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Effectiveness of Certain Design Solutions on Reducing Vehicle Speeds

FINAL REPORT

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Submitted by

Dr. Janice Daniel
New Jersey Institute of Technology

NJDOT Research Project Manager
Dr. Nazhat Aboobaker

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16. Abstract

One of the initiatives of the U.S. Department of Transportation is to increase the use of bicycling and to accommodate bicycle and pedestrian needs in designing transportation facilities for urban and suburban areas. The congressionally mandated National Bicycling and Walking Study also has set
goals to: (1)double the percentage of all trips made by bicycling or walking; and (2) to reduce the current number of bicycling and walking injuries and fatalities by 10 percent. One approach to enhancing the safety of bicyclists and pedestrians, is to ensure safe vehicular speeds on residential and commercial roadways through the use of traffic calming measures.

Traffic calming is defined by the Institute of Traffic Engineers as "the combination of mainly physical measures that reduce the negative effects of motor vehicle use, alter driver behavior and improve conditions for non-motorized street users" (Lockwood, 1997). The objective of traffic calming is to reduce the speed and volume of traffic to acceptable levels and to thereby increase the safety of the roadway (Ewing, 1999). The focus of this research is to explore various design solutions that will reduce vehicle speeds, especially in business and residential areas. The intent of the research is to provide a preliminary investigation to identify design solutions and locations where these solutions would be appropriate so that a later field implementation and evaluation of speed-reduction treatments can be conducted.

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Table of Contents

List of Figures

List of Tables

Chapter I

INTRODUCTION

Overview

One of the initiatives of the U.S. Department of Transportation is to increase the use of bicycling and to accommodate bicycle and pedestrian needs in designing transportation facilities for urban and suburban areas. The congressionally mandated *National Bicycling and Walking Study* also has set goals to: (1)double the percentage of all trips made by bicycling or walking; and (2) to reduce the current number of bicycling and walking injuries and fatalities by 10 percent. One approach to enhancing the safety of bicyclists and pedestrians is to ensure safe vehicular speeds on residential and commercial roadways through the use of traffic calming measures.

Traffic calming is defined by the Institute of Traffic Engineers as "the combination of mainly physical measures that reduce the negative effects of motor vehicle use, alter driver behavior and improve conditions for non-motorized street users" [(1)]. The objective of traffic calming is to reduce the speed and volume of traffic to acceptable levels and to thereby increase the safety of the roadway [(2)]. Research has shown that one prevalent factor associated with motor vehicle crashes is speeding. Speeding, as defined by a police crash report, is exceeding the posted speed limit or driving too fast for conditions. Speeding increases the potential for loss of vehicle control; reduces the effectiveness of passenger safety equipment; increases the amount of stopping distance required; increases the amount of distance traveled during driver reaction time; and increases the degree of crash severity resulting in more disabling injuries [(3)].

Background

In 2000, 29 percent of all fatal crashes in the United States indicated that speeding was a contributing factor. Speed-related fatal crashes are defined as fatal crashes meeting any one of the following conditions: (1) at least one driver-related factor for any driver in the crash had a value corresponding to "Driving too fast for Conditions or in Excess of Posted Speed Limit"; (2) at least one violation charged to any driver in the crash was speed-related (except driving too slowly); or (3) the travel speed of at least one vehicle exceeded the posted speed limit by 10 or more miles per hour. Also in 2000, 593,000 reported injuries were due to speed-related crashes. Many of these crashes occurred on non-Interstate roadways with 85 percent of speed-related fatalities occurring on non-Interstate highways. The Federal Highway Administration (FHWA, 2000) reports that almost half of all speeding fatalities occur on local and collector roads with the speeding fatality rate on these roadways almost triple that of the Interstates. The implications of the large number of speed-related crashes on local and collector roadways are safety concerns to all users of these roadways, including pedestrians and bicyclists.

Research Problem

The focus of this research is to explore various design solutions that may reduce vehicle speeds, especially in business and residential areas. The intent of the research is to provide a preliminary investigation to identify design solutions and locations where these solutions would be appropriate so that a later field implementation and evaluation of speed-reduction treatments can be conducted.

Research Objectives

The overall objective of the work performed under Task Order No. TO-37 *Effectiveness of Certain Design Solutions* is to evaluate the effectiveness of various traffic calming treatments on motorist's speeds. The research focuses on treatments appropriate for commercial and residential areas where speed limits are less than 35 miles per hour. The research also focuses on treatments and study locations to improve the safety of motorists, while maintaining and or improving the safety of pedestrians and bicyclists.

Specific objectives accomplished in the research include:

- To identify locations in New Jersey where traffic calming treatments may be beneficial to motorists, bicyclists and pedestrians;
- To determine appropriate traffic calming treatments for these locations; and
- To conduct a human factors study to evaluate the potential benefits and effectiveness of the proposed traffic calming treatment.

The tasks to be performed to achieve these objectives include:

<u>Phase I</u> Literature Search

<u>Task 1.</u> Make a comprehensive and detailed presentation on the results of the national and international literature search.

<u>Task 2.</u> Review accident records to determine the locations where reported speed related fatalities occurred and if these sites would benefit from the installation of speed reduction techniques

<u>Task 3.</u> Prepare and present a before and after study plan to the RSIP outlining the laboratory human factors study to determine the appropriate speed reduction techniques for each of the ten locations. Perform the human factors study.

Task 4. Prepare a detailed plan and budget for monitoring pedestrians, bicyclists, vehicle speeds, enforcement, parking, etc, at each location.

Task 5. Prepare quarterly reports, a Tech Brief and a final report, with appropriate tables, graphs and charts in hard copy version, pdf file format, Word97, and on CD ROM in accordance with NJDOT reporting requirements.

Organization

This report is organized into seven chapters. Chapter I provides an introduction to the research, stating the research objectives and the tasks performed to accomplish these objectives. Chapter II provides a literature review covering the state-of-the practice of traffic calming in the United States and abroad and the experiences of local and state Departments of Transportation using various traffic calming measures. Chapter III provides a discussion of the selection process used to identify locations where traffic calming measures may be beneficial. Chapter IV provides the results of the human factors study used to determine the effectiveness, suitability and potential of the traffic calming treatments to reduce speeds. Chapter V provides details of the evaluation and implementation plan for each of the study locations. Finally, Chapter VI summarizes the research and provides conclusions and next steps.

