Modeling of Pedestrian Midblock Crossing Speed with Respect to Vehicle Gap Acceptance

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ABSTRACT

When reconstructing pedestrian impacts, it is important to identify the time to impact available. One of the assumptions when calculating the time to impact is the speed of the pedestrian. Although the majority of pedestrian collisions (including fatalities) occur midblock, most of the research conducted for pedestrian speeds is based on pedestrians travelling in a controlled environment (i.e. crosswalks, sidewalks, etc.).

When a pedestrian is crossing midblock or "jay-walking," there may be a sense of urgency for the pedestrian due to approaching vehicles. The sense of urgency is dependent upon the proximity of vehicles that are approaching, and/or the lane of the approaching vehicle with respect to the pedestrian. In this study, 304 pedestrian movements were analyzed, as they crossed midblock across traffic. Pedestrian speeds in relation to the accepted gap and the positioning of approaching vehicles were analyzed.

INTRODUCTION

The distance travelled by a struck pedestrian is typically readily available to a reconstructionist, as the area of impact or the pedestrian's position within a particular lane is commonly known. The crossing speed of the pedestrian, which is generally assumed, is the focus of the research presented in this study. Once the speed is determined and the time to impact is calculated, a reconstructionist can then determine if a collision was potentially avoidable.

The majority of the related available research measured the speed of pedestrians who were travelling in an area where there is no conflicting vehicle traffic, such as within crosswalks [1,2,3,4,5], or closed course environments [6-7]. The data collected would typically be separated into walking, jogging, and running speeds and segregated by age, gender, group size, or some other factor that was specifically being examined by the author(s). In this study the midblock movement of pedestrians was compared to the gap between the pedestrian and the primary hazard vehicle (the vehicle which posed the highest risk of colliding with the pedestrian). In addition, the relationship between the speed of the pedestrian and the lane in which the primary hazard vehicle was positioned was also analyzed. These specific relationships have not been examined or assessed in any other published literature, and are the focus of this paper.

During this study hundreds of naturalistic pedestrian midblock movements were captured and studied. None of the pedestrians involved in this study were aware of the study being conducted, nor were any of the vehicles along the roadway.

This research is most useful in the absence of reliable statements or if the pedestrian saw the vehicle but believed that they had enough time to cross, before being struck. The statistics and models presented in this paper offer quantifiable data and trends regarding how vehicle proximity (i.e. vehicle gap) influences pedestrian crossing speed, and hence the time to impact.

TESTING

Scene Description

The test data was collected in front of a community centre located at 1245 Eglinton Avenue West, in Mississauga, Ontario. Eglinton Avenue West ran east-west and at this location was straight and level, with three through lanes in each direction. There was also a single lane dedicated to left turning traffic between the eastbound and westbound lanes. The curb lanes, centre lanes, and passing lanes in each direction were about 4.3 m, 3.4 m, and 3.7 m wide respectively. The posted speed limit was 60 km/h.

There was an average of about 25 and 23 through (non-turning) vehicles per minute during the data collection period within the tested area on April 17 and April 22, 2011 respectively. On April 13, 2012, traffic was heavier, especially in the westbound lanes; the average was about 41 through vehicles per minute during the data collection period within the tested area. Figure 1 illustrates the area of the test.

Figure 1. Easterly view of Eglinton Ave. West near the community centre, taken from the middle of the road.

Date/Time of Data Collection

Data was gathered on three separate dates; April 17, 2011, April 22, 2011, and April 13, 2012, between 4:00 p.m. and 7:00 p.m. These specific days and times were chosen because they coincided with a particularly busy time at the community center when parking overflow was expected. This would cause pedestrians to park on the south side of Eglinton Avenue West at a plaza parking lot, and cross midblock to the community center located on the north side of the roadway.

Specifically, April 17, 2011 and April 22, 2011 corresponded to Palm Sunday and Good Friday on both the Julian and Gregorian calendars. Traffic was lower on these dates as they were non-business days. April 13, 2012 corresponded to Good Friday on the Julian calendar only; this was a normal business day and traffic flow was notably higher than the other two test dates.

Equipment Setup

High definition video cameras (30 frames per second) were used to capture the data. On the first day of testing (April 17, 2011), a digital camera was placed on the median located east of the test area, facing west. This camera's view was perpendicular to the north-south path of crossing pedestrians, and parallel to the east-west path of vehicles. The position of the camera on April 17, 2011 is illustrated in Figure 2.

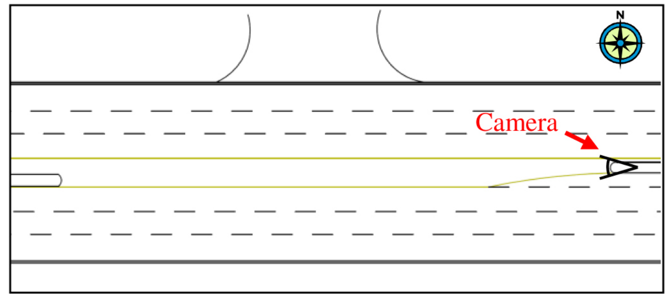

Figure 2. View of the location of the camera on April 17, 2011.

On April 22, 2011, two cameras were used. The first camera was placed in the same position as on April 17, 2011, facing west, located on the median east of the test area. The second camera was positioned on the south side of the road, facing north towards the community center. The positions of the cameras on April 22, 2011 are illustrated in Figure 3.

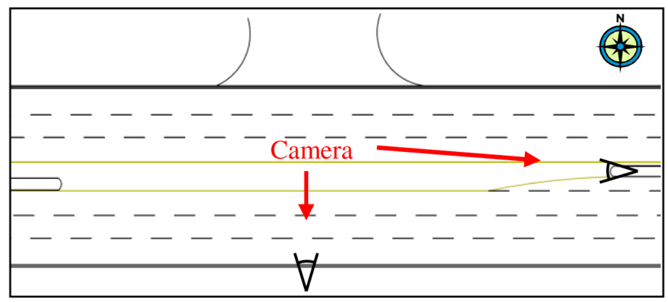

Figure 3. View of the location of the cameras on April 22, 2011.

On April 13, 2012, two cameras were also used. The first camera was placed on the east median facing west (similar to the other two days of testing). The second camera was placed on the median west of the test area, facing east. The positions of the cameras on April 13, 2012 are illustrated in Figure 4.

