential difference between a uni- and a bidirectional intersection is that in the bidirectional case each link carries two flows, one into and one out of the intersection. In order to solve such a model with the

*Department of Transport Science, KTH Royal Institute of Technology

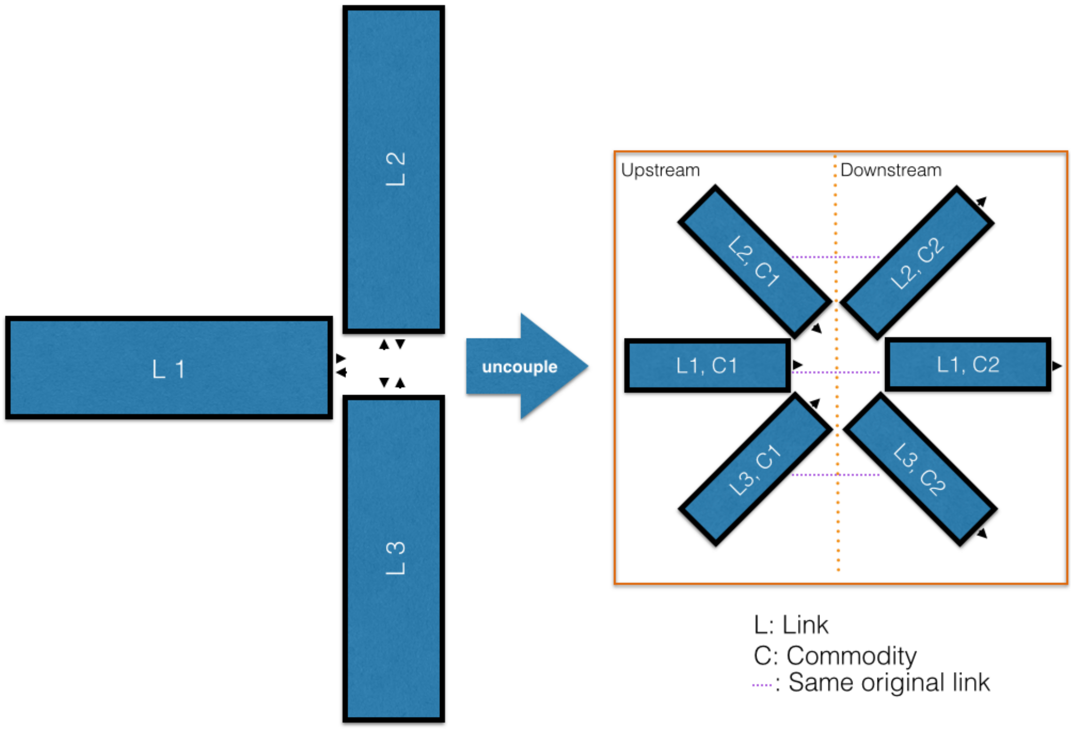


Figure 1: From an intersection of bi to uni-directional flow links

INM, the system of the bidirectional FDs describing the flows on the links has to be expressed as a system of uni-directional FDs. The bidirectional FD of Flötteröd and Rohde (2011) provides this possibility. It is coupled with the INM as follows: Let n be the number of links at the intersection, the flows in each link are described by a system of two uni-directional FDs specifying its receiving and sending flows. Each link can then be defined as two commodities. Commodity 1 representing the sending part of the link, and commodity 2 representing the receiving part. Each of these commodities is described, using the same approach as Flötteröd and Lämmel (2015), by a uni-directional FD that takes as an additional parameter the flow on the other commodity. Finally, the intersection of n bi-directional flow links is defined as the intersection of n up and n down-stream links (whose uni-directional FD influence each other). The application of INM is consequently possible, Figure 1.

