# ESTIMATION OF CAPACITY DECREASE CAUSED BY MID-BLOCK CROSSING PEDESTRIANS IN HANOI

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## Abstract

Crosswalks are designed to help people cross the street safely and help the traffic operate properly. Traffic designers often suppose that pedestrians will cross roadways at designated crosswalks, however, in Vietnam, observation of pedestrian behavior clearly indicates that people habitually cross at mid-block locations not at crosswalk. They are likely to do it only when the place they want to approach is accidentally near a crosswalk. Though there are not many crosswalks designed on streets, which imposes negative impacts on the traffic performance, it does not mean pedestrians can allow themselves to cross the road anywhere they want. Very few pedestrians choose to go out of their way to cross at an intersection. Most of them prefer to take the most direct route possible to get to their destination, even if this means crossing several lanes of high-speed traffic. It is no doubt that sudden street crossing imposes negative impacts on the traffic performance, let alone traffic accidents. This research was carried out with strict adherence to justified methods of data collection (recording videos at several traffic locations) and analysis in order to maximize its validity and reliability. This paper focuses on estimating the capacity decrease caused by mid-block crossing pedestrians and it is meant to find out the impacts of pedestrian crossings at mid-block locations on the traffic flow. One factor is taken into consideration, namely, traffic capacity, which means that the study aims at the objective as: To estimate the decrease of capacity caused by crossing pedestrians. The results of the paper will help the city planners and traffic engineers solve the current problems and predict the future problems relating to crossing pedestrians.

**Keywords:** Crosswalks design, Capacity decrease, Pedestrian's behavior, Traffic performance, Mid- block crossing pedestrians

## 1. Introduction

### 1.1 Overview

Traffic designers often suppose that pedestrians will cross roadways at designated crosswalks. However, observation of pedestrian behavior clearly indicates that people habitually cross at mid-block locations. Very few pedestrians choose to go out of their way to cross at an intersection. Most of them prefer to take the most direct route possible to get to their destination, even if this means crossing several lanes of high-speed traffic.

Especially in Vietnam, most of the pedestrians do not have the habit of crossing the road at crosswalks. They are likely to do it only when the place they want to approach is accidentally near a crosswalk. It is because to most people, crossing the street where they want to and when they want to be easier than waiting until they get all the way to the crosswalk and the little green man lights up. Though it is a fact that there are not many crosswalks designed on streets in Vietnam, it does not mean pedestrians can allow themselves to cross the road anywhere they want. It is no doubt that sudden street crossing imposes negative impacts on the traffic performance, let alone traffic accidents.

### 1.2 Research objective

The research is meant to find out the impacts of pedestrian crossings at mid-block locations on the traffic flow. The main factor is taken into consideration, namely, traffic capacity,

which means that the study aims at main objective as: To estimate the decrease of capacity caused by crossing pedestrians.

## 2. Literature review

This part sheds light on the literature of the study, specifically the background of the issue and a number of studies related to the research topic. Though this research focuses only on a study site located in Vietnam, those documents were very valuable sources of information.

### 2.1 Typical psychological features of pedestrians

According to Traffic Safety course book compiled by lecturers working at Hanoi University of Transportation and Communication (UTC), people's awareness of traffic law is one of the most important factors resulting in the situation of traffic jams and traffic accidents in Vietnam. 80% of traffic jams and traffic accidents are related to the low awareness of traffic users. Here is a general breakdown of levels of risk of different modes of transport, and of ranked levels of awareness of, and adherence to, laws and safe behavior:

Risk level : airplanes < trains < cars < motorbikes <bicycles<pedestrians

Awareness level: airplanes > trains > cars > motorbikes > bicycles > pedestrians

In Vietnam, pedestrians have the lowest level of awareness because they always want to save the travel time and energy. Additionally, pedestrians are not fined when they violate the traffic laws. Currently, only Germany, the US, Belgium, and the Netherlands have laws applied to pedestrians.