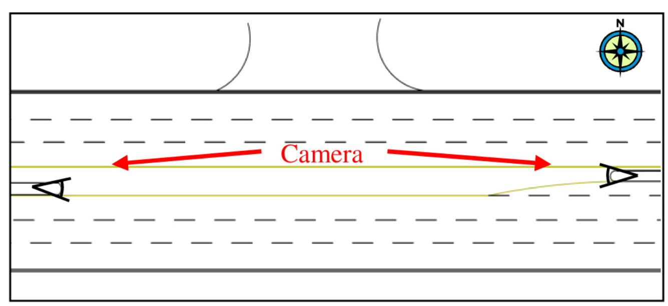

Figure 4. View of the location of the cameras on April 13, 2012.

Figure 5 illustrates the eastbound facing camera's view of the test area, as set up on April 13, 2012.

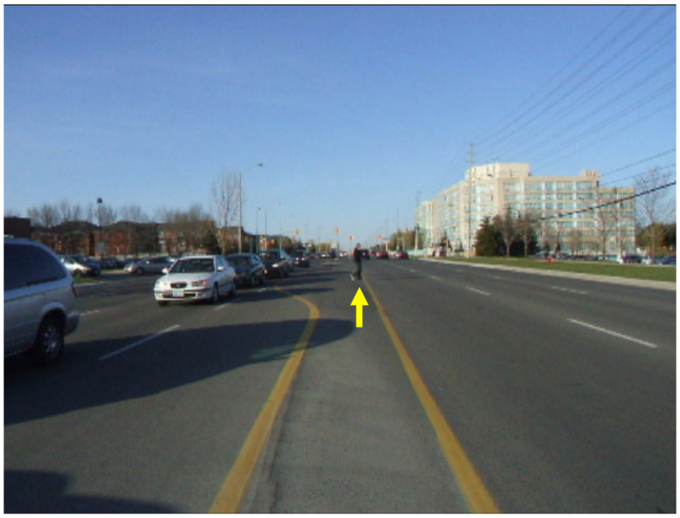

Figure 5. Screen capture illustrating a southbound pedestrian about to cross the eastbound lanes.

Compiling the Data

Pedestrian Speed

Video analysis of the recordings was performed to calculate the pedestrian speeds. Only adult pedestrian crossings were analyzed. In cases where a group of pedestrians crossed together each pedestrian in the group was analyzed individually. For each pedestrian crossing midblock, the time in which s/he crossed a known distance was determined. The eastbound through lanes were treated as one segment, and the westbound through lanes were treated as a second segment. The pedestrian movements in the shared left turn lane in the middle of the roadway were disregarded, as the traffic volume was lower and vehicles were travelling at significantly lower speeds through this lane. In other words, the sense of urgency for the pedestrians crossing this lane would have been significantly reduced. Each segment (which was composed of a curb lane, a middle lane, and a passing lane) was about 11.4 m wide. Figure 6 illustrates the test area.

The time in which a pedestrian crossed the eastbound and westbound through lanes was the difference between the time stamp of when they first entered the lanes and the time stamp when they exited the lanes. Specifically, the time stamps were entered for when the pedestrian's foot was flat on the pavement of the lane (as they entered) and when their foot was flat on the curb/centre median/designated left turn lanes (as they exited). The pedestrian's average speed was the distance travelled (which was 11.4 m in either direction) divided by the time (the difference between the time stamp at entry and the time stamp at exit). The entries that were not included in this study are as follows:

- Pedestrians that stopped at any point within the through lanes (i.e. began to cross, and then stopped in either the near lane or middle lane to wait for traffic to pass).

- Pedestrians that did not cross in a northerly/southerly direction (i.e. pedestrians that crossed in a diagonal manner).

- Pedestrians who were not visible in the videos as to when they entered/exited a segment (the eastbound/westbound lanes), such as when vehicles obstructed the camera's view of a pedestrian's foot as s/he enters/exits a segment (the eastbound/westbound lanes).

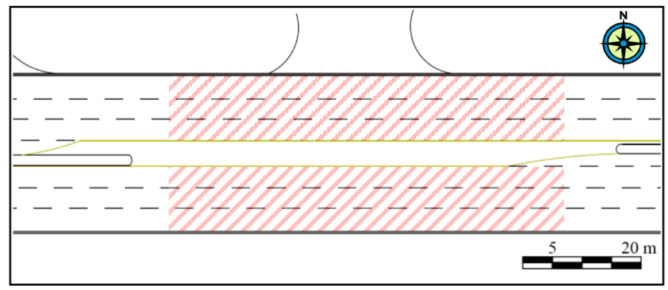

Figure 6. Scale diagram of the test area. The dashed red area outlines the two segments over which pedestrian midblock movements were recorded and analyzed.

There were 242 different pedestrians captured and analyzed in this study, as they crossed the two segments of the roadway (the westbound through lanes, and the eastbound through lanes). The pedestrian's movements through the eastbound lanes were considered a separate entry from their movements through the westbound lanes. For some pedestrians their movement through one segment was excluded due to the reasons listed above. This resulted in a total of 304 separate entries based on 242 different pedestrians.

Gap

Gap is the time difference between when a pedestrian entered the lanes, and when the primary hazard vehicle crossed the pedestrian's path behind him/her.

The primary hazard vehicle was the vehicle which posed the highest risk of colliding with the pedestrian. The primary hazard vehicle was not necessarily the vehicle which was in the closest lane to the pedestrian, or the vehicle which was the shortest distance away. This concept is clarified below.

Figure 7 illustrates a hypothetical case in which a pedestrian is walking in a northerly direction across the eastbound lanes as s/he is being approached by two eastbound vehicles. As illustrated, the vehicle that is in the lane furthest from the pedestrian (the yellow vehicle) is a shorter east-west distance away from the pedestrian than the vehicle that is in the closer lane (the blue vehicle).