Chapter II

LITERATURE REVIEW

Background

Within in the last 30 years much has been written about traffic calming measures. The Institute of Transportation Engineers (ITE) has created a website that serves as a clearinghouse for many of these reports and articles (4). A total of 64 articles and reports are included in this website providing information on a variety of traffic calming devices. In addition, ITE has prepared a report, *Traffic Calming: State of the Practice* (2), containing a synthesis of traffic calming experiences in the United States and Canada. The report includes information on traffic calming in residential areas, high speed rural highways and transitions into rural communities.

A literature review was performed covering: (1) the state-of-the practice of traffic calming in the United States and abroad; (2) experience of local and state Departments of Transportation using various traffic calming measures; and (3) the legal and political concerns governing the installation of traffic calming measures on New Jersey roadways. The review sought to analyze, describe and critique pertinent domestic and international literature to determine the effectiveness, safety and political concerns related to the implementation of traffic calming measures.

History

New Jersey is cited in the Institute for Transportation Engineer's *Traffic Calming: State of the Practice* (2) as one of the first locations where traffic calming was implemented in the United States. In the late 1940's and early 1950's cities like Montclair, New Jersey, used street closures and traffic diverters as a means of reducing volumes to promote safer roadways. Since that time, traffic calming programs have been implemented in hundreds of jurisdictions across the country.

Traffic calming measures had their beginnings in the late 1960s in the Dutch city of Delft. To avoid cut-through traffic, streets were turned into "woonerven" or "living yards" which amounted to obstacle courses for motor vehicles. Streets were beautified to include tables, benches and parking designed to narrow the street. The primary purpose of traffic calming is to reduce vehicle speeds and volume to levels that are acceptable for the functional classification of the roadway or surrounding areas. Traffic calming can be used to reduce vehicle speeds, volumes, or both. Volume-control measures limit the access of vehicles and have as their primary purpose to discourage or eliminate through traffic. Some of the treatments used to control volume include: full street closures, half-closures, diagonal diverters, median diverters, median barriers, and forced-turn islands.

Traffic Calming Measures

This research focuses on traffic calming measures whose primary goal is to reduce vehicular speeds, while not adversely affecting bicyclists and pedestrians. These types of measures can be divided into three categories: vertical measures, horizontal measures, and road narrowings. Vertical measures use forces of vertical acceleration to discourage speed. Types of vertical measures include speed humps, speed tables, raised intersections, textured pavements. Horizontal measures use forces of lateral acceleration to discourage speed. Some of the control measures included in this category include traffic circles, roundabouts, chicanes, lateral shifts and realigned intersections. The third speed-control category is road narrowing. Road narrowing uses a psycho-perceptive sense of enclosure to discourage speed. Some of these control measures include neckdowns, center islands and chokers. The following provides a description of these measures, along with potential impacts and identified obstacles to their implementation.

Vertical Control Measures

Vertical control measures use forces of vertical acceleration to discourage speeding. Some of the measures included in this type of speed-control are speed humps, speed tables, raised intersections and textured pavements.

Speed Humps

Speed humps, or road humps, are rounded raised areas placed across the roadway and are, by far, the most widely used traffic control measure in the United States. This measure was originally developed in the early 1970s in Great Britain by the Transport and Road Research Laboratory (TRRL)[(5)]. Speed humps differ from speed bumps in their length and height. Speed bumps, which are more commonly used in parking lots and private roadways, are generally from 3 to 6 inches in height and from 1 to 3 feet in length. Speed humps have a length of either 12 or 14 feet in the direction of travel. ITE guidelines recommend a 12-foot hump as this length prevents passenger vehicles from straddling the hump thereby reducing the likelihood of bottoming out. The ITE design also calls for a height of 3 to 4 inches for speed humps. A four-inch high speed hump has been shown to produce rough driving conditions, therefore most communities limit the height of the speed hump to 3.5 inches.

Figure 1 shows typical speed hump dimensions. In this figure the speed hump has a parabolic shape. The speed hump, however, can take several additional shapes including a sinusoid, circle, or flat-top shape as shown in Figure 2. ITE recommends a parabolic shape, with an expected 85^{th} percentile speed of 15 to 20 mph. A 14-foot speed hump is also used with the same height and shape of the 12-foot hump. This

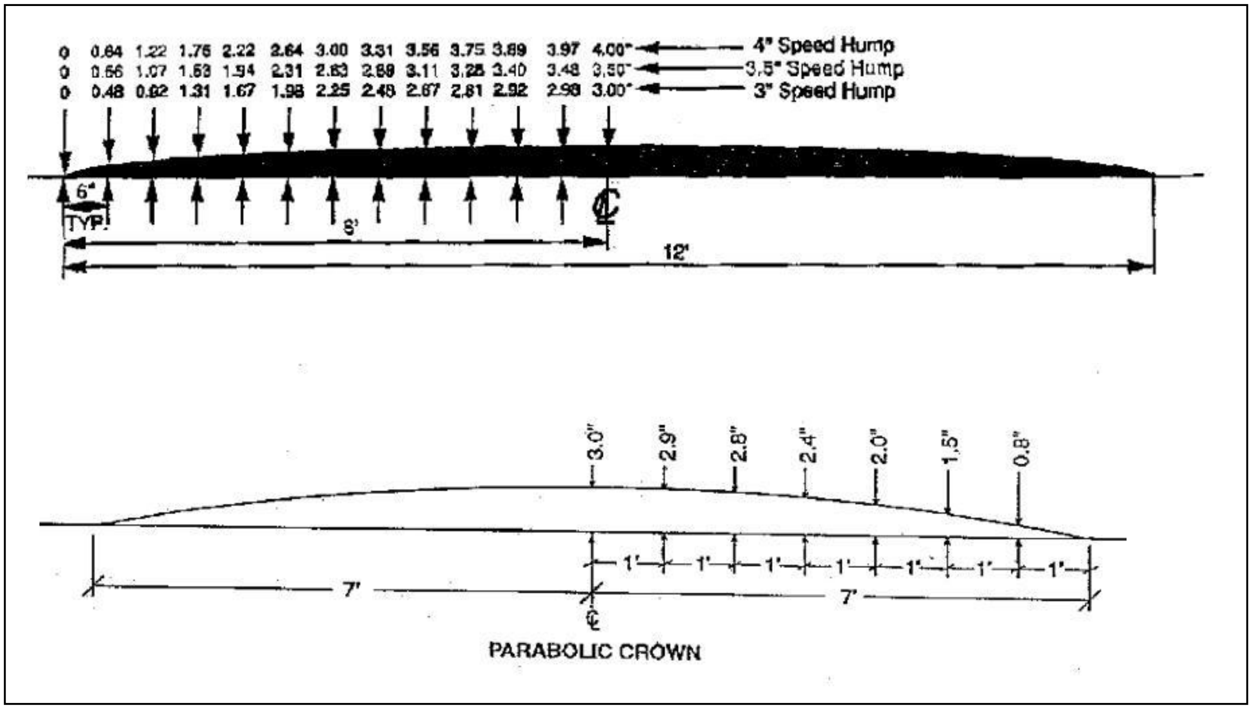

Figure 1. **12-foot and 14-foot Speed Hump Profile** [(2)]