The whole work can be then used in a context of a cell transmission model, where a pedestrian network can seen as a set of cells transmitting flows in simple interface or node intersection. Note that a simple interface is a special case of node intersections, with only two intersecting links. The dynamics in the network, in terms of origins and destination of pedestrians, are mainly subject to the turning fractions, arrivals and departures from the network and cells capacities. The key difference of this work to related approaches such as Hänseler et al. (2014) is that we focus a modeling approach from first principles that, as the cell size approaches zero

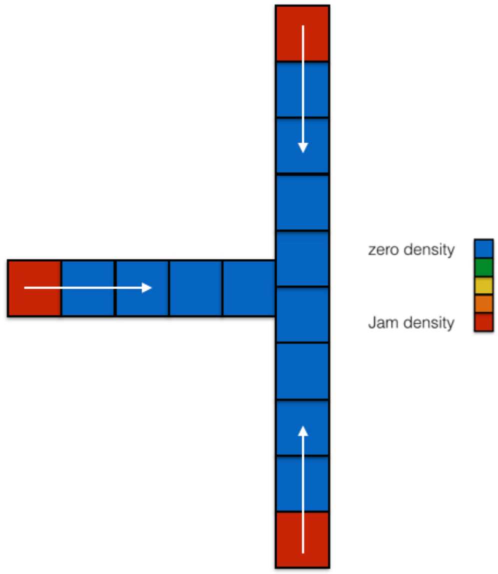


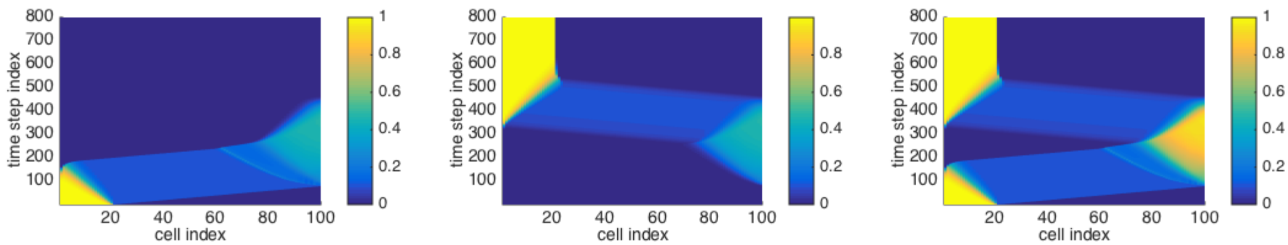
Figure 2: The experiment set up

converges to a system of two uni-directional kinematic wave models (KWM).

3 Results

Figure 2 shows the following experiment; a T intersection, on each link, the same densities of pedestrians are sent toward the intersection, and supposed to turn equally to two other links. Each link is made by 100 small cells in which the first 20 are totally full of pedestrians (i.e at jam density). The goal of the experiment is to see how the densities change over-time at the level of the intersection both in the free flow-regime, and in congested regime.

Figure 3 shows how the density changes over time at the level of every cell of the T intersection. In particular it shows the following behaviour at the level of every link: First, a growing queue at the level of the intersection, the queue is mainly due to the bottleneck effect that each group has on the other; the group of pedestrians walking toward the intersection to the group leaving it. Following this phase, the dissipation of the queue starts right after the encountering pedestrians pass each other.



Column 1 represents densities going to the intersection, Column 2 densities from the intersection to the end point of the links, and column 3 the sum of those densities.
Cell Index refers to the link cell indexes
The color blue refers to a zero density and yellow to jam density

Figure 3: The experiment result

References

[1] Smits, Erik-Sander and Bliemer, Michiel C. J. and Pel, Adam J. and van Arem, Bart, "A family of macroscopic node models", Transportation Research Part B: Methodological 74 (2015), pp. 20–39.

[2] Flötteröd, Gunnar and Rohde, Jannis, "Operational macroscopic modeling of complex urban road intersections", Transportation Research Part B: Methodological 45, 6 (2011), pp. 903–922.

[3] Flötteröd, Gunnar and Lämmel, Gregor, "Bidirectional pedestrian fundamental diagram", Transportation Research Part B: Methodological 71 (2015), pp. 194–212.

[4] Hänseler, Flurin S. and Bierlaire, Michel and Farooq, Bilal and Mählematter, Thomas, "A macroscopic loading model for time-varying pedestrian flows in public walking areas", Transportation Research Part B: Methodological 69 (2014), pp. 60–80.