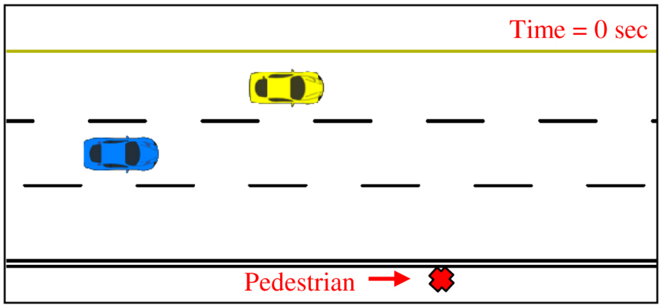

Figure 7. Illustration of a northerly pedestrian about to cross the eastbound lanes (not to scale).

Figure 8 represents some period in time after Figure 7, and illustrates that the yellow vehicle is not the primary hazard vehicle as it passes in front of the pedestrian and would not pose a risk of colliding with him/her. The primary hazard vehicle in this case would be the blue vehicle.

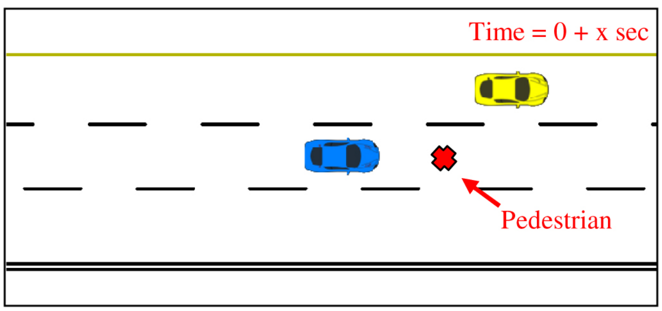

Figure 8. Illustration of a northerly pedestrian crossing the eastbound lanes (not to scale).

Figure 9 illustrates another hypothetical case in which a pedestrian is walking in a northerly direction across the eastbound lanes as s/he is approached by two eastbound vehicles. As illustrated, the two approaching vehicles are travelling side by side an equal east-west distance away from the pedestrian.

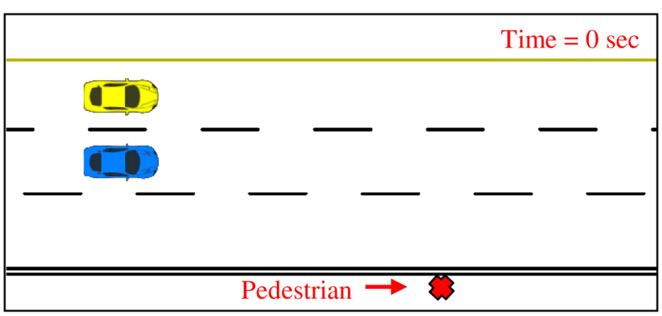

Figure 9. Illustration of a northerly pedestrian about to cross the eastbound lanes (not to scale).

Figure 10 represents some period in time after Figure 9, and illustrates that the primary hazard vehicle is the yellow vehicle. This is because the pedestrian would require more time and distance to clear the path of the yellow vehicle and hence it posed the highest risk of colliding with him/her.

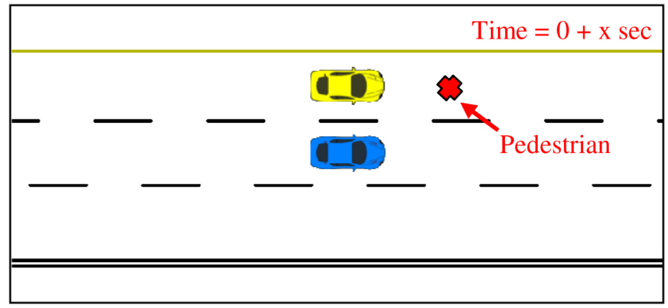

Figure 10. Illustration of a northerly pedestrian crossing the eastbound lanes (not to scale).

The gap entries that were not included in this study are as follows:

• When traffic was gridlocked; this is when the vehicles were travelling significantly slower than the posted speed limit, or even stopped.

• When the vehicle slowed down significantly or stopped for pedestrians.

Note that for this portion of the data, the video recordings from the cameras that were on the center medians were used because these cameras were facing perpendicular to the pedestrian movements. The time stamps determined in these videos were validated with the time stamps from the videos captured by the camera that was positioned on the south curb, perpendicular to the path of the vehicles.

The videos were viewed frame-by-frame and the time was recorded when a pedestrian entered and exited the eastbound/westbound lanes. The time when the primary hazard vehicle crossed each pedestrian's path was also recorded. Note that these data entries were performed independently by two individuals and some of their entries were compared to ensure consistency in the data entry process.

The speed calculation method was validated by comparing it to speeds recorded by a high resolution GPS logger. Specifically, a test volunteer crossed the road holding a GPS logger, while being videotaped. The crossing speed of the volunteer was assessed based on analysis of the video and the speeds recorded by the GPS logger. The speeds from the two methods were within approximately 0.05 m/s. It should be noted that the data from this test volunteer was not included in our observations described below, only naturalistic/unaware pedestrian observations were included.

OBSERVATIONS

During the test dates, pedestrians of various ages were observed crossing the roadway. Some pedestrians elected to walk across the roadway, while others elected to jog. Other

Table 1. Summary of observations

Observations (All Pedestrians)		
	Pedestrian Speed	Gap
Average	1.84 m/s	15.69 sec
Median	1.69 m/s	11.36 sec
Standard Deviation	0.58 m/s	13.10 sec
Minimum	0.97 m/s	2.54 sec
Maximum	4.58 m/s	86.45 sec
Count	304	304

pedestrians would partially jog across the roadway and then run, or a different combination of these movements. It was observed that traffic on the roadway had an effect on pedestrian behavior; however, there were exceptions. For example, there were pedestrians who ran across the road when there were no vehicles in close proximity, and there were some pedestrians who casually walked across the road despite vehicles that were in close proximity. The observations are summarized in Table 1. It should be noted that the two values in each row of the table are not correlated to the same pedestrian; for example the maximum speed noted in Table 1 (4.58 m/s) was actually related to a gap of 4.79 seconds, not a gap of 86.45 seconds which may be incorrectly inferred from the table.

Considering that the test roadway was relatively large (three westbound through lanes and three eastbound through lanes, with a dedicated left turn lane separating the eastbound lanes and the westbound lanes), the observed pedestrians were sorted into three groups for modeling:

1. Pedestrians who encountered the primary hazard vehicle in the near lane (i.e. pedestrians who accepted a near-lane gap)

2. Pedestrians who encountered the primary hazard vehicle in the second (middle) lane (i.e. pedestrians who accepted a middle lane gap)

3. Pedestrians who encountered the primary hazard vehicle in the third (far) lane (i.e. pedestrians who accepted a far lane gap)

Tables 2-3 summarize the descriptive statistics of these three groups.