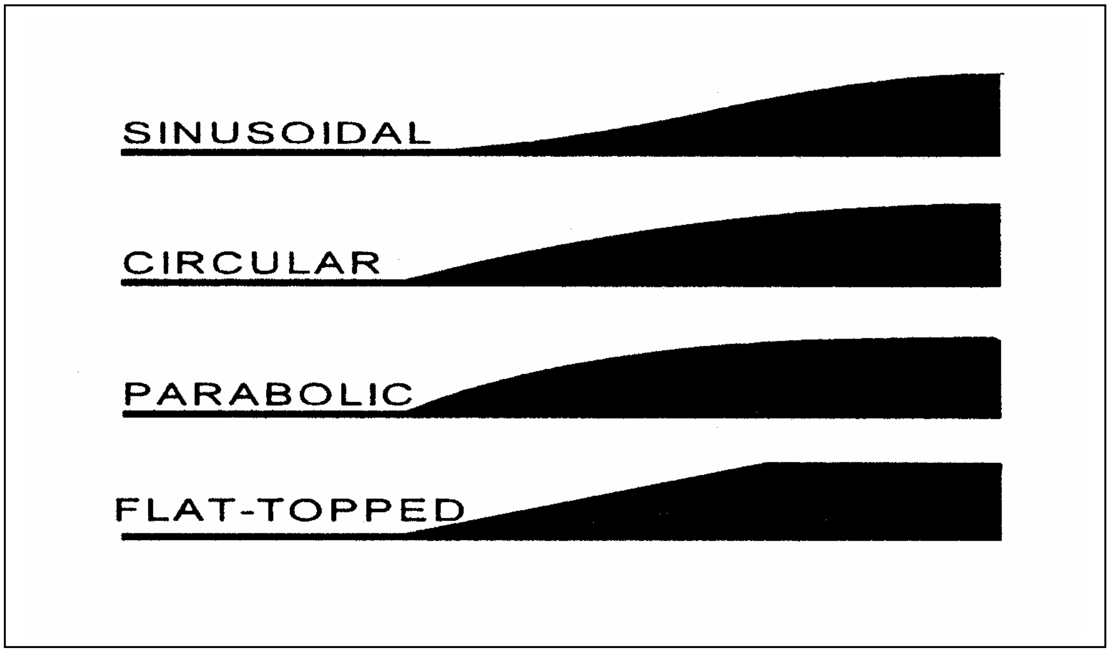

Figure 2. Speed Hump Rise (Source: ITE, 199?)

length results in a gentler ride with an 85th percentile speed approximately 3 mph higher than the 12-foot hump.

Although traffic speeds are decreased at speed hump locations, the speed reduction is limited to the location at the hump. To reduce speeds for a length of roadway, successive humps may be used. The speed reductions achieved by the speed humps must be weighed against some negative aspects associated with these measures. Air quality and energy consumption may be negatively impacted as a result of the speed humps as vehicles must reduce their speeds. These devices many times cause vehicles to divert to other roadways. Although passenger car occupants may experience a smooth ride over the speed hump, occupants of large trucks, buses and emergency vehicles may experience some discomfort while traveling over the devices.

On the positive side, speed humps have not been found to pose a safety hazard when they are properly designed and installed at appropriate locations. Accidents may actually remain constant after a speed hump is installed. The reduction in speeds, however, implies an improvement in safety on the roadway. ITE guidelines recommend that a traffic engineering study should be performed and alternative traffic control measures considered prior to installing the speed hump. Additional guidelines state that speed humps should only be installed where:

- Streets classified as "local";
- No more than 2 travel lanes or 40 foot pavement width;
- Horizontal curve of 300 foot radius or more;
- Vertical curve with adequate stopping sight distance;
- Grade of 8 percent or less;
- Posted speed limit of 30 mph or less;
- No more than 5 percent long wheel-base vehicles;
- Not on primary emergency response route or bus route; and
- Majority of residents support.

Speed humps are comparatively less costly than other traffic-calming devices with some estimated costs at $2000.

Gwinett County Department of Transportation in Georgia has installed over 730 speed humps [(6)]. Table 1 shows a before/after comparison of the 85th percentile speeds on roadways where speed humps were installed. The Table shows that the average reduction in speeds as a result of the speed humps is about 9 mph. The attitude of the county in installing speed humps is that they are "allowed" rather than recommended. Only after the speed humps have been requested by the local residents, and a speeding problem verified by the County's Department of Transportation, are speed humps considered for a location. The process used in implementing a speed hump involves a problem identification meeting with all interested parties, followed by a meeting to discuss traffic calming alternatives to the problem. The advantages, disadvantages, and costs associated with the alternatives are also discussed. A task

Table 1. Effect of Speed Humps on 85th Percentile Speed

Subdivision	Before	After	Change (mph)	Change (Percent)
Arrowhead Trail	38.6	28.2	-10.4	-27%
Bishops Lane (Kings Hill)	39.6	29.8	-9.8	-25%
Clearwater Drive	40.9	30.3	-10.6	-26%
Dakota	34.6	25.9	-8.7	-25%
Fitzpatrick Way	39.3	29.6	-9.7	-25%
Gwinn Drive	38.5	27.5	-11	-29%
Jane Road	35.5	27.9	-7.6	-21%
Kelley's Mill	37.2	30.4	-6.8	-18%
Mountain Manor	38	30.4	-7.6	-20%
Parker Woods	37.1	26.7	-10.4	-28%
Plantation Gate	35.5	30.1	-5.4	-15%
River Oak Village	37.6	29.4	-8.2	-22%
Rocky Hill Drive	47	32.5	-14.5	-31%
Rosedale Creek	37.9	29.1	-8.8	-23%
Sadlers Wook	40	34.1	-5.9	-15%
Simpson Mill	36.3	29.5	-6.8	-19%
Stillwood Forest	38.2	30.4	-7.8	-20%
Sweetwater Estates	38.1	25.9	-12.2	-32%
Waterford Park	38	28	-10	-26%
Weston Drive	37.1	27.1	-10	-27%
AVERAGES	**38.3**	**29.1**	**-9.1**	**-24%**

Source: Bretherton, 2001[6]

force is then formed to determine which options should be offered. Then through surveys, referendums, petitions, or even further meetings, a consensus on the final option is determined. Gwinett County has found this approach to installing speed humps to result in a successful program.

