An Analysis of Reducing Pedestrian-Walking-Speed Impacts on Intersection Traffic MOEs

A Thesis Proposal

By

XIAOHAN LI

Submitted to the Office of Graduate Studies of Texas A&M University

In partial fulfillment of the requirements for the degree of MASTER OF SCIENCE

Major Subject: Civil Engineering

August 2014
INTRODUCTION

Pedestrian traffic is an important part of a signalized intersection. However, few efforts were made by the government and other traffic research department to analyze pedestrian impacts. There are two major reference documents related to signalized intersections that have been widely used in United States – the Highway Capacity Manual (HCM) and the Manual on Uniform Traffic Control Devices (MUTCD). Both of them include provisions for addressing pedestrian traffic, but the impacts on the overall traffic measures of effectiveness (MOEs) caused by pedestrians at intersections are limited in both documents. As a low-speed traffic component, pedestrians may take up the time that could be utilized by vehicles on the other street to pass through the intersection when crossing the street and prompt increase the total delay of the intersection. Therefore, to minimize traffic delays and increase traffic efficiency, the study of pedestrian-walking-speed impacts is important.

In the 2003 MUTCD (1), the pedestrian walking speed used to calculate the pedestrian clearance time was set to be 4.0 ft/sec. In the latest version, the 2009 edition of the MUTCD, this pedestrian-walking-speed value has been decreased to 3.5 ft/sec plus an exception at locations “where an extended pushbutton press function has been installed to provide slower pedestrians an opportunity to request and receive a longer pedestrian clearance time” (2) attached to it. Extended pushbutton is a recall function which is able to provide extra clearance time to prolong the original one for slower pedestrians. Therefore, by providing an extended pushbutton, the pedestrian walking speed for calculation can keep using 4.0 ft/sec, which means the basic length of pedestrian intervals could keep a relatively short time. According to the document “Federal Register” (3, 4) for the 2009 MUTCD, such changes were in order to enhance pedestrian safety. These modifications are based on the pedestrian walking speed research included in NCHRP Report 562 (5). As pedestrian walking speed gets slower, the pedestrian clearance time becomes longer, which is likely to extend optimal cycle length or to change the splits within a cycle to meet the pedestrians’ crossing demands. It could also impact traffic MOE indexes, such as delay and number of stop and processes to change the entire traffic condition.

The purpose of this research is to analyze the impacts which exerted from the change of the pedestrian walking speed to the traffic MOEs. By using Synchro Studio 7, the researcher is focusing on the pedestrian walking speed reduction impacts of traffic MOEs during this study.

PROBLEM STATEMENT

Many studies focused on the impacts of various traffic characteristics on traffic MOEs, such as signal phasing, proportion of left-turn vehicles and heavy vehicles. However, studies on the impacts of pedestrian walking speed on traffic MOEs are limited and unclear. Under this condition, theoretical results may easily deviate from actual traffic conditions.

In the 2009 MUTCD, the general pedestrian walking speed which was used as a basis of the calculation of pedestrian clearance time was reduced from 4.0 ft/sec (used by 2003 MUTCD) to 3.5 ft/sec. This reduction increased the total pedestrian intervals that needed for pedestrian to cross a given intersection. The width of the major street is usually greater than that of the minor street at an intersection. As a result, the minimum green time for the minor street through movement will be longer than the minimum green time on the major street through movement because of the required pedestrian crossing time. When pedestrian walking speed decreases, the
minimum green time on the minor street gets longer, which would like to cause more delay on the major street and even create impacts on the whole intersection in some circumstances.

This project aims at analyzing the impacts of the pedestrian walking speed reduction to traffic MOEs at signalized intersections. Synchro 7 will be used to comprehensively assess the levels of service (LOS) and delays for the whole intersection as well as each of its approaches. The researcher will discuss the differences which been made by the reduction of pedestrian walking speed on the traffic MOEs. What’s more, the recommendations on how to use the extended pushbutton press function will be discussed, too.