Table 2. Summary pedestrian speed observations, with respect to the lane of the primary hazard vehicle

	Vehicle Lane		
	Near	Middle	Far
Average Pedestrian Speed (m/s)	1.71	1.83	1.99
Median Pedestrian Speed (m/s)	1.59	1.70	1.78
Standard Deviation (m/s)	0.45	0.55	0.70
Minimum Speed (m/s)	1.02	0.97	0.98
Maximum Speed (m/s)	3.48	4.09	4.58
Count	103	103	98

Table 3. Summary gap acceptance, with respect to the lane of the primary hazard vehicle

	Vehicle Lane		
	Near	Middle	Far
Average Pedestrian Gap (sec)	14.58	18.25	14.16
Median Pedestrian Gap (sec)	10.79	12.26	11.96
Standard Deviation (sec)	11.30	17.21	8.93
Minimum Gap (sec)	2.54	3.17	4.79
Maximum Gap (sec)	60.36	86.45	51.93
Count	103	103	98

Figures 11,12,13 illustrate the observations described in Tables 2-3 above.

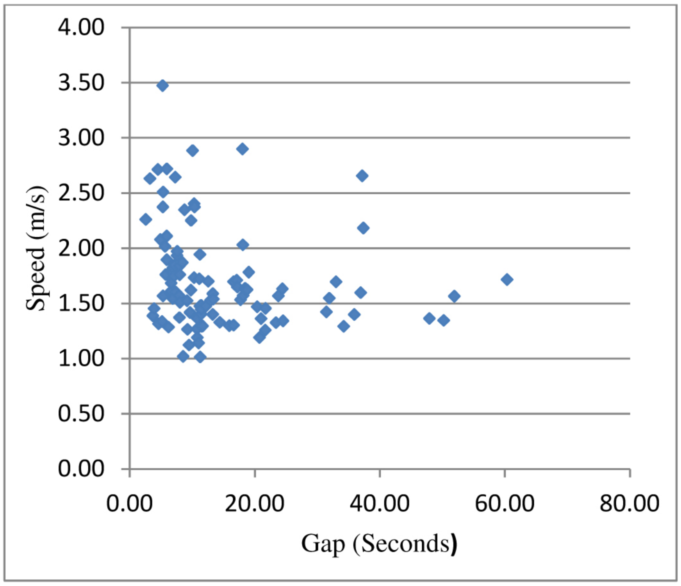

Figure 11. Observations of pedestrians who accepted a near-lane gap

An observation that was made while analyzing this data was that the speed of pedestrians appeared to be affected by the lane of the approaching primary hazard vehicle. For example, the average speed of pedestrians when the primary hazard vehicle was in the near (1st) lane was 1.71 m/s, while the average speed of pedestrians when the primary hazard vehicle was in the middle (2nd) lane was 1.83 m/s. Furthermore, the average speed of pedestrians was 1.99 m/s when the primary hazard vehicle was in the far (3rd) lane. This trend is illustrated in Figure 14.