In an effort to reduce speeds without the need for increased police enforcement, the City of San Leandro, California used speed humps on five streets [7]. The city learned several lessons from this pilot traffic calming program including that the speed humps cause noise. From a survey of residents located within 150 feet of the hump, the respondents indicated that the speed humps resulted in increased noise from vehicles decelerating to and accelerating from the hump. The City used speed humps with two profiles: a gentler hump of 2.5 inches by 22 feet long; and a steeper hump of 3 inches by 12 feet. A second lesson learned was that steeper humps were more effective at reducing speeds and that this effect reduces further away from the speed hump.

Another lesson learned was that the speed humps, as well as one traffic circle used in the traffic calming pilot program, did not result in a change in volumes. Although, a high percentage of residents initially signed petitions requesting speed humps, the residents became reluctant to install the humps in front of their residence. The City required approval from the two property owners where the speed hump would be installed. The lesson learned from this was petitions should not be trusted. The City also learned that the humps became popular after they were installed with many requests for these humps to be installed in surrounding neighborhoods. Finally, the City learned that a policy must exist on where speed humps should be installed. Without such a policy it was possible for one street in the City to get four speed humps, when speeds on the street were not as high as other adjacent roadways.

In 1982, the City of Omaha(NE) began a speed hump program installing over 60 speed humps by 1989 [8]. To determine the impact of the speed hump after installation, the City mailed postcards to residents adjacent to the speed humps. Over 80 percent of the residents were in favor of the speed hump. The most common complaints included:

- Speeding still exists;
- Stop signs should be used instead of speed humps;
- Increase enforcement should be used to slow traffic, not speed humps;
- People drive on lawns to avoid speed humps;
- Increased noise level on street;
- Speed humps cause vehicle damage;
- Less on-street parking;
- Speed humps are not effective at speeds greater than 50 mph; and
- Concerns about emergency vehicle operation.

The City also investigated the perception that speed humps reduce accidents by comparing the number of accidents before and after the speed hump installation at 19 locations. The study showed a total of 30 accidents for the time period prior to the installation of the speed hump, compared to 40 accidents after the speed hump was installed with the majority of the accidents property damange only accidents. Prior to the speed humps, collisions with parked vehicles accounted for 23 percent of total accidents. After the installation, this type of accident accounted for 43 percent of accidents. Sideswipes also increased from 6 percent to 20 percent. The study concluded that a t-test comparison showed no significant difference between the before and after number of accidents. The study does point out, however, that accident reduction is not necessarily an expected result of speed humps.

Split Speed Bump

The City of Portland (OR) developed a modified speed bump to address concerns associated with emergency vehicles traversing speed bumps [9]. The concerns surrounded the slowing of fire engines or trucks on the City's 22-foot speed humps that impacted the Fire Bureau's 4-minute fire response time. The 22-foot speed hump was designed for roadways with high volumes and on transit or fire response routes. To accommodate this goal of the Fire Bureau, a split speed bump was used where two halves of a 22-foot speed hump were used separated by a long enough distance that an emergency vehicle could go through at 20 mph.

Speed Tables

Speed tables are modified speed humps with a flat-top designed to allow the wheelbase of a passenger car to rest on top. As speed tables provide a gentler slope than speed humps, there is a growing shift towards the use of more speed tables instead of speed humps. The gentle slope, however, results in speed reductions not as large for a speed table as compared to a speed hump. Speed tables result in an 85th percentile speed of between 25 and 30 mph.

The speed table may be constructed with brick or other textured materials and marked for pedestrian crossings, raised crosswalks or raised crossings. One design for the speed table is the Seminole County, Florida design which is 3 to 4 inches high and 22 feet long in the direction of travel. This design, as shown in Figure 3, has a 6-foot ramp on each side of the speed table, and a 10-foot flat-top area is provided. Gwinett County has a slightly altered design of this speed table using a straight ramp rather than a curved ramp. Figure 4 shows this alternative design.

The City of Boca Raton, Florida implemented a neighborhood traffic calming program where speed tables were the only traffic calming measure used [(10)]. Traffic calming measures were restricted to speed tables to eliminate costs associated with the construction of other, more expensive features, and to eliminate costs associated with hiring a consultant to perform the design work. The design used by the city includes an 18-foot roadway narrowing width, a 4-inch high speed hump with a length of 22 feet, 6-foot approach taper, 10-foot flat-top and a 6-foot departure taper profile. At one location where speed tables was implemented, the 85th percentile speed was reduced from 33 mph to 21 mph at the speed table and 28 feet 350 feet away from the speed table for one location. At a second location, the 85th percentile speed was reduced from 31 mph to 21 mph at the speed table to 28 mph 200 feet away from the speed table.

Horizontal Measures

Horizontal measures are designed to force drivers to reduce their speeds by impeding straight-through movements, causing drivers to shift horizontally. The following provides a brief description of these speed-control measures.

Traffic Circles

Traffic circles are raised islands, placed in intersections, around which traffic circulates, and are meant to prevent drivers from speeding through intersections. This measure is the most common horizontal measure and has been used in the United States since 1905 with the opening of Columbus Circle in New York City. The designs of circles used at the

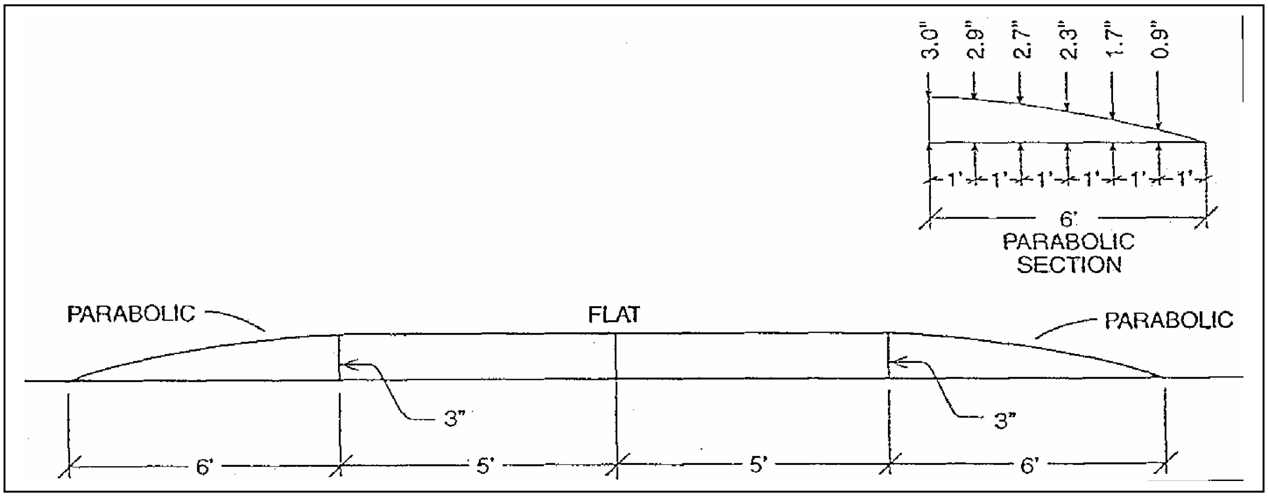

Figure 3. Original 22-foot Speed Table Profile (Reid, 1998)