Factors that affect pedestrians' behaviors:

- Social factors: age, gender.

+ Age: people from the age of 20-26 are the most careless group of pedestrians.

+ Gender: female pedestrians are more careful than male pedestrians.

- Technical factors: delay, traffic volume

+ Delay: the time people have to wait until they can cross the road should be less than or equal to 30 seconds. If that time is greater than 30 seconds, people tend to cross the road before they are allowed to. The delay time of pedestrians is a function with 2 variables: $t = f(v, B)$; where v is the speed of people when crossing roads, and B is the width of the road. The optimal speed is $v^* = 1.2$ m/sec (approximately 4 km/h). If $v > v^*$, unsafe conditions exist for pedestrians; if $v < v^*$, traffic efficiency is decreased.

+ Traffic volume: accidents often happen in low traffic volume conditions because both vehicle users and pedestrians do not pay much attention to the roads.

- Environment: scenery in the street, fresh/polluted air.

### 2.2Pedestrian crossing facilities (Crosswalk and pedestrian signals)

A pedestrian crossing or crosswalk is a designated point on a road at which some means are employed to assist pedestrians wishing to cross. They are designed to keep pedestrians together where they can be seen by motorists, and where they can cross most safely across the flow of vehicular traffic. Pedestrian crossings are often found at intersections, but may also be at other points on busy roads that would otherwise be too unsafe to cross without assistance due to vehicle numbers, speed or road widths. They are also commonly installed where large numbers of pedestrians are attempting to cross (such as in shopping areas) or where vulnerable road users (such as school children) regularly cross.

Signalized pedestrian crosswalks clearly separate when each type of traffic (pedestrians or road vehicles) can use the crossing. Unsignalized crosswalks or mid-block crosswalks generally assist pedestrians, and usually prioritize pedestrians, depending on the locality. Pedestrian crossings, especially when combined with other features like pedestrian priority or raised surfaces, can be used as a traffic calming technique.

When pedestrians experience more than a 30-s delay, they become impatient, and engage in risk-taking behavior.

### 2.3 Traffic characteristics of motorcycles

Motorcycles account for the greatest proportion among transportation modes in Vietnam. According to the report on the implementation plan

of urgent solutions to traffic accidents and traffic congestion alleviation in Ho Chi Minh City (2007), statistics in August 2007 show that the number of the city's registered vehicles was 3,513,953, of which automobiles were 316,135 and motor vehicles were 3,197,818 (1,200 motor vehicles and nearly 100 automobiles were newly registered a day), not to mention about 60,000 automobiles and 700,000 motor vehicles with the number plates of other provinces, and nearly 2,000,000 bicycles traveling in the city.

For the biggest share of motorcycles in the transportation mode share, in order to have a better understanding on the behaviors of motorcycles when they encounter a crossing pedestrian, it is important to study their traffic characteristics.

In Hanoi, the average vehicle speed in the urban area is from 18 to 32 km/h. Traffic volumes on the city's major routes have reached 1800 to 3600 units per hour. Hanoi's narrow roads and numerous intersections were not designed to handle these traffic volumes. Therefore, the vehicles are obliged to idle or change frequently their speed, which causes chaotic traffic flow and accidents. Motorcycles account for a much higher percentage of total vehicular flow than automobiles, and the peak transportation flow occurs in different times of the day: 7:00 to 8:00 a.m. and 4:30 to 5:30 p.m.

## 3. Methodology

### 3.1 Data collection

#### 3.1.1 Data collection methodology

Pedestrian crossing activities and the movements of the affected vehicles are studied through the analysis of the field data collected by a direct observation of pedestrian activities using two video cameras placed at two different positions as follows:

- One camera was set up overhead at the study site, right angles to the direction of vehicle traffic to record the movements of vehicles and pedestrians.
- Another camera was placed on the pavement beside the street to record the characteristics of affected drivers including gender and number of people on the vehicles.

