

## **Pedestrian Safety through a Raised Median and Redesigned Intersections**

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### **ABSTRACT**

This paper documents the effect of a raised median, signalized and redesigned intersections, curbs, and sidewalks on vehicle speed, pedestrian exposure risk, driver predictability, and vehicle volume along a four lane suburban roadway in central New Jersey. The analysis used both qualitative tools (speed and volume counts, timing runs) and qualitative methods (pedestrian tracking, video, before-after photography). The results are as follows:

- 85<sup>th</sup> percentile vehicle speed fell by two miles per hour.
- Pedestrian exposure risk decreased by 28 percent.
- The median allows pedestrians to cross one direction of traffic at a time.
- Signals, curbs, median, redesigned intersections and striping patterns work together to manage driver behavior.
- Vehicle volumes were not affected.
- Vehicle speeds acted independently of vehicle volumes.

A collision analysis projected a savings of 1.7 million dollars over the next three years in direct and indirect costs.

The goal was to produce a simple and straightforward analysis tool for similar projects in the area. Some of the benefits of roadway projects such as these can be quantified numerically while others rely on qualitative analyses. For example, before-after speeds are easily gathered and compared, while before-after pedestrian behavior at the raised median require a more in depth approach made easier by digital cameras. Together, before-after data and before-after imaging present a more holistic picture of the benefits/limitations of a project.

## INTRODUCTION

Traditional roadway improvement projects in the United States have been generally auto-oriented. Most seek to improve travel conditions for motorists by increasing traffic flow and/or speed. Traffic calming and pedestrian safety projects, where changes in a roadway's design seek to "reduce traffic speeds and cut-through volumes in the interest of street safety, livability, and other public purposes," (1) differ in a variety of ways. As such, an evaluation of traffic calming effectiveness must be holistic and comprehensive. For this project the Township of Plainsboro and Middlesex County desired a simple method to predict how the project would impact on traffic and safety, especially that of pedestrians.

The draft New Jersey Department of Transportation's traffic calming policy highlights three performance objectives common to most traffic calming projects: reduce vehicle speed, reduce pedestrian exposure risk and increase driver predictability. Vehicle speed is a clear determinant of crash rates and severity. Exposure risk is the amount of time that pedestrians and cyclists are exposed to traffic and its inherent dangers. Driver predictability describes the ability of pedestrians, cyclists and other motorists to best predict the speed and actions of drivers. Together with vehicle volume and a collision analysis, they provide a simple yet straightforward framework to assess the effectiveness of these projects.

## SITE DESCRIPTION

In 2001 Plainsboro Township (near Princeton, New Jersey) reconstructed an approximately 3200 foot long section of Plainsboro Road, a four lane suburban roadway with four major intersections at about 1000-foot intervals. Prior to the reconstruction only the outer two intersection were signalized (A and D on Figure 1). The road was 64 feet wide with 12-foot lanes, a striped median, narrow shoulders, neither curbs nor sidewalks, and two mid-block marked crosswalks. See Table 1.

The reconstruction consisted of:

- a redesign of the two interior intersections with signals, intersection-only bike lanes, stop lines, textured crosswalks, and removal of two free turn lanes (B and C on Figure 1),
- a 7.5-foot wide, 900-foot long raised median between the two interior intersections (E on Figure 1),
- a narrower roadway width of 53 feet,
- timing the signals to maintain speeds at the speed limit of 45 mph, and
- curbs, bike lanes, street trees, sidewalks and bus shelters along the corridor.

| <b>Before</b>        | <b>Feet</b> | <b>After</b>             | <b>Feet</b> |
|----------------------|-------------|--------------------------|-------------|
| Shoulder             | 3           | Bike Lane                | 4           |
| Travel lane          | 12          | Travel lane              | 10.5        |
| Travel lane          | 12          | Travel lane              | 10.5        |
|                      |             | Inside shoulder          | 1.5         |
| Flush median         | 10          | Raised median            | 7.5         |
|                      |             | Inside shoulder          | 1.5         |
| Travel lane          | 12          | Travel lane              | 10.5        |
| Travel lane          | 12          | Travel lane              | 10.5        |
| Shoulder             | 3           | Bike Lane                | 4           |
| Total pavement width | 64          | Total curb to curb width | 60.5        |
|                      |             | Total width minus median | 53          |

**Table 1: Roadway Profile at Median**

Figure 1 through Figure 11 document the site with a (before) aerial view and before-after still images.