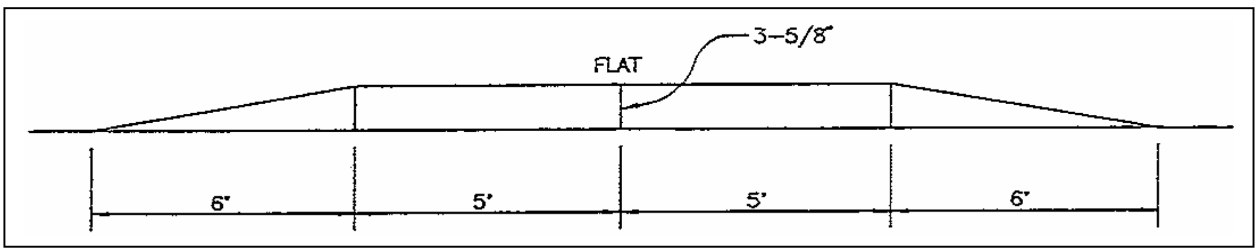

Figure 4. Alternative 22-foot Speed Table Profile (Reid, 1998)

time allowed for high-speed entering, merging and weaving vehicles with priority given to entering vehicles. This design and operation led to a high number of accidents and congestion. As a result, traffic circles have not being very widely used in the United States since the 1950s. Some of the problems associated with traffic circles were eliminated with the design of the modern roundabout. In this design, entering vehicles must yield to vehicles already using the traffic circle and smaller circular intersections were proposed with adequate horizontal curvature of vehicle paths so as to achieve slower entry and circulating speeds.

Traffic circles can have a traffic calming effect at intersections by impeding vehicles traveling straight-through the intersection. Traffic circles or neighborhood traffic circles are one of three types of circular intersection. Neighborhood traffic circles are used at intersections for purposes of traffic calming and/or for aesthetic purposes. Rotaries are a second type of circular intersection and refer to the old-style circular intersection used prior to the 1960s. Roundabouts, the third type of circular intersection, have characteristics such as they provide yield control of all entering vehicles, channelized approaches, and are designed in such a way so that travel speeds on the circulating roadway are less than 30 mph.

Ullman [11] reports that a minimum traffic circle diameter of 7 m (24 feet) should be used, with a recommended diameter of 8 to 10 meters. Some jurisdictions limit the use of traffic circles to roadways with volumes between 300 and 3000 vpd, and with an 85th percentile speed of more than 35 mph. Traffic circles can result in a reduction in speed of up to 13 km/h (8 mph). Construction costs can be as high as $6000 for each circle or can be significantly lower depending on the size and location of the circle.

Several concerns of note related to the use of traffic circles include the inability of large vehicles to turn around small-radius curves. Several alternatives exist for correcting this problem. One approach is to make the traffic circle partially or wholly mountable by adding what is referred to as a truck apron. As shown in Figure 5, the apron is the mountable portion of the central island adjacent to the circulatory roadway.

Other concerns surround pedestrians and bicyclists and the horizontal deflection of motor vehicles into pedestrian and bicycle crossing areas. For this reason, traffic circles are not used in some communities where pedestrians and bicycles are known to use the roadway. Finally, some have argued that traffic circles are not always effective in controlling vehicle operating speeds.

The use of small traffic circles for reducing vehicle speeds is prevalent in the city of Seattle, Washington. In 1988, the city had as many as 800 traffic circles on residential streets [12]. Similar types of circles have also been constructed in Arundel and Montgomery County, Maryland [13]. The traffic circle designs used in Maryland included considerable horizontal deflection resulting in entry speeds between 18 and 20 mph. Vehicles on the main roadways entering the traffic circle are given the right-of-way over vehicles entering from the side streets. Left-turns for smaller vehicles are made by traveling 270 degrees around the circle. Although a mountable curve four feet wide is used on the apron to accommodate the wheel track of trucks, large trucks cannot operate within the turning radius of the circles. As a result, large trucks make a left in front of the circle. To eliminate the problem with trucks making a left in front of the circle, roundabouts were instead constructed in Prince Georges County rather than constructing traffic circles. The total inscribed diameter for the roundabout is approximately 100 feet. This larger diameter is difficult to accommodate at a residential intersection.

The counties in Maryland where traffic circles and roundabouts were installed found these measures to be effective as an intersection traffic calming device. The 85th percentile speed was observed to decrease from 40 mph, before installation of the traffic circle, to 20 to 22 mph after the traffic circle.

Roundabouts

Roundabouts are similar to traffic circles, but are larger than traffic circles and are used more on roadways with higher volumes. Although guidelines on the design and operation of roundabouts have been developed, there are no standards on the design and operation of traffic circles. The FHWA publication on roundabouts categorizes six types of roundabouts based on the size and environment in which the roundabout is located [(14)]. The six categories include:

- Mini-roundabout;
- Urban compact roundabout;
- Urban single-lane roundabout;
- Urban double-lane roundabout;
- Rural single-lane roundabout; and
- Rural double-lane roundabouts.

Table 2 provides geometric and operational elements for each of the six roundabout categories. The mini-roundabout and urban compact roundabout may be appropriate for traffic calming purposes as these roundabout designs have a low number of approach lanes and low entry speeds. Figures 6 and 7 show typical designs of these two categories of roundabouts. These types of roundabouts are used where the average operating speed is 35 mph or less and where there is limited right-of-way for a larger roundabout. These types of roundabouts are perceived to be pedestrian-friendly as speeds are low and crossing distances are short.

