Development of Link Performance Functions in High Pedestrian–Vehicle Interaction Environments

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Link performance functions are part of the foundation of conducting traffic assignment analysis on a given network; insofar that past literature has provided examples of these kinds of functions being used as the basis for such. High pedestrian–vehicle interaction road environments, such as shared space, are now becoming a more investigated topic in roadway design in suburban environments with low or medium traffic flows. Through determining what kind of relationships exist between a control environment and those implementing these kinds of road designs, it is possible to not only create a link performance function by non-linear least squares regression for roads with these implementations, but to also view such implementations affect the travel time along such. This work provides the results of the implementation of such environments in a simulation, and demonstrates how it compares to the results derived from a control environment built in the same simulation.

Key Words: *link performance, traffic assignment, pedestrian-vehicle interaction, low-medium traffic flow, simulation, shared space*

1. Objective

(1) Background

a) Link Performance Functions

Link performance functions, as per Patriksson[1)], arose from the need for an algorithm that compares weights more than just an elementary shortest-path or all-or-nothing algorithm. These functions, essential in determining further characteristics of traffic assignment on a link, effectively act as a means of displaying the correlation between performance and vehicle flows. As further detailed by Patriksson[2)], they most often take the form of either non-linear natural exponential functions such as, $y = t_a \times e^{(\frac{f_a}{c_a} - 1)}$, or forms like $y = t_a \times 2^{(\frac{f_a}{c_a} - 1)}$, where y represents a dependent variable, f_a represents the traffic flow, t_a represents a given travel time, c_a represents the practical limit to flow before travel times have exponential changes.

b) Concept of Shared Space

The concept of shared space is a novel paradigm in the realm of traffic engineering that was designed in order to create a system where pedestrians could maintain similar utility to slow moving automobiles, in a space that is equally "shared" between those two such parties. Previous authors[3)] have defined some of the features of a shared space; which are either commonly found therein, and or are mentioned in German literature as occurring in *Begegnungszone*: where pedestrians are likely to encounter and interact with vehicles, hence the English meaning word being approximately "encounter zone". These defined features include a lack of center lane marking, low-elevation curbs, a lessened amount of parking spaces, a lack of physical boundaries, a lack of traffic control devices, and a road design based on natural guidance.

Due to the lack of road marking and traffic control devices, both pedestrian and driver are more likely to exercise greater caution, hence minimizing the potential for road conflicts between the users who "share" the space[3], making this type of road design ideal for areas where there high pedestrian traffic.

(2) Implementations in Previous Literature

In past literature there have been forays into the study of this type of interaction between vehicles and pedestrians, including in areas that exhibited the characteristics of shared space. However, these mostly focused on the routing problems faced by agents on an individual level rather than on link performance or impact on travel times.[4) 5)]

Furthermore, while previous literature such as István & Zsuzsanna[6] measurse the effects of the implementation of a crossing on the vehicle travel time across a link, it does not give a full picture of what would occur in areas such as shared spaces, where pedestrians had the ability to cross freely, nor does it provide link performance functions. As such, the objective of this study is to construct link performance functions, of a form similar to that seen in Patriksson[2] through regression analysis of microsimulated data.

2. Method

(1) Building a Simulation Environment

In order to measure the link performance of an area having free crossing pedestrians, which is one of the key characteristics of shared space, the first step was to develop a simulation environment which could simulate such conditions to at least a reasonable degree. Utilizing VISSIM, a traffic microsimulation software; a simulation environment with two four-way intersections, both in signalized and non-signalized configurations was developed (Detailed in **Figure 1**).

a) Configurations

There were three configurations thereof: one control, one with an unsignalized zebra crossing in the middle of the main link, and one which attempts to simulate the freedom of shared spaces, with a series of 11, 1.5-meter crossing spaces across the middle of the main link. Across all environments, all other road/lane widths were kept to a standard 3.5 meters, and traffic priority was given to the road going through the center. This road had variable traffic flows between 250 and 600 vph (vehicles per hour). The other roads as part of the intersection had a static flow of 100 vph.

There were two pedestrian inputs on six pedestrian areas, one on each side of the main through road, these pedestrians would pathfind to any of the other five pedestrian areas. The pedestrian traffic flow varied between 100 and 250 pph (pedestrians per hour).

b) Simulation Process and Outputs

The simulation process was conducted 32 times across all vehicle traffic densities for all possible pedestrian traffic densities for a total of over 5000 unique simulations.

After outputting and taking note of vehicle travel times at these different traffic flows, the results were plotted to scatter plots, with points demonstrating the vehicle flow – time, or $f_a - t_a$, relationship across four different pedestrian traffic densities.

(2) Data Analysis

The data that has been gathered thus far is mostly limited to that heretofore explained. As of this moment, basic comparisons between changes have been able to be established between the measurements obtained from both the control and test environments. Such details can be seen in **Table 1** and **Table 2**, and give a basic overview as to the changes in travel times upon implementation of the experimental road designs (either the single zebra crossing, or the pseudo-shared space).