RESEARCH OBJECTIVES

There are two major objectives in this study. The first objective is to analyze the impacts of the change if pedestrian walking speed to the intersection traffic MOEs under different traffic conditions; and the second one is to provide recommendations on the use of pedestrian extended pushbutton function. The subtasks listed below support the completion of this goal:

- Evaluate traffic MOEs of intersections and approaches under two pedestrian walking speeds, 3.5 ft/sec and 4.0 ft/sec, separately; analyze the trends among different transportation scenarios (further explanation in Task 2 and Task 3);
- Compare the delay differences under the two different walking speeds, analyze MOE differences amongst different intersection and traffic settings and discuss the impacts of pedestrian-walking-speed reduction on the traffic MOEs under different intersection traffic flows;
- Discuss if there are significant impacts on intersection MOEs when pedestrian walking speed changes;
- Conclude the impacts of the change of pedestrian speeds on traffic MOEs. Provide recommendations and guidelines on how to best use the pedestrian extended pushbutton function according to the study results.

BACKGROUND

In order to study the impacts of the change of pedestrian walking speed to the intersection traffic MOEs, relevant knowledge and background should be reviewed beforehand. The following sections mainly discuss the changes of pedestrian speed in MUTCD, the simulation software that will be used during this study, key points about intersection traffic MOEs, such as definitions and equations, as well as the methodology that will be used in this research.

MUTCD Changes

MUTCD establishes standards for traffic control devices used in the United States. As a critical traffic component, the MUTCD also addresses pedestrian traffic control issues at signalized intersections, one of which is the walking speed used to calculate the crossing times. The pedestrian speed which is used to calculate the length of pedestrian clearance time was changed between the 2003 and 2009 MUTCDs.

The 2003 edition (1) stated that:
The pedestrian clearance time should be sufficient to allow a pedestrian crossing in the crosswalk who left the curb or shoulder during the WALKING PERSON (symbolizing WALK) signal indication to travel at a walking speed of 1.2 m (4 ft) per second, to at least the far side of the travelled way or to a median of sufficient width for pedestrians to wait. Where pedestrians who walk slower than 1.2 m (4 ft) per second, or pedestrians who use wheelchairs, routinely use the crosswalk, a walking speed of less than 1.2 m (4 ft) per second should be considered in determining the pedestrian clearance time.

In the 2009 edition, the items for the pedestrian walking speed in calculating pedestrian clearance time were changed to:

“The pedestrian clearance time should be sufficient to allow a pedestrian crossing in the crosswalk who left the curb or shoulder at the end of the WALKING PERSON (symbolizing WALK) signal indication to travel at a walking speed of 3.5 feet per second to at least the far side of the traveled way or to a median of sufficient width for pedestrians to wait.”

and

“A walking speed of up to 4 feet per second may be used to evaluate the sufficiency of the pedestrian clearance time at locations where an extended pushbutton press function has been installed to provide slower pedestrians an opportunity to request and receive a longer pedestrian clearance time. Passive pedestrian detection may also be used to automatically adjust the pedestrian clearance time based on the pedestrian’s actual walking speed or actual clearance of the crosswalk.”

In the 2009 MUTCD, pedestrian walking speed that was used as a basis to calculate the pedestrian clearance time was separated into two parts: 4.0 ft/sec with an extended pushbutton press function and 3.5 ft/sec for other circumstances.

Additionally, the 2009 MUTCD provides a second method to calculate the complete pedestrian intervals.

“The total of the walk interval and pedestrian clearance time should be sufficient to allow a pedestrian crossing in the crosswalk who left the pedestrian detector (or, if no pedestrian detector is present, a location 6 feet from the face of the curb or from the edge of the pavement) at the beginning of the WALKING PERSON (symbolizing WALK) signal indication to travel at a walking speed of 3 feet per second to the far side of the traveled way being crossed or to the median if a two-stage pedestrian crossing sequence is used. Any additional time that is required to satisfy the conditions of this paragraph should be added to the walk interval.”

After calculations, the longer pedestrian intervals would be used to determine the walk interval and pedestrian clearance time.

To manipulate traffic conditions under different types of intersections, the researcher will use the widely used simulation software, Synchro 7, to perform the analysis.
Synchro Studio

Synchro Studio is a traffic signal timing optimization and coordination software program. It is developed by the Trafficware Company and also based on HCM. Its features include traffic analysis, timing optimization, and simulation applications (6).