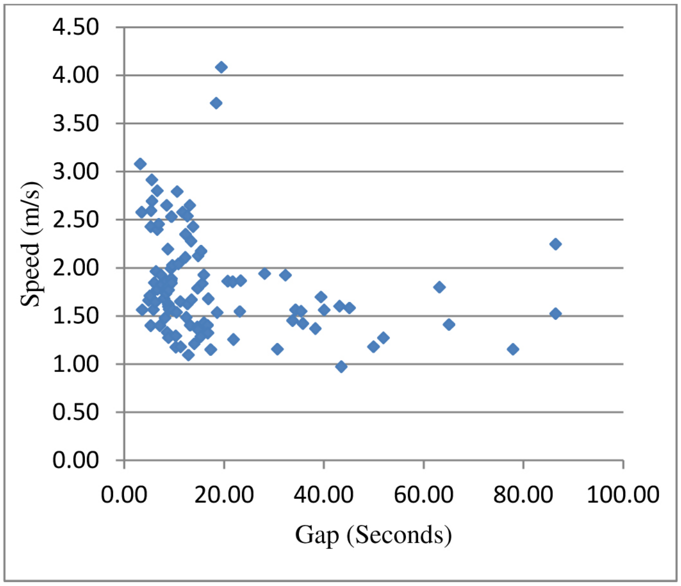

Figure 12. Observations of pedestrians who accepted a middle-lane gap

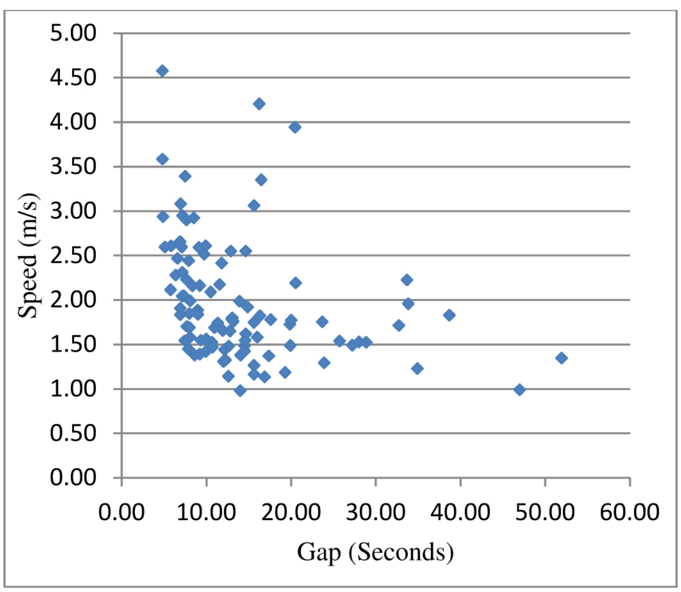

Figure 13. Observations of pedestrians who accepted a far-lane gap

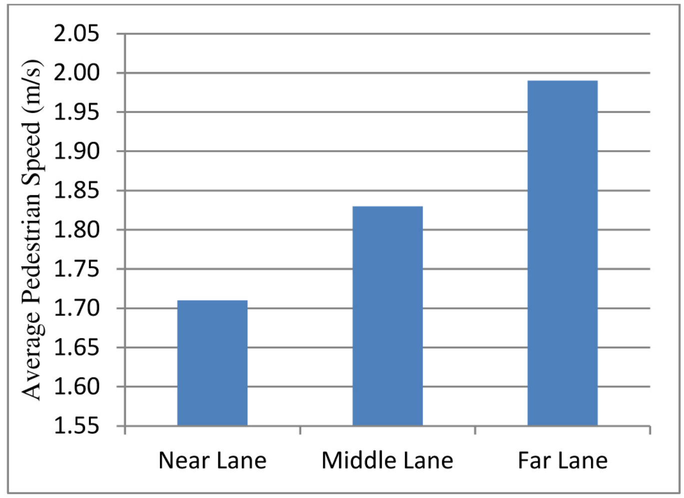

Figure 14. Average pedestrian crossing speed versus lane of approaching primary hazard vehicle

Data Modeling

Figure 15 illustrates the plot of all 304 data entries, relating speed with respect to gap.

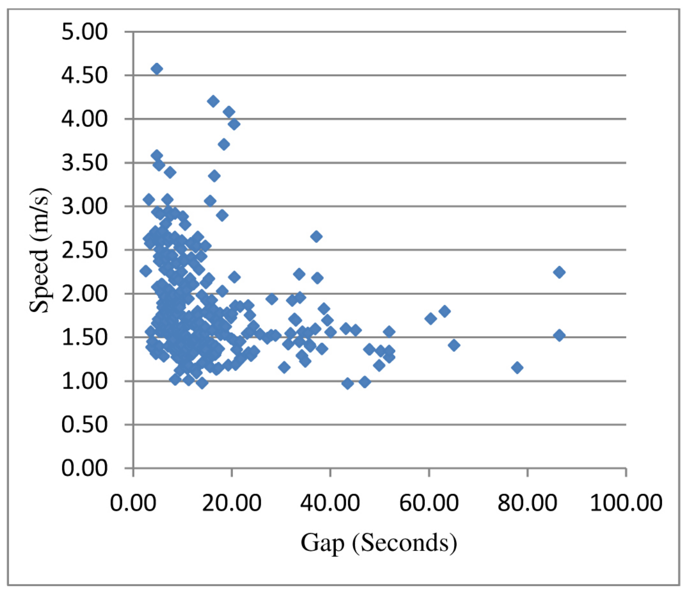

Figure 15. Overall observations of pedestrian crossing speed versus accepted gap (all lanes included).

Visually, the data in Figure 15 indicated that when the gap was approximately 20 seconds or greater, the proximity of the vehicle had little effect on the crossing speed of the pedestrian. Where the gap was less than about 20 seconds, the speed of the pedestrian would be influenced by the primary hazard vehicle's proximity. As the gap decreased, pedestrians were observed, in general, to travel faster. However, there were certain outliers in our observations where subjects elected to run across the roadway when there were no vehicles in close proximity. For the purposes of our data modeling analysis we excluded outliers; pedestrians who had a crossing speed of over 2.5 m/s with a gap of over 15 seconds. These excluded subjects appeared to have elected to jog, when there were no vehicles in close proximity (further than the closest signalized intersection). When Figure 15 is reformatted to only include pedestrians who accepted a gap of less than 20 seconds, it can be observed that pedestrian crossing speed was quicker when the gap was short, and pedestrian crossing speed trended towards a speed of about 1.5 m/s as the gap increased (see Figure 16). The outliers described above are clearly identifiable in Figure 16, which included 242 data points.

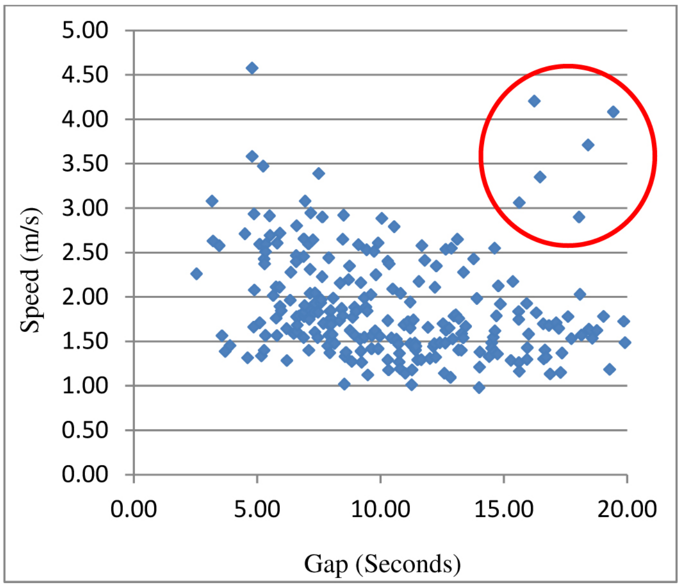

Figure 16. Overall observations of pedestrian crossing speed versus accepted gap (all lanes included), up to a gap of 20 seconds. The outliers (with a speed of more than 2.5 m/s and a gap greater than 15 sec) are highlighted in red.

The data was analyzed by breaking it down into five subsets to identify potential trends as follows:

1. Gap acceptances of less than 5 seconds
2. Gap acceptances of between 5 and 10 seconds
3. Gap acceptances of between 10 and 15 seconds
4. Gap acceptances of between 15 and 20 seconds
5. Gap acceptances of greater than 20 seconds

Table 4 illustrates the descriptive statistics of these five subsets. It should be noted that the outliers in our observations (speed of over 2.5 m/s, gap of over 15 sec) were not included in these breakdowns. There were a total of eight outliers that were excluded from our 304 observations (six exclusions had gap acceptances of 15 to 20 seconds, two exclusions were above gaps of 20 seconds).