Recording time is about 7 hours. The study site is located in Hanoi downtown, which is a two-way street with the road width of 11 meters. Following is the video recording timetable:

**Table 1:** Video recording timetable

| Site | Date | Time |
|---|---|---|
| Thai Thinh St. | Wed. 22 June 2011 | 7:30 AM – 10:00 AM |
| Thai Thinh St. | Wed. 22 June 2011 | 4:30 PM – 6:00 PM |
| Thai Thinh St. | Thu. 23 June 2011 | 9:20 AM – 11:15 AM |
| Thai Thinh St. | Fri. 24 June 2011 | 5:00 PM – 6:15 PM |

**Fig. 1:** Video image of study site

The recorded videos were then replayed in a computer with VLC media player. The films were reviewed at either slow speed to scan full-required observation of the road segment or high speed to skip unnecessary data. The video player also allowed users to stop the films at any time to isolate a single traffic scene for detailed observation or analysis. A single person could handle all these works both on-site and in the transportation laboratory.

Motorcycles' speeds, volumes, and positions were identified from image video files. In order to estimate speeds of motorcycles, the spot speed technique was applied. The speeds of traffic entities were determined by the distance they can

travel for a given period of time, a.k.a. interval. In this study, the time intervals were decided to be 0.5 seconds and 2 seconds for the objective of estimating the capacity decrease of the traffic flow, respectively.

### 3.1.2 Data extraction methodology

The data extraction techniques were employed to select information from raw data in the videos and to carry out statistical analysis. In order to extract data from raw data, the computer software named SEV.exe is useful. This software was developed in the transportation laboratory for this specific purpose. The input file is a video clip with the resolution of 640 x 480 pixels. The output file is an Excel compatible file, which has advantages in analyzing numbered data and operating necessary functions.

The vehicle positions were identified from image video files every 2 second interval (for the estimation of capacity decrease). These positions regarding time events were calculated based on screen coordinates, and then were converted to roadway coordinates by using the transformation method, which was explained by Khan *et al* (2001). The trajectory data for any vehicle were achieved by clicking on a specific part of that vehicle at every interval. Then, the vehicle's trajectory data were used for the next step to calculate the speed of that vehicle.

Figure 2 shows the interface of SEV software for analyzing data. The length of the road segment is 46 meters and the width of the road is 11 meters

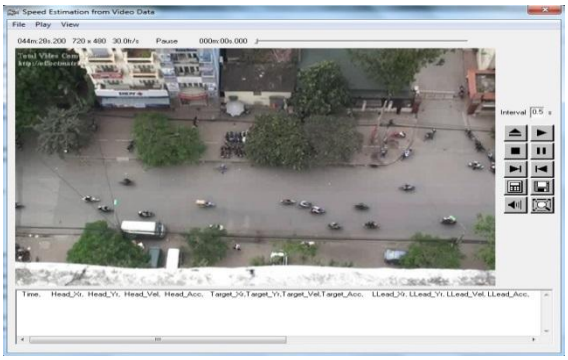

**Fig. 2:** Screenshot of SEV software for analyzing traffic data

SEV software was employed to extract the data from videos. Positions of the vehicles affected by crossing pedestrians were identified from image video files every 0.5 seconds to calculate the speed change to serve the objective of traffic delay estimation. As for the objective of traffic capacity decrease estimation, positions of all the vehicles travelling on the road segment in a given period of time were identified every 2 seconds. These positions were calculated according to screen coordinates then converted into roadway coordinates by using SEV software.

Figure 3 represents the diagram of data collection and extraction using video recorders, media player, and SEV software.