The major parts of Synchro Studio are the macroscopic analysis and optimization software application, Synchro, which includes traffic simulation software application SimTraffic and 3D Viewer application. There are also additional software modules such as Warrants, TripGen, SimTraffic CID and Intersection Capacity Utilization (ICU) in Synchro studio package (7). In this research, Synchro 7 will be applied to do the research.

Traffic MOEs

According to 2010 HCM, control delay, speed, number of stops, queue length, volume-to-capacity (demand-to-capacity) ratios, pedestrian space, bicycle speed, number of meeting/passing events and level of service (LOS) are key performance measures used in evaluating the operation of motorized vehicles on interrupted-flow roadways. Generally, traffic delay is commonly used to assess traffic conditions. The control delay is one of the indexes to determine the LOS for a signalized intersection (8).

Delay

On the basis of 2010 HCM, there are three components of control delay: uniform delay, incremental delay and initial queue delay. Uniform delay is the delay when arrivals are assumed to be random throughout the cycle. Incremental delay consists of two components: delay due to an occasionally demand-exceeds-capacity and delay during a sustained oversaturation. Initial queue delay accounts for the additional delay incurred due to an initial queue (8).

In Synchro, there is a different delay system, including control delay, queue delay and total delay. Control delay is the component of delay caused by the downstream control devices and does not include queue delay; queue delay is an analysis of the effects of queues and blocking in short links and short turning bays; while total delay is the sum of control delay and queue delay (9). In this research, as there’s neither short turning bay nor short links (only one intersection per scenario), queue delay is always equal to 0.

Synchro uses a different method, The Percentile Delay Method, to calculate traffic delays. The Percentile Delay Method looks at five levels of traffic arrivals so that signals can be evaluated under different traffic loads, which makes the final results more practical (9).

Besides delay, traffic engineers often take LOS as an important reference when dealing with traffic conditions.

LOS

The HCM defined six levels to represent the operation conditions, ranging from A to F. LOS A represents the best traffic condition while LOS F represents the worst one (8). LOS is widely used in road designs and traffic condition assessments. In synchro, LOS is based upon the Synchro Control delay.

09-10-2014
Control Variable Method

*Control variable method* is widely used in Physics to resolve the multi-factor (multivariable) problems. The key point of this method is turning the given multi-factor problem into multiple single variable problems. Control variable method is able to look into each variable and study impacts as well as characteristics of those variables one by one. Afterwards, the problem will be solved synthetically. It is an important method in science study and can be applied in a great many kinds of scientific explorations and experiments (10). As I also have multiple factors that need to be dealt with in this project, the researcher applies control variable method into this research.

RESEARCH STUDY DESIGN

To obtain the objectives of this research, the researcher proposes five tasks: literature review, intersection and traffic feature selection, scenario settings, simulation software selection and data analysis, and conclusion and recommendations. The details on those five tasks are listed below:

**Task 1: Literature Review**

Studies focused on the change of pedestrian-walking-speed impacts to traffic MOEs are limited. Portions of related literatures had been reviewed by the researcher before the proposal, such as MUTCD 2003 and 2009, 2010 HCM, etc. According to the objective of this project, the researcher plan to further review the 2003 and the 2009 MUTCDs as well as experiences and findings obtained by Synchro 7. The related advantages, disadvantages, limitations, principles and methodologies are going to be studied. The researcher is also trying to find the former studies that related to impacts from the change of pedestrian walking speed to the traffic MOEs under different intersections. What’s more, papers that related to traffic characteristic impacts on Traffic MOEs are in the researcher’s review list as well. The methods, principles and some other research issues may meaningful and helpful in this research.

By getting sufficient information on the study objectives, predetermined intersection and traffic features of the project need to be selected.

