Pedestrians and cars in urban networks: effect of various interaction strategies

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Introduction

Conventional wisdom holds that the interests of pedestrians and cars are diametrically opposed: what is good for pedestrians is not good for cars and vice versa. As cars became dominant in the first half of the 20^{th} century, this line of thinking led to a strict separation of cars and pedestrians, with crosswalks provided mostly at intersections. In the last 40 years, European cities have developed more pedestrian-friendly designs for minor streets, generally motivated by safety. The most pedestrian-friendly example is "shared space", originally developed in the Netherlands *(1)*. Recent theoretical work has shown that providing more crosswalks, up to and including shared space, could improve the car capacity of a street *(2, 3)*. The objective of this work is to study the theoretical implications of crosswalk type and placement in an urban street grid on pedestrian and car flows. Whether to prioritize cars or pedestrians in the design of urban streets remains a policy question. This research aims to inform the decision of policymakers and to show that there might be different designs that are beneficial to both modes.

Methodology

Three scenarios of crosswalk placement are considered and they are evaluated using performance metrics specific to pedestrians and cars. The base scenario represents how most signalized grid networks currently accommodate pedestrians: through crosswalks at the intersections. The midblock scenarios eliminate all crosswalks at intersections and replace them with one or two crosswalks which divide each link into two or three equal parts, respectively. It is assumed that pedestrians must cross with the green phase at intersection crossings and can cross without delay (forcing cars to yield) at midblock crossings.

For pedestrians, travel time is the performance measure. Travel times are deterministic in all three scenarios, though they depend on the time of departure in the base scenario due to the signal interactions. For cars, the performance measure is the shape of the macroscopic fundamental diagram (MFD), which predicts network performance for different combinations of vehicle density and pedestrian flow.

The scenarios are evaluated in a simulation model of a 4x4 grid network. Both streets and sidewalks loop around to avoid edge effects. From a car or pedestrian perspective, the grid is effectively infinite. Pedestrians are modeled by generating trips for all origin-destination (OD) pairs and departure times with respect to the common cycle of all traffic signals. Pedestrians choose their routes dynamically to avoid waiting at traffic signals. This heuristic matches real behavior *(4)*, since there are many equidistant paths in a grid network. Cars are loaded onto the network at the beginning and drive around for the duration of the simulation. They are modelled by Newell's car following *(5)*. To model pedestrian-car interactions, pedestrian arrivals at crosswalks are smoothed to create a survival function. Headways are then drawn from this distribution and cars must wait for a suitable gap. At each intersection, cars have a turning probability of 30%. Queues form when pedestrians block the path of turning vehicles, and a queue of 2 or more cars blocks through traffic.

Findings

The effect on pedestrians is found to depend on trip characteristics. The average trip length is 435m in the baseline scenario, 656m with one midblock crossing, and 585m with two midblock crossings. There is an increase in distance because some pedestrians have to go out of their way to reach the nearest crosswalk. All pedestrian nodes are located at street corners which introduced some bias, in reality many trips which start or end in the middle of a block would have detours in the baseline scenario. Some of the disbenefit from added distance is gained back because pedestrians do not have to wait at any crosswalk in the midblock scenarios. 25% of pedestrians in the one midblock scenario and 26% in the two midblock scenario experience a reduction in travel time. A further 10% in the one midblock scenario and 46% in the two midblock scenario have a difference in average travel time smaller than one cycle. An ordering of OD pairs from uniaxial to diagonal shows that the diagonal trips benefit most from midblock crossings. This finding makes sense because diagonal trips are able to use midblock crossings without adding distance. Pedestrians also benefit from the elimination of travel time variability. There are many OD pairs where the one and two midblock travel times are worse than the base scenario on average but better than a subset of departure times. Since people sometimes plan for a worst-case (e.g. 95^{th} percentile) travel time to avoid being late, the midblock scenarios could allow such pedestrians to leave later.

The macroscopic fundamental diagrams show that the midblock scenarios with low pedestrian flow (250 peds/h/link) are similar to the base case, but for higher pedestrian flows they begin to diverge. The base scenario has an advantage in terms of traffic flow at low densities, with freeflow speeds persisting until 25 veh/km. In contrast, pedestrian flow lowers traffic flow (and therefore speed) in the midblock scenarios even when vehicle densities are low. On the other hand, performance degrades more gradually in the midblock scenarios. At higher levels of pedestrian flow (above 1000 peds/hr/link), the midblock scenarios perform better than the base case above 25 veh/km. At lower levels of pedestrian flow, there is a modest performance boost above 45 veh/km. This performance boost delays jam density, which is reached at 45 veh/km in the base case, 55 veh/km in the one midblock case, and 70 veh/km in the two midblock case. The explanation is likely that the midblock scenarios avoid the problem of wasted green time that results when a queue of turning vehicles waiting for pedestrians blocks through traffic.

Conclusions

The finding that midblock scenarios increase average trip length is likely a consequence of the location of the origin/destination nodes. All of the nodes in this model are located at intersections. If nodes were present in other locations, trips starting and ending at these nodes would have to detour in the baseline case.

Midblock crossings eliminate conflicts between turning vehicles and pedestrians, but reduce the speed of through traffic and flatten the MFD. Whether this tradeoff is worthwhile depends on the car density and pedestrian flow.

This paper used sharply contrasting scenarios to isolate the effect of crosswalks at intersections and midblock locations. For real-world implementation, it is probably better to combine the two. Adding midblock crosswalks to an existing network like the base scenario would divert diagonal trips away from intersections, reducing conflicts with turning vehicles, without inconveniencing pedestrians that want to cross at intersections.

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