## BEFORE-AFTER DATA ANALYSES

**Vehicle Speed**

Speeds recorded by an automatic traffic recorder (ATR) placed at the median show that the hourly average and 85<sup>th</sup> percentile speeds fell by two to three miles per hour. See Table 2. This is consistent with research showing that a one-foot change in lane width produces a 2.5 mph change in vehicle speed. (2) At the median, the lanes were narrowed by 1.5 feet, from 12 to 10.5 feet. Accordingly the speeds could be expected to decrease by 3.75 mph. Another factor are the new signals, where before was essentially a free-flow condition.

|    |            | <b>Average</b> | <b>85<sup>th</sup> percentile</b> |
|----|------------|----------------|-----------------------------------|
| WB | Before     | 46             | 51                                |
|    | After      | 44             | 49                                |
|    | Difference | <b>-2</b>      | <b>-2</b>                         |
| EB | Before     | 47             | 52                                |
|    | After      | 44             | 49                                |
|    | Difference | <b>-3</b>      | <b>-3</b>                         |

**Table 2: Speeds at Median, mph**

A caveat on the speed data - the before surveys were taken during the month of May with the after counts performed in January and February. The speed reduction could be a result of a seasonal shift, yet in both time periods the roadway was dry, the weather clear and the driving conditions good. Variations in speed is a subject in need of additional research.

**Midblock Pedestrian Exposure Risk**

Exposure risk is the time which a person is exposed to on-coming traffic while crossing a street. This is the time in which one is basically in danger of being hit by a car (notwithstanding vehicles that mount the curb or swerve off the road). A measure of exposure risk at midblock is the width of the traveled way – that within the edge lines or curbs. Before, Plainsboro Road was approximately 58 feet wide from edge line to edge line. With the median, the roadway was transformed into two 21-foot wide streets for a total “exposed” width of 42 feet. Pedestrians walk at between 2.8 and 7 feet per second. Before construction, crossing the traveled way took 8 to 21 seconds. Now it takes between 6 and 15 seconds, respectively. This differential indicates that exposure risk decreased by 28 percent. See Table 3.

|            | <b>Traveled Way<br/>width</b> | <b>Crossing time<br/>2.8 fps</b> | <b>Crossing time<br/>7.0 fps</b> |
|------------|-------------------------------|----------------------------------|----------------------------------|
| Before     | 58 feet                       | 21 sec.                          | 8 sec.                           |
| After      | 42 feet                       | 15 sec.                          | 6 sec.                           |
| Difference |                               | <b>28 %</b>                      | <b>28 %</b>                      |

**Table 3: Pedestrian Crossing Time**

More importantly, with the median, pedestrians and cyclists now have the opportunity to cross the street midblock in segments. All things being equal, it is safer to cross a one-way street, because there is only one direction of traffic with which to contend.

### Driver Predictability

An overall measure of roadway safety is driver predictability. Examining the physical characteristics of the roadway and making a qualitative judgment regarding the ability of pedestrians, cyclists, and other motorists to predict the speed and actions of drivers can assess driver predictability. For example, if the speeds on a street are relatively constant, then crossing pedestrians will be better able to judge how much time they have to cross the street. Similarly, if an intersection is channelized, a driver will know where to steer and where others will be, than if the intersection is open and unmarked. (3, 4, 5, 6)

The addition of a median and curbs increases driver predictability by keeping vehicles on the roadway and in their half of the roadway. While not a safety panacea, traffic signals direct drivers to stop for pedestrians, which makes crossing the street easier and more predictable. Signals also create gaps in the traffic stream, which make crossing mid-block easier. Striped bike lanes and stop lines at the intersection help to organize the area so that all users are better informed of others' actions. By removing free-right turn lanes drivers must now turn more slowly, thus more predictably. See Figure 6 through Figure 9.

The scope of the project did not allow for a more intensive quantification of driver predictability. For instance before-after turning speeds would help substantiate the removal of the free right turn lanes. More complete crash data (which was not available) would help to determine the safety benefit of the median and signals.