**Task 2: Intersection and Traffic Feature Selection**

This research focuses upon the most common intersection type: the four-way signalized intersection with angles of 90°. Besides pedestrian walking speeds, three more factors that related to the traffic MOEs are chosen:

*Volume*

Volume is the total number of vehicles that passes over a given point or section of a lane or roadway during a given time interval (8). On a given street, as the volume increasing, the traffic condition would get worse and the cycle length of traffic signal would become more and more critical. However, considering pedestrian walking speed, the phase splits of the minor street may have to be prolonged to provide enough time for pedestrians to cross the intersection, which is likely to increase the delay of the major street and may increase the delay of the whole intersection and decrease the traffic effectiveness.
In this project, the volume of each approach will be chosen for different types of roadways. The impacts from the change of pedestrian walking speeds to the traffic MOEs will be presented by performing incremental volume values at studied intersections with Synchro 7.

What’s more, traffic MOEs of different lane groups may exhibit different variation trends and features when impacted by pedestrian walking speed. Therefore, the researcher plans to analyze the MOE performances shown by different lane groups (e.g., left-turn lane group, through-lane group and right-turn lane group, if there is any) as well.

**Length of Crosswalk and Additional Distance**

The length of crosswalk is the one of the basic factors of the pedestrian clearance time. The majority of the pedestrian clearance time is formed by the walk time cost on the crosswalk. The impacts of pedestrian clearance time to the cycle length will become more and more significant along with the increase of crosswalk length. Such impacts may further increase the control delay of the intersection. Therefore, analyzing the significance of pedestrian speed reduction impacts under different lengths of crosswalk is important in this study. The length of crosswalk is defined indirectly by varying the number of lanes, median widths, and other components of roadway, as listed below:

- **Lane Number:** The number of lanes for each approach of intersections should be defined by the sum of lane numbers in all lane groups. Lanes for opposing traffic are also part of roadway width.
- **Median Width:** the median width makes a big difference to the time that pedestrians need to cross the intersection. This part will be directly put into pedestrian clearance time calculation.
- **Distance between the curb and related pedestrian push button:** if there is a pedestrian push button located on at least one side of the street, there should be a distance between the curb and related push button. If the length of this distance is relatively long, the minimum walk interval may not able to support pedestrian walk into the intersection area from the push button. Therefore, as an identification of the total pedestrian cross interval, it should be taken into consideration as well.

**Signal Phasing and Timing**

Signal timing plan is part of the foundation of signalized traffic management. Different signal timing would make big differences on intersection MOEs. Classic signal timing methods pay little attention to pedestrian signals, which will lead to an aberration on evaluations of traffic MOEs. Therefore, the final results should be limited under given signal timing plan type (such as 4-phase timing plan with no overlap). Researcher needs to take care of the impacts of pedestrian speed to MOEs by different signal timing plans. To manage the scope of this effort, the researcher may only take four-phase fixed signal timing plan in this project. No overlap will be included in the analysis.

**Pedestrian Speed Selection**

2009 MUTCD changed the pedestrian walking speed from 4.0 ft/sec to 3.5 ft/sec when there is no extended pushbutton. Such change will influence the minimum green time and even the
whole signal cycle of vehicles. 3.5 ft/sec and 4.0 ft/sec are chosen to evaluate the change of pedestrian walking speed impacts. The second method using 3.0 ft/sec in 2009 MUTCD will also be used in the study.

**Task 3: Scenario and Control Settings on the Basis of Chosen Characteristics**

To manage the scope of this project, the researcher will set up a series of scenarios and controls. Scenarios and controls will be chosen not only to simplify the topic, but also to be representative to typical conditions. The scenarios and controls of this research are listed below:

- All the vehicles will have the same acceleration and declaration rates and keep still; drivers owns the same reaction time; all vehicles have identical left-turn and right-turn speeds; and vehicles arrive randomly.
- Weather is not taken into consideration;
- The post speed limit is 40 mph for the major street and 30 mph for the minor street throughout all scenarios.

The four major features, volume, crosswalk length, signal phasing and pedestrian walking speed, should be subdivided according to different traffic situations.

- Firstly, the major and minor lane number, median width and horizontal offsets of the pedestrian pushbutton are set up to create a serious of intersection outlines;
- Secondly, the base volume of each approach will be chosen on given scenarios. The increasing pace would base upon circumstances;
- Thirdly, four-phase signal timing plan will be evaluated for each type of intersection;
- Finally, each of the traffic situations will be performed with two different pedestrian walking speeds, 3.5 ft/sec and 4.0 ft/sec, according to 2003 and 2009 MUTCD separately.