A more detailed analysis, including the development of link performance functions, through using non-linear regression analysis and curve fitting techniques, specifically non-linear least squares, is

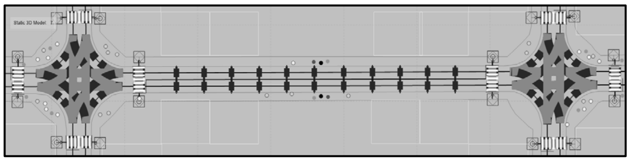

Figure 1- Environment with Multiple Crossings

Table 1- Travel Time Comparison between pseudo-shared space and a Control Intersection at 250 Pedestrians per Hour at a Signalized Crossing

Traffic Flow (V/H)	Travel time (s) Control	Travel time (s) Exp.[Note 1)]	Percent Change
250	30.76	31.61	2.69%
275	31.30	31.97	2.10%
300	31.92	32.66	2.28%
325	32.39	33.33	2.84%
350	33.06	33.96	2.65%
375	33.27	34.69	4.09%
400	35.02	36.20	3.27%
425	35.32	36.79	4.00%
450	37.50	38.67	3.03%
475	38.56	42.23	8.70%
500	40.39	45.59	11.41%
525	42.50	47.12	9.82%
550	45.46	49.72	8.58%
575	49.45	53.64	7.82%
600	53.76	59.94	10.31%

Table 2- Travel Time Comparison between a Single Zebra Crossing and a Control Intersection at 250 Pedestrians per Hour at a Signalized Crossing

Traffic Flow (V/H)	Travel time (s) Control	Travel time (s) Zebra[Note 2)]	Percent Change
250	30.76	30.83	0.23%
275	31.30	30.96	-1.10%
300	31.92	31.56	-1.12%
325	32.39	32.17	-0.67%
350	33.06	32.31	-2.32%
375	33.27	32.75	-1.59%
400	35.02	33.78	-3.66%
425	35.32	34.74	-1.67%
450	37.50	35.82	-4.69%
475	38.56	37.80	-2.00%
500	40.39	38.37	-5.26%
525	42.50	39.73	-6.96%
550	45.46	42.34	-7.36%
575	49.45	45.25	-9.27%
600	53.76	50.10	-7.31%

planned and intended to serve as the main result.

This function would therefore be intended to provide a basis for development of a more in-depth traffic assignment model for such networks.

3. Interim Results and Discussion

(1) Interim Results

Overall, the results yielded, as seen in the following **Figure 2**, demonstrate some expected behaviors, namely that intersection signal control maintains a strong influence on the results across all other parts of the simulation. For instance, it appears that the presence or absence of signal control determines if the implementation of free crossing induces a detrimental increase to the overall travel time, this is something that remained true in testing both the single zebra crossing and the shared space design.

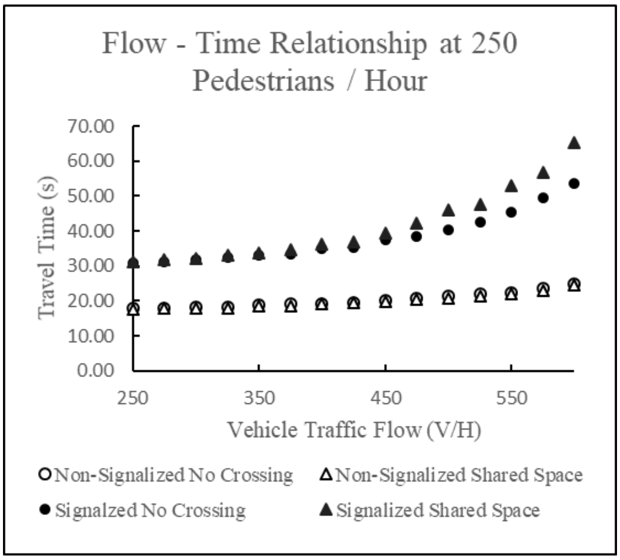

Figure 2 - Flow – Time Relationship Scatterplot

The apparent lack of any real change between the travel times of the control and experimental intersections in the non-signalized configurations means that it is possible that signal control could be the factor which determines if the implementation of areas like shared space could lead to a negative increase in time (t_a) or in practical link capacity (c_a).

(2) Discussion

The results gathered so far provide two important points for this research going forward. The first of which being the aforementioned effect of signal control on whether or not the implementation of the pseudo-shared space road design would have a negative effect on the overall travel times, in that their critical capacity is lower regardless of any type of road implementation. This is especially notable given that these kinds of high interaction road designs are often found in suburban areas that have traffic signaling only at the junctions of major roads.

More importantly, these preliminary results also demonstrate the applicability of non-linear curve fitting to the kinds of high-interaction road implementations meant to mimic the constant interactions seen in shared spaces, like those developed through the simulation environment.

With the practicality of measuring the flow–time relationship of high-interaction road implementations guaranteed, it should therefore be possible to develop link performance functions for such environments and possible begin to use them in traffic assignment models.

NOTES

Note 1) Referring to the pseudo-shared space environment

Note 2) Environment with a single Zebra crossing

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