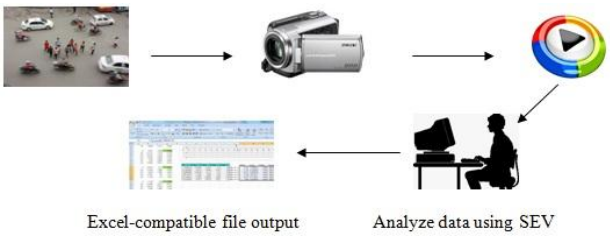


**Fig. 3:** Diagram of data collection and extraction using video techniques

### 3.2 Measurement

***Estimation of the decrease of capacity***

According to the observation made from viewing the videos, in 1 minute, there are at most 3 groups of pedestrians crossing at the road segment. It is supposed that the traffic capacity varies and is commensurate with the number of pedestrian groups.

Speed, density, and volume play the key roles to evaluate how effective a road can handle a traffic jam. Among three, speed – volume relationship is usually applied as an efficient tool for calculating the traffic capacity of a carriage way.

The objective of this part is to present the methodology to find out the relationship between traffic flow and mean stream speed in 4 cases of no pedestrians, 1, 2, and 3 groups of pedestrians; whereby the capacity change can be estimated.

As a matter of fact, it is difficult to estimate the traffic volume under heterogeneous traffic flow unless different vehicle types are converted into a common unit. Since motorcycles cover the biggest proportion among all transportation modes in

Vietnam, it is better to use motorcycle unit (MCU) instead of passenger car unit (PCU) to calculate traffic volume.

The traffic volume data were collected for every 1 minute then were converted to an equivalent flow rate with the unit of motorcycle per hour (MCU/h). In addition, to satisfy the requirement of dimensional analysis in the computation, the speed unit of meter per second was also converted to kilometer per hour (km/h).

In order to have an overall visual image of the relationship between traffic flow and mean stream speed, a scatter plot diagram was created.

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Because of the similarity in the road system with heterogeneous traffic of India and Vietnam, the MCU conversion method recommended by Indian Roads Congress (IRC) (Morris et al., 2000) was employed in this research. Table 2 shows the MCU's factors for vehicles by the conversion of IRC.

**Table 2**: Recommended MCU's factors for vehicles by the conversion of IRC

| No. | Type | MCU |
|---|---|---|
| 1 | Cycle | 0.80 |
| 2 | Motorcycle | 1.00 |
| 3 | Car | 2.00 |
| 4 | Minibus | 4.40 |
| 5 | Bus | 8.00 |

The relationship between traffic flow (Q) and mean stream speed (V) is described as an exponential function as follows:

$$Q = a\,V \exp(-V/b) \qquad (3\text{-}1)$$

Where: Q: traffic flow (MCU/h)
V: mean stream speed (km/h)
a, b: parameters

For different cases of different numbers of pedestrian groups, the flow – speed functions are shown as below:

In case of
$N = 0$: $Q_0 = a_0\,V_0 \exp(-V_0/b_0)$
$N = 1$: $Q_1 = a_1\,V_1 \exp(-V_1/b_1)$
$N = 2$: $Q_2 = a_2\,V_2 \exp(-V_2/b_2)$
$N = 3$: $Q_3 = a_3\,V_3 \exp(-V_3/b_3)$

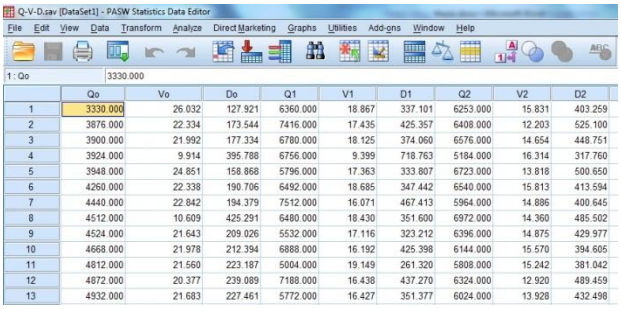
In which, N is the number of pedestrian groups in 1 minute.

To find the maximum value of the above function, its derivative was obtained as below:

$$y' = (1 - x/b)\,a \exp(-x/b) \qquad (3\text{-}2)$$

In which, y is considered as Q, x is considered as V.