To get research data sets, all the scenarios will be performed on Synchro 7. Simulation software program selection is a significant segment before data analysis.

**Task 4: Simulation Software Selection and Data Analysis**

The researcher chose Synchro 7 to simulate all the scenarios. On the basis of data sets yielded by Synchro 7, the researcher will use control variable method to analyze the MOEs with two different pedestrian walking speeds, 3.5 ft/sec and 4.0 ft/sec, under all the traffic scenarios; discuss the change trends of MOEs between the two pedestrian walking speed as the volume increasing; use statistic methods to analysis if the differences are statistic significant; and ultimately, comprehensively analyze all the data results. The data analysis will include both vertical and horizontal comparisons.

*Vertical Comparison*

This comparison of MOEs is on the basis of a single intersection with a given type of timing plan. In pace with the increasing of the volume, by comparing the traffic MOEs under two different pedestrian walking speeds (3.5 ft/sec and 4.0 ft/sec), the researcher is going to evaluate the regions of volume within which, the traffic MOEs get impacted by the change of pedestrian walking speed significantly in both mathematical and practical ways.
What’s more, considering practical situation, when pedestrian walking speed decreased, managers may not want to, or able to modify the signal cycle length to improve traffic condition (e.g., given intersection is coordinated with other intersections). The researcher plans to apply reasonable cycle lengths other than optimum ones to the two different pedestrian walking speeds to see under such circumstances, how traffic MOEs and traffic conditions change as well.

**Horizontal Comparison**

Horizontal comparison analyzes the impact degrees among different intersections and signal timing characteristics. When focusing on the impacts that caused by the combination of crosswalk length and pedestrian speed, the researcher would like to change signalized intersection features that contributing to crosswalk length one by one. On the other words, the researcher will keep other intersection features constant when evaluate impacts of the length of crosswalk. The author will study the MOE difference resulting from different pedestrian walking speed under different number of major and minor through lanes, median width and different horizontal offsets of the pedestrian pushbutton.

**Synthetic Analysis**

A comprehensive analysis will be performed to study the sensitivity of different types of intersections responding to the change of pedestrian speeds. By discussing the differences of delay caused by reducing pedestrian walking speed, the researcher is trying to find the impact significances from the change of pedestrian walking speed to the intersection traffic MOEs under different intersection features.

**Task 5: Conclusions and Recommendations**

The researcher will make conclusions according to the data analysis during this section. All the conclusions will relate to the following segments:

- Under different traffic scenarios, whether or not MOEs will change significantly when considering the different pedestrian walking speed. If yes, the researcher will try to find the mode of those changes.
- Classify the different change type of MOEs (e.g., MOE fluctuation caused by volume, crosswalk length, lane group variation, etc).

The final goals of this research are to analyze whether the differences caused by reducing pedestrian walking speed from 4.0 ft/sec to 3.5 ft/sec are significant in both mathematical and practical views, and come up with recommendations on the application of pedestrian extended pushbutton function.

**POTENTIAL BENEFIT OF STUDY**

Potential benefits of this research are:

- Study impacts of pedestrian walking speed to signalized intersections. Try to find the “regular pattern” of MOE curves affected by the reduction of pedestrian walking speed.
- Provide the change trends of MOEs when considering different pedestrian walking speed;

---

09-10-2014
Basing on the MOE difference analysis, relevant traffic control devices can be better used to improve intersection traffic condition;

Provide recommendations on how to use pedestrian extended pushbutton function to decrease the automobile delay at the intersection areas rationally.

**SCHEDULE**

The schedule of this project is listed in TABLE 1.

<table>
<thead>
<tr>
<th>Month</th>
<th>Task</th>
<th>April</th>
<th>May</th>
<th>June</th>
<th>July</th>
<th>August</th>
<th>September</th>
</tr>
</thead>
<tbody>
<tr>
<td>Task 1:</td>
<td>Literature Review</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Task 2:</td>
<td>Intersection and Traffic Feature Selection</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Task 3:</td>
<td>Scenarios Settings</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Task 4:</td>
<td>Software Selection and Data Analysis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Task 5:</td>
<td>Conclusions and Recommendations</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**REFERENCE**