### Vehicle Volume

Vehicle volume counts on Plainsboro Road were taken before and after construction. The before surveys were taken during the month of May. The after counts were performed in January and February. The counts were adjusted for monthly and daily traffic fluctuations using adjustment factors, developed by the NJDOT based on continuous traffic survey data. [These adjustment factors allow the use of weekend data, when normally only weekday should be used.] Dividing the counts by a factor gives an adjusted volume, which can be compared directly to surveys performed on other days or in other months.

As evidenced in Table 4 and Table 5, the project had a neutral impact on overall traffic volumes. Westbound traffic rose by five percent, while eastbound traffic fell six percent. This is consistent with the nature of the installation, which was not designed to affect volume.

| Month  | Day   | Actual Volume | Factor | Adjusted Volume | Average    |
|--------|-------|---------------|--------|-----------------|------------|
| May 01 | Fri   | 9035          | 1.171  | 7715            |            |
| May 01 | Sat   | 5823          | 0.847  | 6876            |            |
|        |       |               |        | Before          | 7296       |
| Jan 02 | Wed   | 8051          | 1.042  | 7729            |            |
| Jan 02 | Thurs | 7975          | 1.047  | 7620            |            |
|        |       |               |        | After           | 7674       |
|        |       |               |        | <b>change</b>   | <b>+5%</b> |

**Table 4: Daily Volume Change - Westbound**

| Month  | Day   | Actual Volume | Factor | Adjusted Volume | Average    |
|--------|-------|---------------|--------|-----------------|------------|
| May 01 | Tues  | 10013         | 1.117  | 8967            |            |
|        |       |               |        | Before          | 8967       |
| Feb 02 | Wed   | 9159          | 1.056  | 8670            |            |
| Feb 02 | Thurs | 8636          | 1.061  | 8138            |            |
|        |       |               |        | After           | 8404       |
|        |       |               |        | <b>change</b>   | <b>-6%</b> |

**Table 5: Daily Volume Change – Eastbound**

### Vehicle Speed v. Volume

By recording both volume and speed, the ATRs permit a look at their relationship, or lack thereof. Vehicle volume swung widely between the middle of the night and rush hour (99-100%), while the 85<sup>th</sup> percentile speeds remain relatively constant (11-18%). In essence, the travel speed along Plainsboro Road is constant regardless of the amount of traffic. This non-relationship may be contrary to the general perception that drivers drive faster in rush hour or that there is more speeding in the middle of the night. In fact the eastbound after survey shows a slight decrease in speeds when there are the most vehicles. The median and signals did not significantly alter this relationship. See Table 6 and Figure 12 through Figure 15.

|    |        | Range of 85 <sup>th</sup> Percentile<br>Speeds, mph |     | Range of Volumes |      |
|----|--------|---|-----|------------------|------|
| WB | Before | 45 - 54   | 17% | 7 - 1392         | 99%  |
|    | After  | 45 - 55   | 18% | 5 - 1398         | 100% |
| EB | Before | 48 - 54   | 11% | 7 - 1503         | 100% |
|    | After  | 46 - 53   | 13% | 3 - 1499         | 100% |

**Table 6: Hourly Speed-Volume Relationship**

### Speed, Crash Rates and Costs

There are proven relationships between vehicle speed, collision rates and pedestrian injury severity. It follows then that if vehicle speed rises or falls, there will be commiserate rise and fall in safety, all other factors being equal.

Performing a collision rate analysis based on vehicle speed is fairly straightforward. One needs the before-after speed differential, existing crash rates and severity, and their monetary value. Collision rates can be calculated using police accident reports and should be derived from a multi-year analysis if practical. A three-year analysis is preferred. Vehicle-bicycle and vehicle-pedestrian injury incidents should be adjusted upwards by around 50% to account for underreporting.

Various reports have compared actual to reported pedestrian-vehicle and bicycle-vehicle injury incidents and found underreporting on the scale of 35 to 85 percent. A study of California children estimated that police reports only cover 80 percent of hospital admissions. (7) A British study found that only 67 percent of slight injuries to pedestrians were reported while 85 percent of serious injuries were. (8) In Germany the figures are 50 percent for major injury and 35 percent for minor. (9) Fatality numbers were not adjusted, as they are generally accurate. Vehicle-vehicle numbers were assumed to be correct as crash data typically includes information from insurance companies as well.