Table 4. Speed observations separated by ranges of gap

	< 5 sec	5 to 10 sec	10 to 15 sec	15 to 20 sec	> 20 sec
Average (m/s)	2.42	1.97	1.70	1.56	1.55
Median (m/s)	2.42	1.85	1.55	1.58	1.53
Std Dev (m/s)	0.94	0.50	0.46	0.26	0.29
Min (m/s)	1.32	1.02	0.98	1.14	0.97
Max (m/s)	4.58	3.48	2.89	2.18	2.25
Count	14	114	75	33	60

The data in Table 4 above illustrates that the average speed of pedestrians was faster when the gap was short, and the average speed decreased as the gap increased. When the gap is between 15 and 20 seconds, the average pedestrian speed is similar to when the gap is over 20 seconds. This indicated that the influence of vehicle proximity appeared to be diminished when the gap was somewhere between 15 and 20 seconds. It is noteworthy that the average speed of pedestrians in this study when the gap was over 20 seconds was 1.55 m/s; this speed is consistent with "normal" adult walking speed found in other research [1,2,3,4,5,6,7,8,9,10,11,12,13]. Therefore, the data in Table 4 indicated that as the gap increased pedestrians would trend towards "normal" walking speeds.

Trend analysis was performed to determine the relationship that best modeled a pedestrian's crossing speed versus gap, for the data entries where the gap was less than 20 seconds. The upper limit of 20 seconds was chosen to include observations where the data was tending towards "normal" walking speeds. The outliers in the data (walking speed of over 2.5 m/s with gaps of over 15 seconds) were excluded for the purposes of this model.

The most significant relationship found was a natural exponent function, as shown in Equation (1).

$$speed = B + A \cdot e^{-C \cdot gap} \tag{1}$$

The A, B and C constants for the combined data set are offered in Table 5, where gap is in seconds, and speed is in units of meters per second (m/s). The combined data set includes pedestrians who accepted a near lane gap, a middle lane gap, and a far lane gap. Power functions, linear functions and polynomial functions were also examined; however, the natural exponent function was found to be the most suitable to represent this research, as the data trended towards the "normal" walking speed of pedestrians, the "B" coefficient in the function.

Table 5. The constants and coefficients for the natural exponent function model to determine pedestrian speed from accepted vehicle gap, for the combined data set of pedestrians who accepted a gap in any lane of less than 20 seconds.

	A	B	C	RMSE
Combined Data Set	1.72	1.47	0.16	0.49

The statistical breakdown for this combined data set is summarized in Table 6 (outliers excluded).

Table 6. Summary of pedestrian observations with gap acceptances of less than 20 seconds (outliers excluded)

Observations (All Lanes, Gap < 20 seconds)	
Average Pedestrian Speed	1.86 m/s
Standard Deviation	0.54 m/s
Count	236

Figures 17 and 18 illustrate the above described natural exponent model.

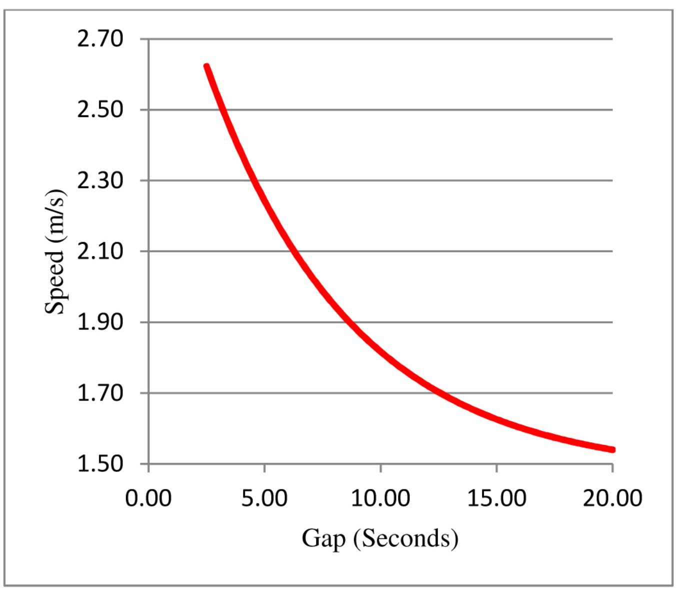

Figure 17. Pedestrian crossing speed versus vehicle gap model, for the combined data set of pedestrians who accepted a gap of less than 20 seconds.

Models were also derived for pedestrians who accepted a near lane gap, pedestrians who accepted a middle lane gap, and pedestrians who accepted a far lane gap. The upper bound of the gap included in these models was also chosen to be 20 seconds for consistency. These model coefficients are described in Table 7.

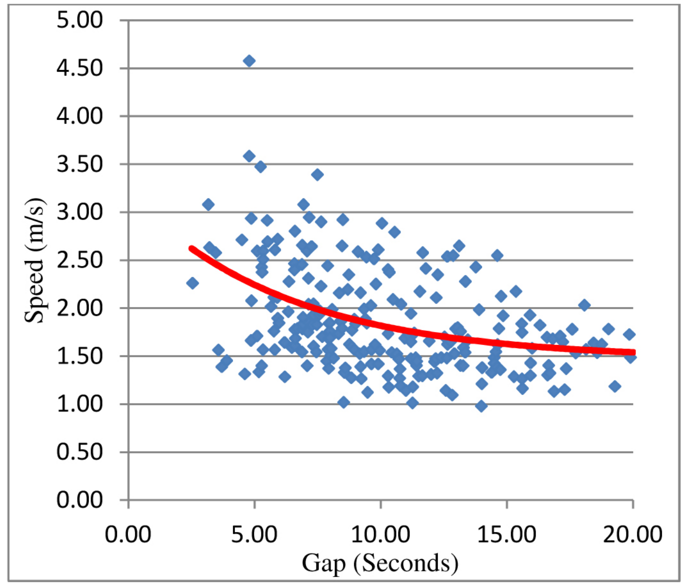

Figure 18. Pedestrian crossing speed versus vehicle gap data, with the model overlay, for the combined data set of pedestrians who accepted a gap of less than 20 seconds.