In this research, the non-linear regression analysis process was performed by using SPSS (Statistic Package for Social Sciences) program.




| | Qo | Vo | Do | Q1 | V1 | D1 | Q2 | V2 | D2 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 3330.000 | 26.032 | 127.921 | 6360.000 | 18.867 | 337.101 | 6253.000 | 15.831 | 403.259 |
| 2 | 3876.000 | 22.334 | 173.544 | 7416.000 | 17.435 | 425.357 | 6408.000 | 12.203 | 525.100 |
| 3 | 3900.000 | 21.992 | 177.334 | 6780.000 | 18.125 | 374.060 | 6576.000 | 14.654 | 448.751 |
| 4 | 3924.000 | 9.914 | 395.788 | 6756.000 | 9.399 | 718.763 | 5184.000 | 16.314 | 317.760 |
| 5 | 3948.000 | 24.851 | 158.868 | 5796.000 | 17.363 | 333.807 | 6723.000 | 13.818 | 500.650 |
| 6 | 4260.000 | 22.338 | 190.706 | 6492.000 | 18.685 | 347.442 | 6540.000 | 15.813 | 413.594 |
| 7 | 4440.000 | 22.842 | 194.379 | 7512.000 | 16.071 | 467.413 | 5964.000 | 14.886 | 400.645 |
| 8 | 4512.000 | 10.609 | 425.291 | 6480.000 | 18.430 | 351.600 | 6972.000 | 14.360 | 485.502 |
| 9 | 4524.000 | 21.643 | 209.026 | 5532.000 | 17.116 | 323.212 | 6396.000 | 14.875 | 429.977 |
| 10 | 4668.000 | 21.978 | 212.394 | 6888.000 | 16.192 | 425.398 | 6144.000 | 15.570 | 394.605 |
| 11 | 4812.000 | 21.560 | 223.187 | 5004.000 | 19.149 | 261.320 | 5808.000 | 15.242 | 381.042 |
| 12 | 4872.000 | 20.377 | 239.089 | 7188.000 | 16.438 | 437.270 | 6324.000 | 12.920 | 489.459 |
| 13 | 4932.000 | 21.683 | 227.461 | 5772.000 | 16.427 | 351.377 | 6024.000 | 13.928 | 432.498 |

**Fig. 4:** Screenshot of SPSS spreadsheet

## 4. Results

### Estimation of the decrease of capacity

This part presents the findings from the calculation of the relationship between traffic flow and speed, as a result of which, the comparison of capacity among the 4 situations of no pedestrians, 1, 2, and 3 groups of pedestrians crossing at the road segment can be obtained.

The data of traffic volume and speed were input into SPSS program for regression analysis process. Parameters are estimated:

**Table 3:** Estimated

| Parameter / N | a | b |
|---|---|---|
| N = 0 | 1785.929 | 10.966 |
| N = 1 | 1786.806 | 10.363 |
| N = 2 | 1826.191 | 9.583 |
| N = 3 | 1921.520 | 8.875 |

In order to find the traffic capacity, a.k.a. maximum flow, it is necessary to identify the maximum point of the curve expressing the flow-speed relationship.

Based on the derivative derived from function [3-1], the maximum flow and optimum speed in each case were obtained as shown in Table 4:

**Table 4:** Capacity and Optimum speed

| | $Q_{max}$ (MCU/h) | $V_{opt}$ (km/h) |
|---|---|---|
| N = 0 | 7204.734 | 10.966 |
| N = 1 | 6811.902 | 10.363 |
| N = 2 | 6438.033 | 9.583 |
| N = 3 | 6273.628 | 8.875 |

The table shows the capacity and optimum speed in different cases of different numbers of groups of pedestrians crossing at the road segment. The differences in capacity and optimum speed can be clearly described in 2 figures below:

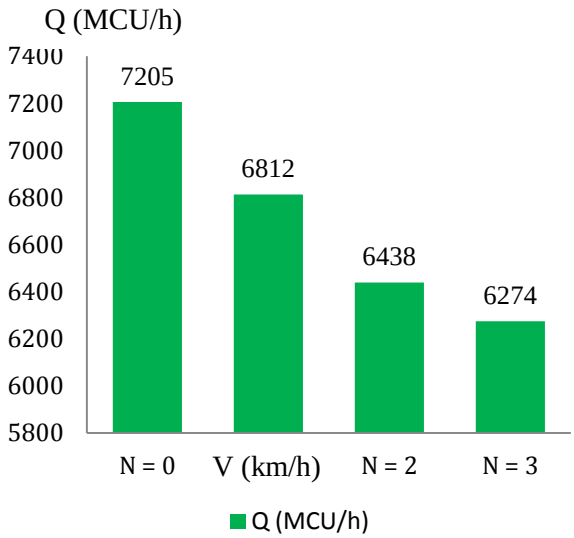



**Fig. 5:** Comparison of traffic capacity among different cases

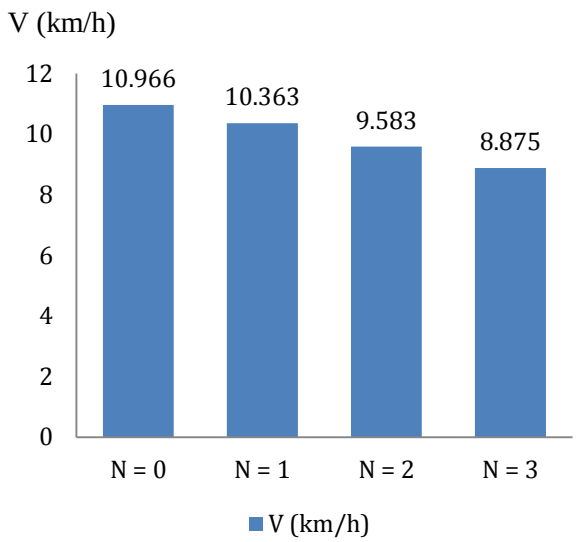



**Fig. 6:** Comparison of speed among different cases

These figures clearly show that the capacity and optimum speed are inversely proportional to the number of crossing pedestrian groups. The more people cross the street, the lower the capacity and the optimum speed are.

## 5. Conclusion/Discussion

### 5.1 Major findings and contribution of the research

Although there have been a number studies concerning the interaction of crossing pedestrians and vehicular traffic as mentioned at Literature Review, there has not been any research studying the impacts of crossing pedestrians at mid-block locations on the traffic flow in terms of capacity decrease.

Therefore, this research was conducted to find out the impacts of pedestrian crossings at mid-block locations on the traffic flow. The main factor was taken into consideration, namely, traffic capacity. The results of the study has answered the main question as follow: how much the capacity decrease is due to crossing pedestrians.

Regarding capacity decrease, the study has provided the models showing the flow – speed relationship of the four cases of no crossing pedestrian, 1, 2, and 3 groups of crossing pedestrians. The results helped the author come to the conclusion that the capacity and optimum speed are inversely proportional to the number of crossing pedestrian groups. The more people cross the street, the lower the capacity and the optimum speed are.

The results of the research will hopefully help the city planners and traffic engineers solve current problems and predict the future problems relating to crossing pedestrians.

### 5.2 Suggestions for further studies

This research focused only on a study site in Hanoi (Vietnam) to develop models for capacity decrease caused by mid-block crossings. Further studies should be carried out to come to general models, which can be applied to other mid-block locations with different road widths and different numbers of lanes.

Since this research has not come up with a perfect solution to the problems at the study site, which has a big number of pedestrians crossing everyday and currently does not have any pedestrian crossing facility. Therefore, further studies may base on the results of this research to find out a better solution so that the problems can be dealt with thoroughly.

## 6. Acknowledgement

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