Table 7 presents the multipliers used by the Federal Highway Administration in determining comprehensive costs related to traffic crashes. The multipliers include direct (property damage, emergency medical services (EMS), medical treatment, lost productivity, insurance payouts) and indirect (insurance premiums, automobile safety features) costs. They do not include more speculative societal costs such as disrupted commuting patterns, moving to a different neighborhood, changing job location, etc.

| <b>Severity</b> | <b>Description</b>    | <b>Cost</b> |
|-----------------|-----------------------|-------------|
| F               | fatality              | \$2,600,000 |
| A               | incapacitating injury | \$180,000   |
| B               | evident injury        | \$36,000    |
| C               | possible injury       | \$19,000    |
| PDO             | property damage only  | \$ 2000     |

**Table 7: FHWA Comprehensive Crash Costs (1994 Dollars) (10)**

Note: The FHWA divides crashes into five categories while the Plainsboro Road data only used four categories. To balance these ‘other injury’ was assigned the mid-point between ‘B-evident injury’ and C-possible injury’: \$25,000.

These multipliers can be applied to existing crash rates to estimate the approximate annual cost to community of the existing roadway configuration and safety conditions.

All other factors being equal, if the speed on the street is lowered, then the severity of any future conflicts will summarily be lowered. Table 8 shows the relationship between vehicle speed and collision rates. Other research suggests that a 3 mph vehicle speed reduction will reduce pedestrian fatalities by 10% and make another 20% less severe. (11) Documentation of vehicle speed before and after construction of the traffic calming project will yield a speed differential rate that can be used to forecast potential reduction in vehicle crashes. This can be an interim surrogate for post-construction observed crash data.

| <b>Speed reduction, mph</b> | <b>Collision reduction</b> |
|-----------------------------|----------------------------|
| 6                           | 42%                        |
| 3                           | 15%                        |
| 1                           | 5%                         |

**Table 8: Speed-collision Relationship (12, 13, 14)**

Multiplying projected or observed post-construction crash data by the appropriate multiplier and adjusting for inflation will provide a projected annual cost to community based on the traffic calmed roadway safety conditions. The difference between this and the annual cost to community based on pre-construction conditions will provide an estimate of potential cost saving from the traffic calming project relative to the cost of construction.

Adding a median and timed signals to Plainsboro Road has reduced vehicle speeds by approximately 2 mph overall. Directly at the median, the 85<sup>th</sup> percentile speed went down 3 mph. Away from the median the speed dropped an average of 1.5 mph.

| <b>Location</b>                                  | <b>Dir.</b> | <b>Before<br/>Speed</b> | <b>After<br/>Speed</b> | <b>difference</b> |
|--|-------------|-------------------------|------------------------|-------------------|
| Centers-Wyndhurst to Hunters Glen-Deer Creek     | WB          | 52                      | 50                     | -2                |
|  | EB          | 51                      | 52                     | +1                |
| Hunters Glen-Deer Creek to Thoreau-park (median) | WB          | 52                      | 49                     | -3                |
|  | EB          | 51                      | 48                     | -3                |
| Thoreau-park to Davison-Tamarron                 | WB          | 50                      | 48                     | -2                |
|  | EB          | 51                      | 48                     | -3                |
| <b>average</b>                                   |             | <b>51</b>               | <b>49</b>              | <b>-2</b>         |

**Table 9: 85th Percentile Speeds along Plainsboro Road, mph**

Twenty-nine months (January 1996 – May 1998) of crash (accident) data for the corridor was compiled by type and severity. It was not possible to assign a location to each incident, so data for the entire corridor was aggregated. The incidents involving a vehicle and bicycle or pedestrians were adjusted upwards by 50% to account for underreporting. Annually, this section of Plainsboro Road witnesses approximately 38 crashes.

| <b>Crash Type</b>          | <b>Fatal</b> | <b>Severe<br/>Injury</b> | <b>Other<br/>Injury</b> | <b>Property<br/>Damage<br/>Only</b> | <b>Total</b> | <b>Annual<br/>Rate</b> |
|----------------------------|--------------|--------------------------|-------------------------|-------------------------------------|--------------|------------------------|
| Vehicle-Vehicle            | 1            | 0                        | 24                      | 54                                  | 79           | 33                     |
| Vehicle-Bicycle/Pedestrian | 1            | 6                        | 5                       | 2                                   | 13           | 5                      |
| <b>Total</b>               | <b>2</b>     | <b>6</b>                 | <b>29</b>               | <b>56</b>                           | <b>92</b>    | <b>38</b>              |