Table 7. The constants and coefficients for the natural exponent function model to determine pedestrian speed from accepted vehicle gap, based on the vehicle's lane in relation to the pedestrian's initial position

	A	B	C	RMSE
Near Lane Gap	1.46	1.51	0.23	0.43
Middle Lane Gap	2.03	1.67	0.26	0.49
Far Lane Gap	4.20	1.44	0.22	0.49

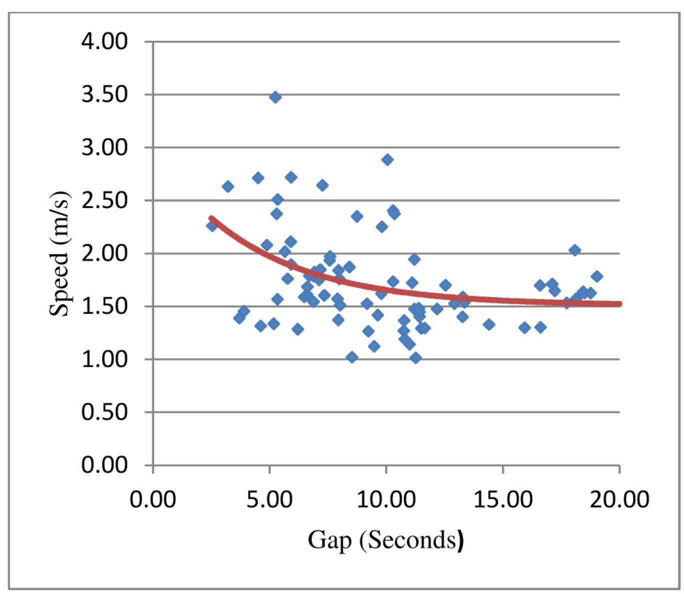

Figure 19. Pedestrian crossing speed versus vehicle gap data with model overlay, for the pedestrians who accepted a near lane gap of less than 20 seconds.

Figure 19 illustrates the plot of walking speed versus accepted near lane gap data (81 data points), with the model overlaid.

Figure 20 illustrates the plot of walking speed versus accepted middle lane gap data (76 data points), with the model overlaid.

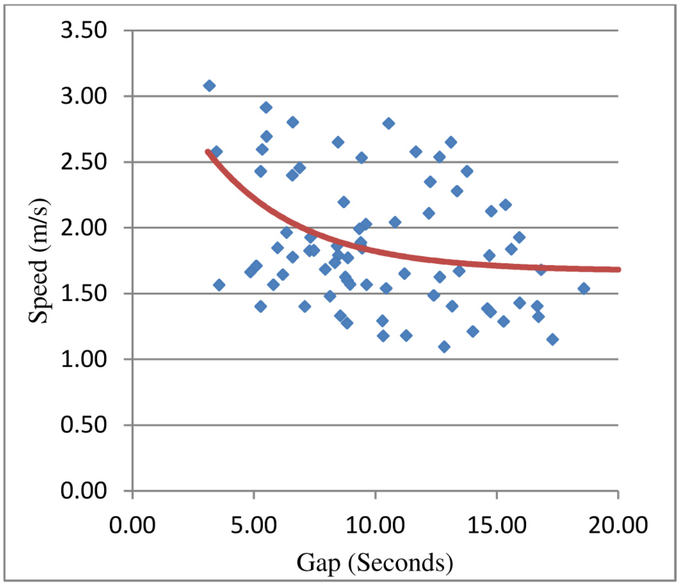

Figure 20. Pedestrian crossing speed versus vehicle gap data with model overlay, for the pedestrians who accepted a middle lane gap of less than 20 seconds.

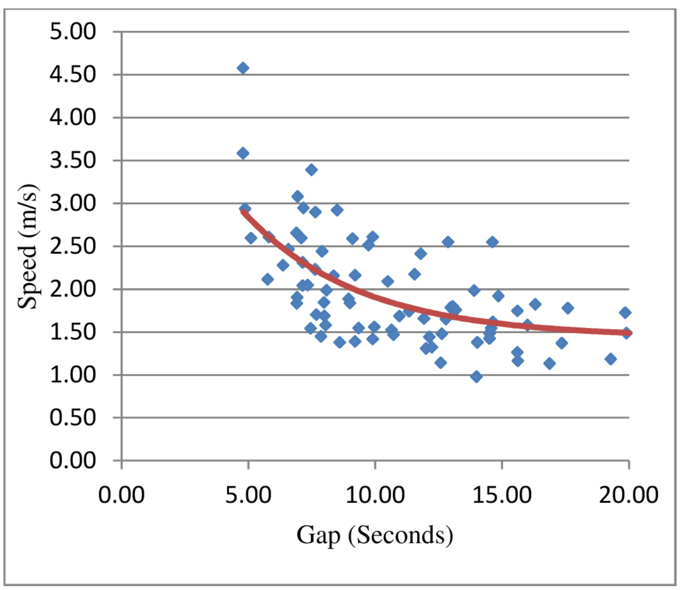

Figure 21. Pedestrian crossing speed versus vehicle gap data with model overlay, for the pedestrians who accepted a far lane gap of less than 20 seconds.

Figure 21 illustrates the plot of walking speed versus accepted far lane gap data (79 data points), with the model overlaid.

These three models (illustrated in Figures 19,20,21) show the most significant difference when the accepted gap is less than 10 seconds. For comparative purposes the three above models are illustrated together in Figure 22.

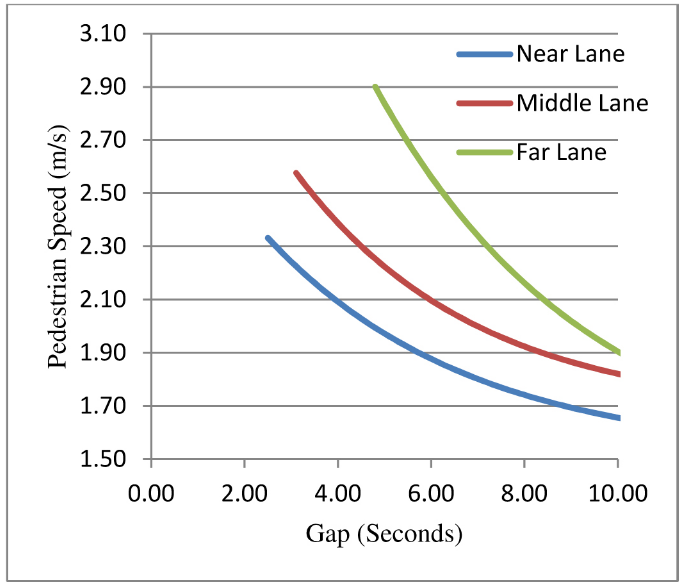

Figure 22. Pedestrian crossing speed versus vehicle gap models, divided based on the approach lane of the primary hazard vehicle.