Flannery and Datta [(15)] investigated the accident experience of existing roundabouts in the United States, to determine the safety performance of these measures. Thirteen roundabouts were studied in Maryland, Florida, Nevada, and California. Six of the thirteen roundabouts were studied for accident experience. The studied roundabouts were originally either stop controlled or signalized intersections, later retrofitted to roundabouts. Each of the roundabouts studied had one entry and circulating lane, the average daily traffic varied from about 4,000 to 18,000 vehicles per day, and each of the roundabouts had a posted speed limits of 35 mph except for one location in Maryland which had a posted speed limit of 45 mph. The study found that for a time period ranging between 1 and 3 years at each location, there were 35 accidents prior to the roundabout retrofit and 13 accidents after. A chi-square test showed that this was a statistically significant reduction in accident experience at the locations studied.

Chicanes

Chicanes are other horizontal measures used for traffic calming. Chicanes are curb extensions that create an S-shaped curve on a street. The effectiveness of this traffic calming measure is questioned as drivers may still speed and maintain a straight driving path if the vehicle crosses the centerline of the roadway. An alternative approach to

Table 2. Design Characteristics for Roundabouts [14]

Design Elements	Mini Roundabouts	Urban Compact	Urban Single-lane	Urban Double-Lane	Rural Single-Lane	Rural Double-Lane
Recommended Maximum Entry Design Speed	25 km/h (15 mph)	25 km/h (15 mph)	35 km/h (20 mph)	40 km/h (25 mph)	40 km/h (25 mph)	50 km/h (30 mph)
Maximum Number of Entering Lanes per Approach	1	1	1	2	1	2
Typical Inscribed Circle Diameter	13 m to 25 m (45 ft to 80 ft)	25 to 30 m (80 to 100 ft)	30 to 40 m (100 to 130 ft)	45 to 55 m (150 to 180 ft)	35 to 40 m (115 to 130 ft)	55 to 60 m (180 to 200 ft)
Splitter Island Treatment	Raised if possible, crosswalk cut if raised	Raised, with crosswalk cut	Raised, with crosswalk cut	Raised, with crosswalk cut	Raised and extended, with crosswalk cut	Raised and extended, with crosswalk cut
Typical Daily Service Volumes on 4-Leg roundabout (veh/day)	10,000	15,000	20,000	Special Calculations Required	20,000	Special Calculations Required

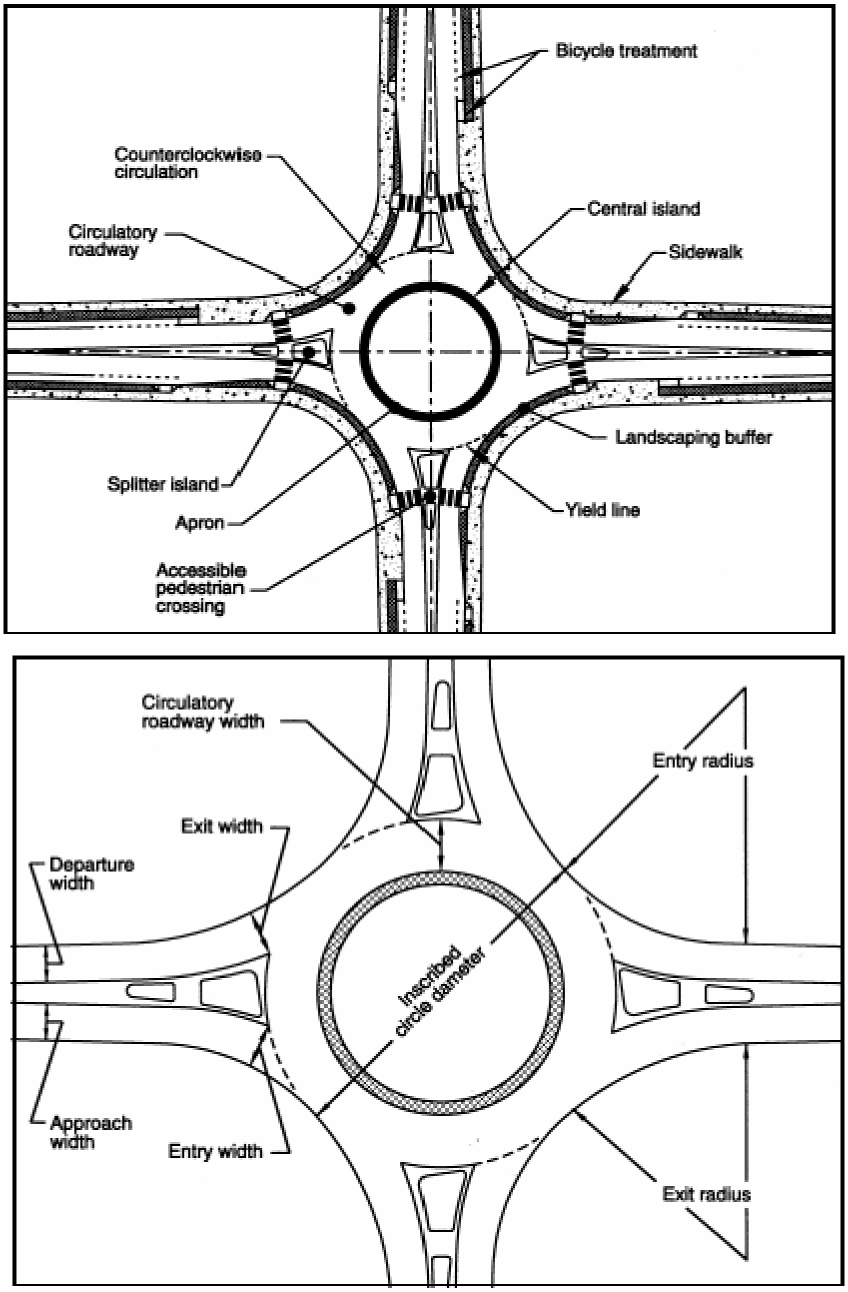

Figure 5. Key Features and Dimensions of a Roundabout [14]

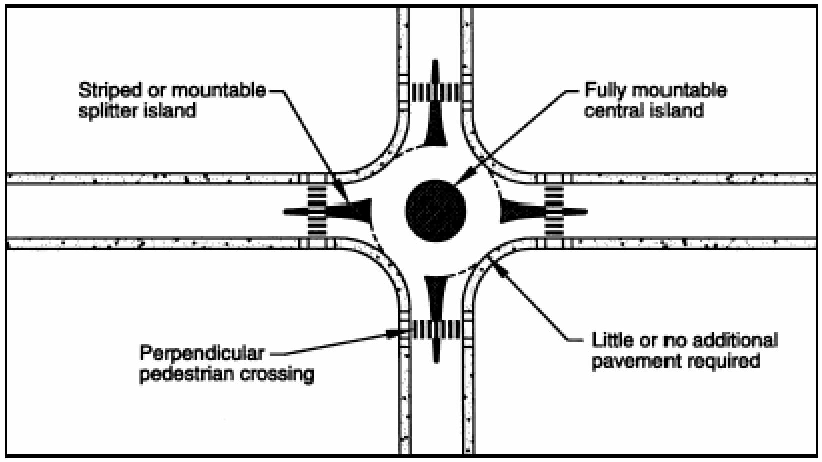

Figure 6. Typical Mini-roundabout [14]