**Table 10: Crashes along Plainsboro Road, Adjusted for Underreporting (1996-98)**

Multiplying the crash numbers in Table 10 by those in Table 7 and adjusting for inflation yields an annual pre-construction cost to community of \$3,870,601. The FHWA numbers are based on 1994 dollars. To adjust for inflation an annual factor of 3.5% was used. The numbers presented are 2002 dollars.

Factoring the crash numbers in Table 10 by the speed-crash relationships shown in Table 8, one can predict the number of crashes will fall to 34 per year.

| <b>Crash Type</b>          | <b>Fatal</b> | <b>Severe<br/>Injury</b> | <b>Other<br/>Injury</b> | <b>Property<br/>Damage<br/>Only</b> | <b>Total</b> | <b>Annual<br/>Rate</b> |
|----------------------------|--------------|--------------------------|-------------------------|-------------------------------------|--------------|------------------------|
| Vehicle-Vehicle            | 1            | 0                        | 22                      | 49                                  | 71           | 29                     |
| Vehicle-Bicycle/Pedestrian | 1            | 5                        | 4                       | 2                                   | 12           | 5                      |
| <b>Total</b>               | <b>2</b>     | <b>5</b>                 | <b>26</b>               | <b>51</b>                           | <b>83</b>    | <b>34</b>              |

**Table 11: Projected Crashes along Plainsboro Road**

Multiplying the forecasted crash data by the associated costs and adjusting for inflation gives an annual post-construction cost to community of \$3,300,743. The difference between pre- and post-construction costs is \$596,859. As such, this project can be projected to save drivers, residents and government approximately 1.7 million dollars over the next three years in direct and indirect costs due to reduce collision rates.

|                                |             |
|--------------------------------|-------------|
| Previous crash costs           | \$3,870,601 |
| Projected crash costs          | \$3,300,743 |
| Projected annual savings       | \$569,859   |
| Projected savings over 3 years | \$1,709,576 |

**Table 12: Projected Savings**

It should be noted that other changes to the roadway would also affect roadway safety. Traffic signals separate events in time. Medians provide pedestrians a safer crossing and reduce head-on collisions. Curbs keep errant vehicles on the roadway. In addition increases in bicycle and pedestrian traffic may increase the number of incidents. Finally, the reader should note that other factors such as tax revenues, property values, environmental impact, and travel mode share are important cost-benefit indicators that were outside the scope of this study. (15, 16)

## CONCLUSION

The analysis of this road reconstruction project sought to do two things: to demonstrate innovative qualitative techniques in analyzing traffic calming and pedestrian safety projects, and to quantitatively evaluate the effect of the project on traffic calming and pedestrian safety.

Based on the evidence gathered in this study, raised medians, narrowed lanes, timed signals, curbs and sidewalks, and redesigned and signalized intersections have a:

- slight effect on vehicle speed,
- a sizable effect on pedestrian exposure risk and driver predictability, and
- a negligible effect on vehicle volumes and the speed-volume relationship.

These effects translate into tangible cost savings for the township and the general public.

Other indicators for traffic calming and pedestrian safety projects - pedestrian and cyclist volume, vehicle noise, vehicle mix, vehicle travel time, vehicle diversion, and air quality - were also studied but the results were inconclusive or not directly related.

It is hoped that these findings may be combined with other research to better understand the benefits/limitations of raised medians for traffic calming and pedestrian safety purposes.