The statistical breakdown of the data for which the above models are based upon is summarized in Tables 8,9,10. Note that the outliers noted previously herein are not included in these breakdowns.

Table 8. Summary of the pedestrians who accepted a near-lane gap of less than 20 seconds

Observations (Near Lane Gap < 20 seconds)	
Average Pedestrian Speed	1.74 m/s
Standard Deviation	0.46 m/s
Count	81

Table 9. Summary of the pedestrians who accepted a middle-lane gap of less than 20 seconds

Observations (Middle Lane Gap < 20 seconds)	
Average Pedestrian Speed	1.87 m/s
Standard Deviation	0.49 m/s
Count	76

Table 10. Summary of pedestrians who accepted a far-lane gap of less than 20 seconds

Observations (Far Lane Gap < 20 seconds)	
Average Pedestrian Speed	1.97 m/s
Standard Deviation	0.64 m/s
Count	79

DISCUSSION

One of the first and largest studies to document walking speeds was performed by Herms [1]. In this study, the 50th percentile walking speed of all of the pedestrians observed was 1.5 m/s (5.0 feet per second). This median speed found by the Herms study was similar to the average walking speed determined by Eubanks [7], which was found to be 1.4 m/s (4.48 feet per second). These studies were performed in a controlled environment, and the proximity of traffic had no effect on their results.

The average speed of pedestrians in this study was about 20% higher than the pedestrian walking speeds noted in other research; however, pedestrians who accepted longer gaps crossed the roadway at a speed that tended to agree and correspond with the previous studies noted above. The higher average found in this study could be attributed to the fact that some pedestrians elected to run/jog across the roadway instead of walking across at a casual pace.

The average speed of pedestrians was higher in this study than other studies which only observed pedestrians within controlled environments or crosswalks; our finding was consistent with research by Knoblauch [14]. In the Knoblauch study it was found that pedestrians would cross the road faster when they entered the roadway against a “don't walk” signal than when they entered the roadway on a “walk” signal. This previous study suggested that pedestrians would tend to cross the road faster if there was the potential for live traffic to cross their path. The speed at which a pedestrian crosses a roadway is a behavior; this behavior is influenced by environmental factors such as the proximity and lane position of the approaching primary hazard vehicle.

The models in this study indicated that pedestrian crossing speed would decrease and trend towards walking speeds of between 1.4 and 1.7 m/s as gap increased. Therefore, the trend of the models indicated that the longer the gap, the more casually a pedestrian would tend to cross the roadway. If no vehicles were in a pedestrian's immediate proximity, pedestrians were observed to generally walk at typical walking speeds noted in other research, such as Herms [1] and Eubanks [7], or slightly faster. This observation holds true regardless of what lane the approaching vehicle was travelling in with respect to the pedestrian.

Conversely, the models indicated that the smaller the gap, the quicker pedestrians would tend to travel across the roadway. This finding makes intuitive sense as pedestrians would want to travel faster when there is a smaller gap to ensure that they cross with a larger margin of safety.

Another finding was that the average speed of pedestrians increased as the primary hazard vehicle's lane became further from the pedestrian, despite the average gap remaining approximately the same regardless of the primary hazard vehicle's lane position. For example, pedestrians on average tended to walk faster when the approaching primary hazard vehicle was two lanes away (i.e. in the middle lane), as opposed to when the approaching vehicle was only one lane away (i.e. in the near lane). This finding may be attributed to the fact that it takes the pedestrian more time to clear each additional lane of traffic. To illustrate, if a pedestrian accepted a near lane gap of 8 seconds they may be able to safely cross the near lane without any need to hurry. However, if the same pedestrian accepted a 2nd (middle) lane gap of 8 seconds, they may have to hurry in order to avoid being struck. This finding may also be attributed to the hypothesis that pedestrians are better able to assess their crossing time over shorter distances (fewer lanes), as compared to longer distances (more lanes). A pedestrian may have a better idea about how long it takes them to cross one lane of traffic as opposed to three lanes of traffic, especially when taking into consideration their crossing time versus the approach time of the primary hazard vehicle.

The overall average crossing speed of pedestrians observed in our study was 1.84 m/s. This average crossing speed was very similar to other midblock crossing research performed by El-Hakim, which found an average crossing speed of 1.81 m/s [15].

There was a high variance in the speed at which pedestrians elected to cross the roadway, especially for shorter accepted gaps. This high variance is reflected in the RMSE values associated with this study's models, which are between 0.4 and 0.5.

Limitations and Future Work

When reconstructing a collision, witness statements regarding the movement of the pedestrian are important and should not be neglected when looking to apply this research. For example, if the involved pedestrian was described as a 10 year old boy who was running across the road, specific research on the running speeds of 10 year old boys would be more appropriate than the values found in this study. However, if there are no reliable witness statements regarding the movement of the pedestrian, this study could be useful in assisting in the reconstruction of the pedestrian's movements prior to impact. Furthermore, this study is not applicable if there is information to suggest that the pedestrian involved in a particular collision was not aware of any approaching traffic.

Initially, the data was further segregated into walking/running/mixed, but it was found that there were not enough observations to further separate the groups and still provide statistically relevant data. If more observations are performed in the future, this is certainly a topic which may be re-examined. Other future work could include identifying the approximate age of each pedestrian, and assessing how the proximity of approaching vehicles influences different age groups. Different locations, environmental and lighting conditions could also be examined to determine if these factors have any influence on the findings in this study. Considering that this study includes walking pedestrians as well as jogging/running pedestrians in the same data set, caution should be used when comparing this study to other pedestrian speed research.

SUMMARY/CONCLUSIONS

Models of pedestrian speed versus gap, and statistical data of this study's observations were presented for pedestrian midblock crossings. The models were based on unaware test subjects crossing a relatively busy roadway. This data was based on 304 unaware pedestrian movements.

The average speed of pedestrians observed in this study was 1.84 m/s; this value is higher than the average speed of pedestrians noted in other research, where the pedestrians were not crossing midblock.

The average speed of pedestrians in this study increased as the primary hazard vehicle's lane became further from the pedestrian (when they decided to cross the roadway).

This study's observations were modeled as natural exponent functions. These models indicated that pedestrian speed increased as the vehicle gap decreased. In addition, as the vehicle gap increased, the model trended toward typical (non-midblock) walking speeds noted in other published research.

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