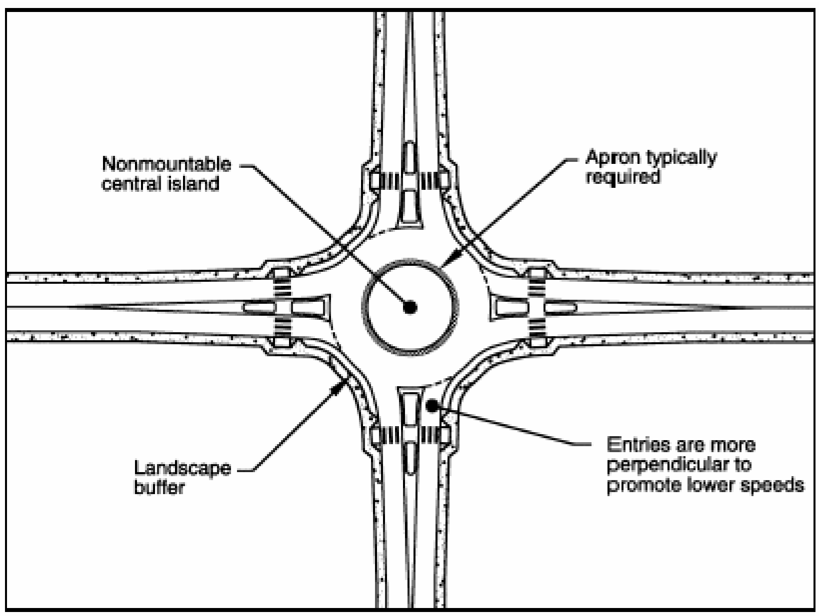

Figure 7. Typical Urban Compact [14]

creating chicanes besides extending the curb area is to alternate on-street parking from one side of the street to the other.

Road Narrowings

Road narrowing uses a psycho-perceptive sense of enclosure to discourage speed. Some of these control measures include neckdowns, center islands and chokers.

Center Island Narrowings

Center island narrowings are raised islands located along the centerline of a street that narrow the travel lanes at that location. These have been used on curves with a history of speeding and just downstream of intersections. This traffic calming measure can help pedestrians by providing a refuge for pedestrians crossing the roadway.

Center island narrowings were used as a traffic calming measure on an arterial roadway, Mohawk Road, in the town of Ancaster in Canada [16]. The island was placed directly on the centerline of the traveled way effectively creating a 2.0 m deflection in the path of travel. Combined with short tapers (10:1), the deflection created a transition that is smooth if traversed at 50 km/h, but uncomfortable if traversed at higher speeds. The width of the median varied between 3.0 m and 4.0 m. In addition to creating a horizontal deflection which forced vehicles to reduce their speeds, the center island reduced the pavement width from 8.6 m into two 4.3 m pieces creating a psychological effect that caused drivers to reduce their speeds. This effect was heightened by placing trees in the median and on the side of the road adjacent to the median.

A before-after study showed that the mean speed for the test section of road dropped from 54.0 km/h to 49.3 km/h. The study also showed that the percentage of vehicles exceeding the speed limit in the test section was also reduced from 67% to 47%. One of the concerns with this traffic calming measure is that the center island narrowings become an obstacle in the roadway with the potential for the median to be struck by vehicles.

Chokers

Another approach for reducing the travel way for vehicles is through the use of chokers. Chokers can take the form of pedestrian peninsulas where the travel width between the peninsulas is one or two travel lanes. The peninsulas can be placed parallel to each other, as shown in Figure 8, or at an angle as shown in Figure 9 [13].

Psycho-Perception Controls

Another category of speed-reduction measures is what has been referred to as psycho-perception controls[17]. Psycho-perception controls are defined by Smith[17] as

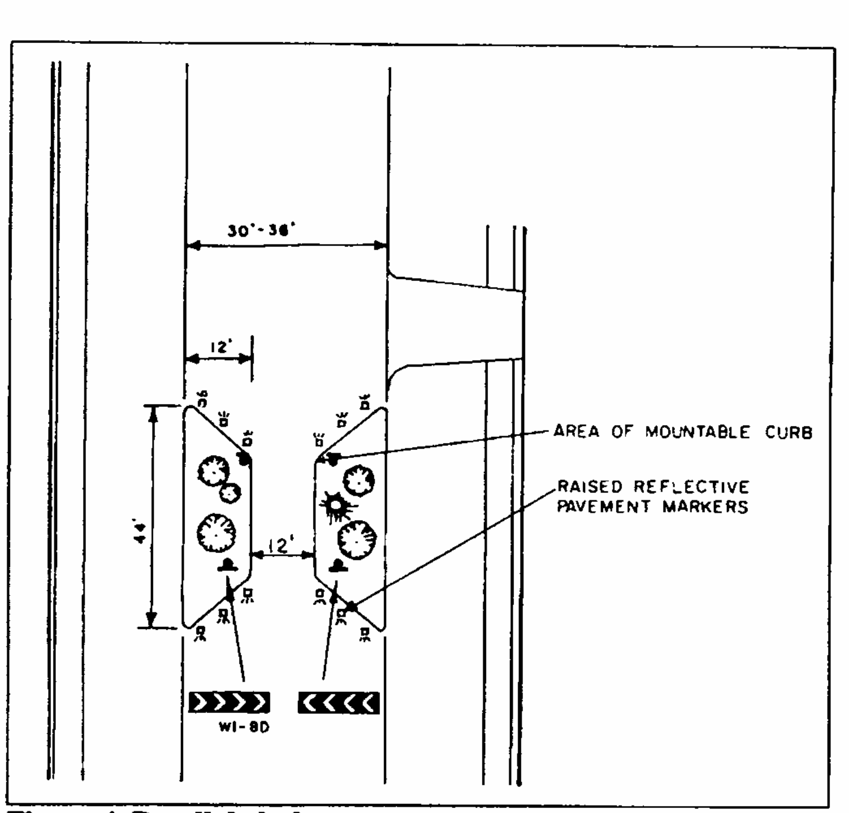

Figure 9. Parallel Choker(13)