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IMAGES

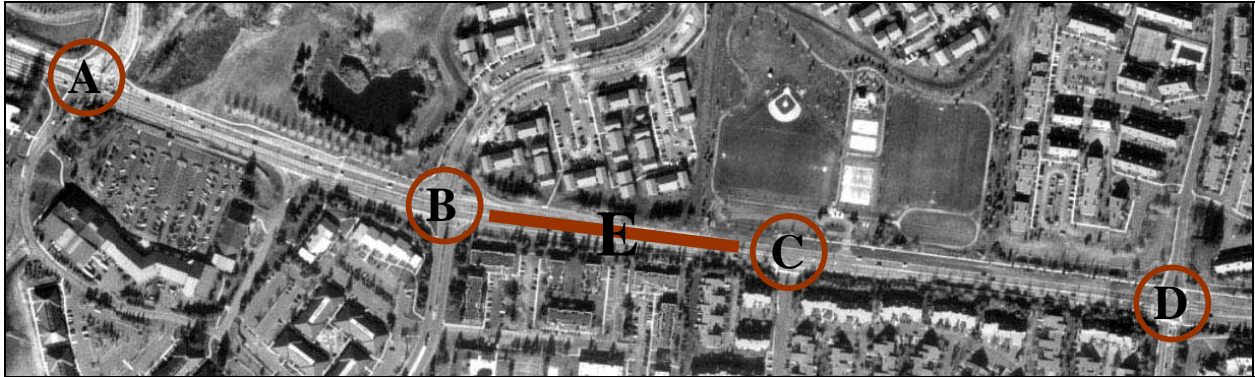


Figure 1: Aerial View (Before)



Figure 2: Before - Flush Median



Figure 3: After - Raised Median



Figure 4: Before – No Curbs or Sidewalk



Figure 5: After – Curbs, Sidewalk, Bus Shelter, Street Trees



**Figure 6: Before – Unsignalized, open interseciton**



**Figure 7: After – Signalized Intersection with Textured Crosswalks and Expanded Islands**



**Figure 8: Before - Free Right Turn Lane**



**Figure 9: After - No Free Right Turn Lane**



**Figure 10: Before - No Signal**



**Figure 11: After - Signal, Stop Line and Bike Lanes**

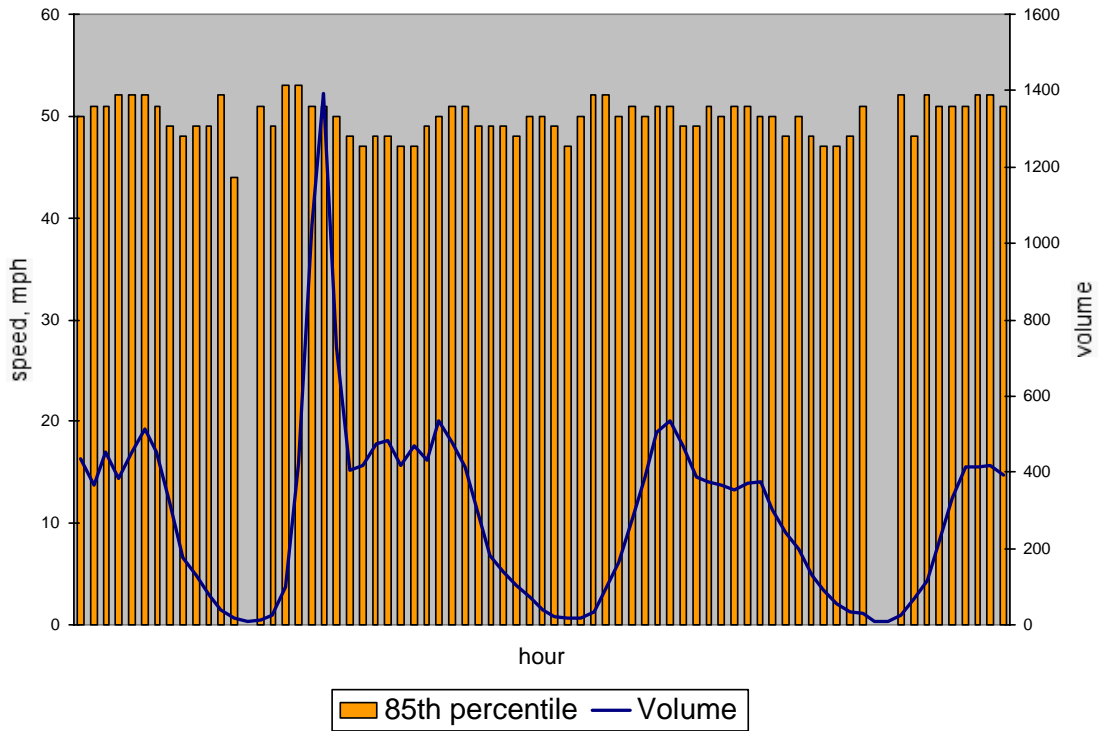


Figure 12: Westbound Speed-Volume Relationship - Before

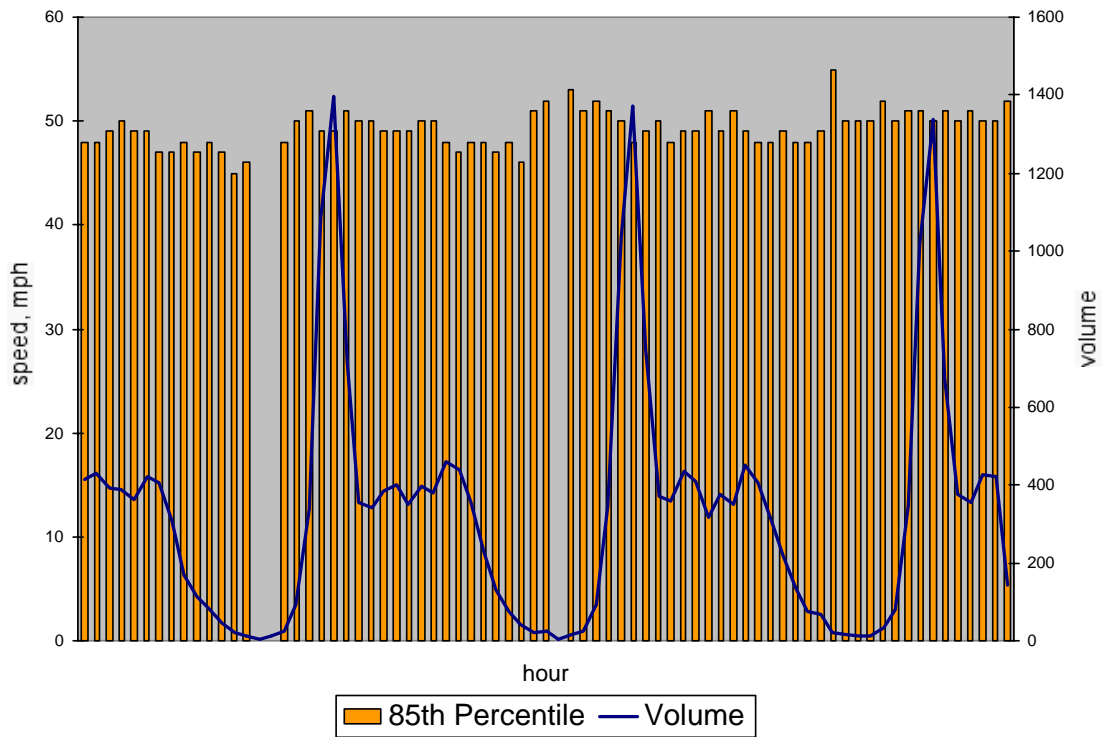


Figure 13: Westbound Speed-Volume Relationship - After

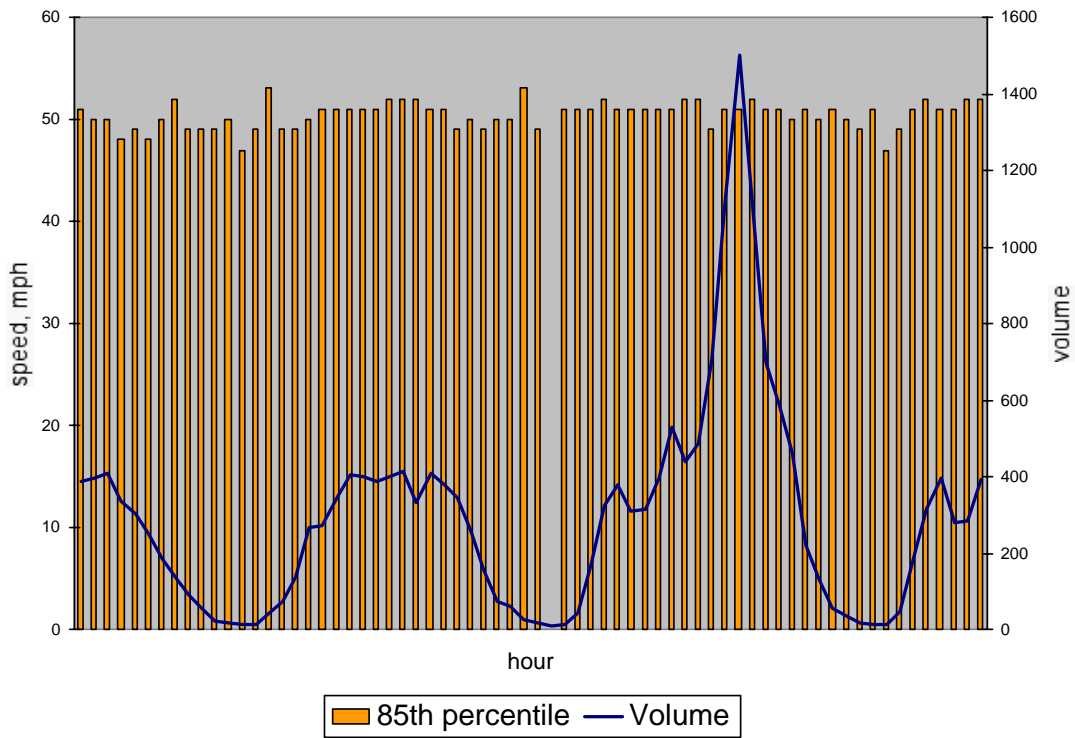


Figure 14: Eastbound Speed-Volume Relationship - Before

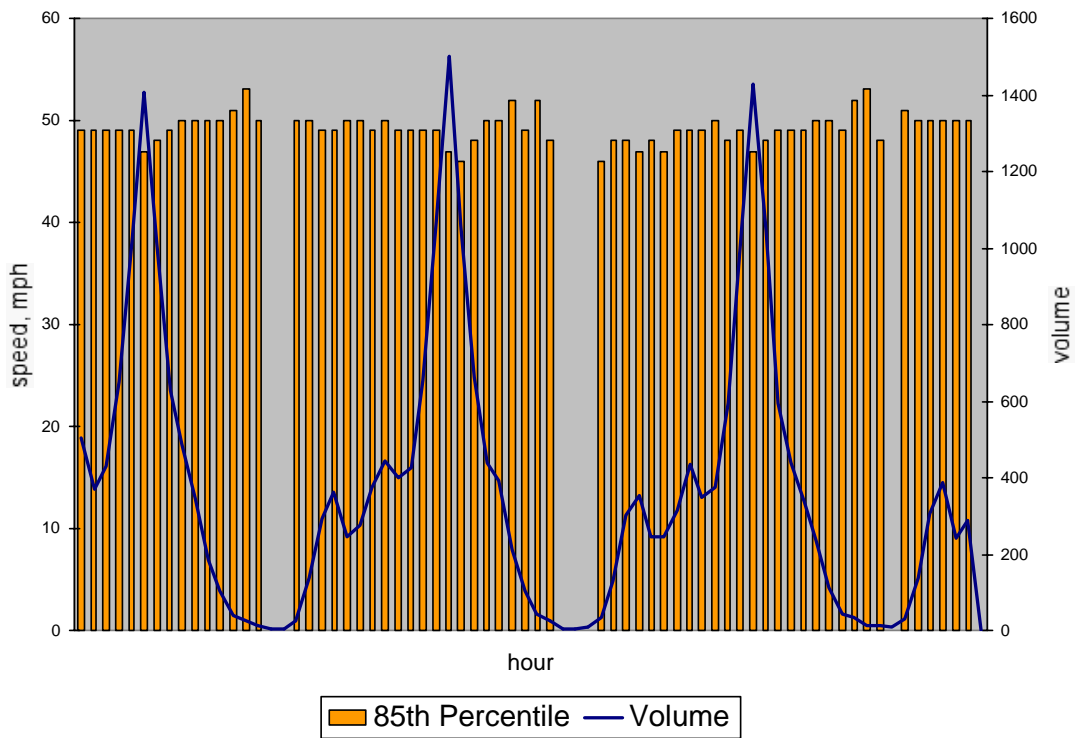


Figure 15: Eastbound Speed-Volume Relationship - After