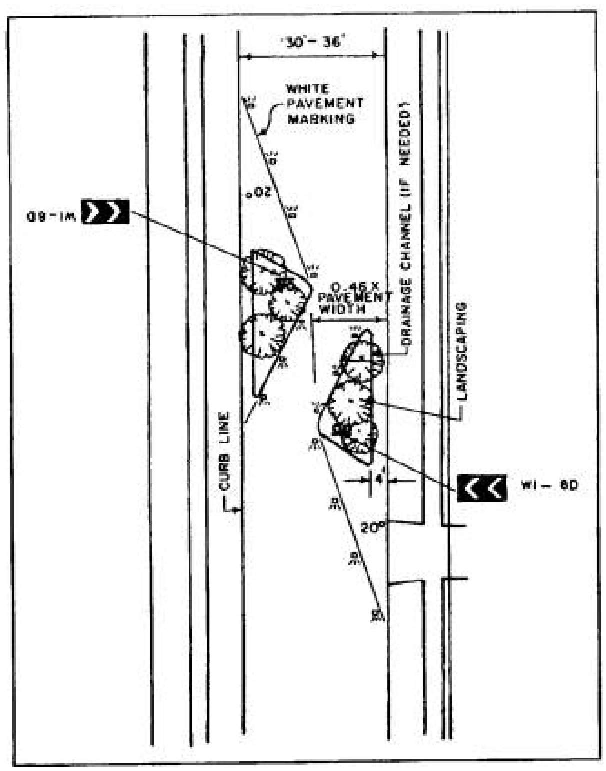

Figure 8. Twisted Choker(13)

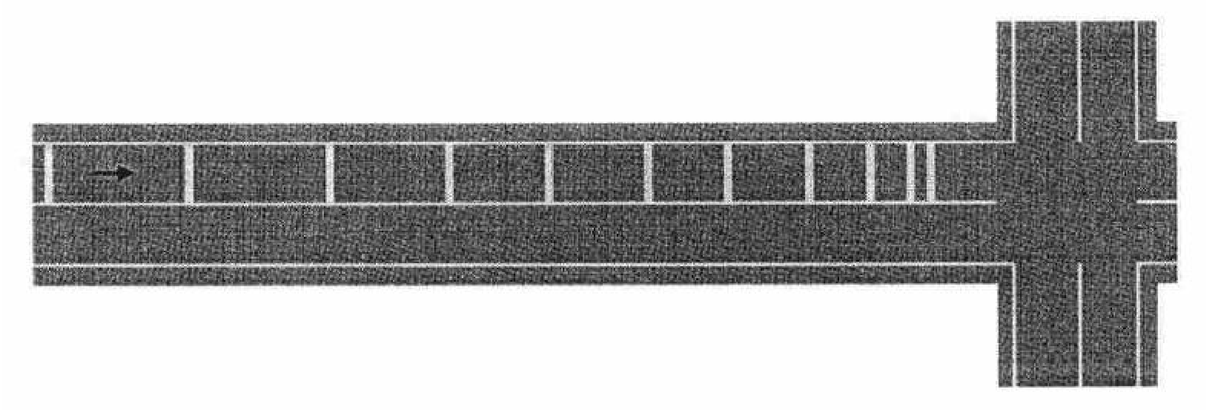

Figure 10. Example of Transverse Lines[1]

controls that "play upon ingrained driver responses to certain stimuli to induce or even trick them into a desired behavior pattern or to use materials and messages which heighten driver response". Some psycho-perception controls include the use of transverse lines with increasingly close spacing, odd speed limit signs, unique message signs, and speed-actuated flashing warning signs.

Edgelines

The use of edgelines located several feet from the pavement edge can have the effect of visually narrowing the roadway. No studies have been performed showing these edgelines reduce speeds, with some studies showing that vehicle operating speeds are as likely to increase with increasing striping.

Transverse Markings

Transverse lines are an attempt to subconscious affect a driver's choice of travel speed by altering the driver's perception of the current speed. Transverse lines, as shown in Figure 10, are high-contrast painted or thermoplastic strips placed across a driving lane, horizontal to the direction of travel[18]. These lines are typically placed at hazard locations and may be 60 cm wide and applied to section lengths of between 50 m to 400 m. The spacing between the lines decrease in the direction of travel.

Two explanations exist for why transverse markings result in decreasing roadway speeds. In the first case, a driver is believed to sense speed through the peripheral visual field. At constant speeds, the rate at which objects in the visual environment move through a driver's lateral peripheral visual field is constant. Transverse lines placed at decreasing distances distort the perception of speed, resulting in the driver's perception that speeds are increasing. To compensate for this sensation, drivers may decrease their speeds. Even as the vehicle is decelerating, the driver may interpret from the decreasing spacing of the transverse lines that speeds are decreasing as needed. The result would be an even greater reduction in speeds.

A second explanation exists as to why drivers reduce their speeds in the presence of transverse lines. In this case, it is believed that drivers underestimate speed when there is no high-contrast textured pattern streaming through their visual field at close range. In the presence of transverse lines, drivers have higher estimates of speed. This speed estimate is believed to be independent of whether the transverse lines are placed at decreasing intervals.

Godley[(18)], using a driving simulator, studied the impact of decreasing spacing of transverse lines on driver speed reduction. In the study, 24 drivers were asked to drive towards intersections with transverse lines with both constant spacing and with reducing spacing. The study found that for both conditions, speeds were reduced during the treatment area only. No significant differences were found in the amount of speed reduction with constant spacing or with reducing spacing.

Speed Management Techniques

Traffic calming techniques are primarily intended for application on lower speed roadways. On higher speed roadways, many of the traffic calming measures may not be appropriate. In this case, speed management techniques are used. The Texas Transportation Institute, in conjunction with the Texas Department of Transportation, developed the *Handbook of Speed Management Techniques*[(19)]. The handbook documents speed management techniques for collector and arterial roadways, in addition to providing information on traffic calming techniques on local streets. The speed management techniques discussed in the Handbook are categorized into four types of measures as shown in Figure 11. With the exception of roundabouts, all of the roadway design techniques are identified in the Handbook as appropriate for local residential streets. Neckdowns and central narrowing islands are identified as being appropriate for both local residential streets and collector/arterial roadways.

Although the focus of this research on design solutions, the following provides a brief description of additional speed management techniques appropriate for higher speed roadways.

Increased Enforcement

The conventional approach for increased enforcement involves the use of public safety officers and/or police personnel who target specific areas to encourage compliance of speed limits. This approach to reducing speeds has been found to be very effective, however, the adherence to the speed limit only exists as long as the enforcement is maintained.

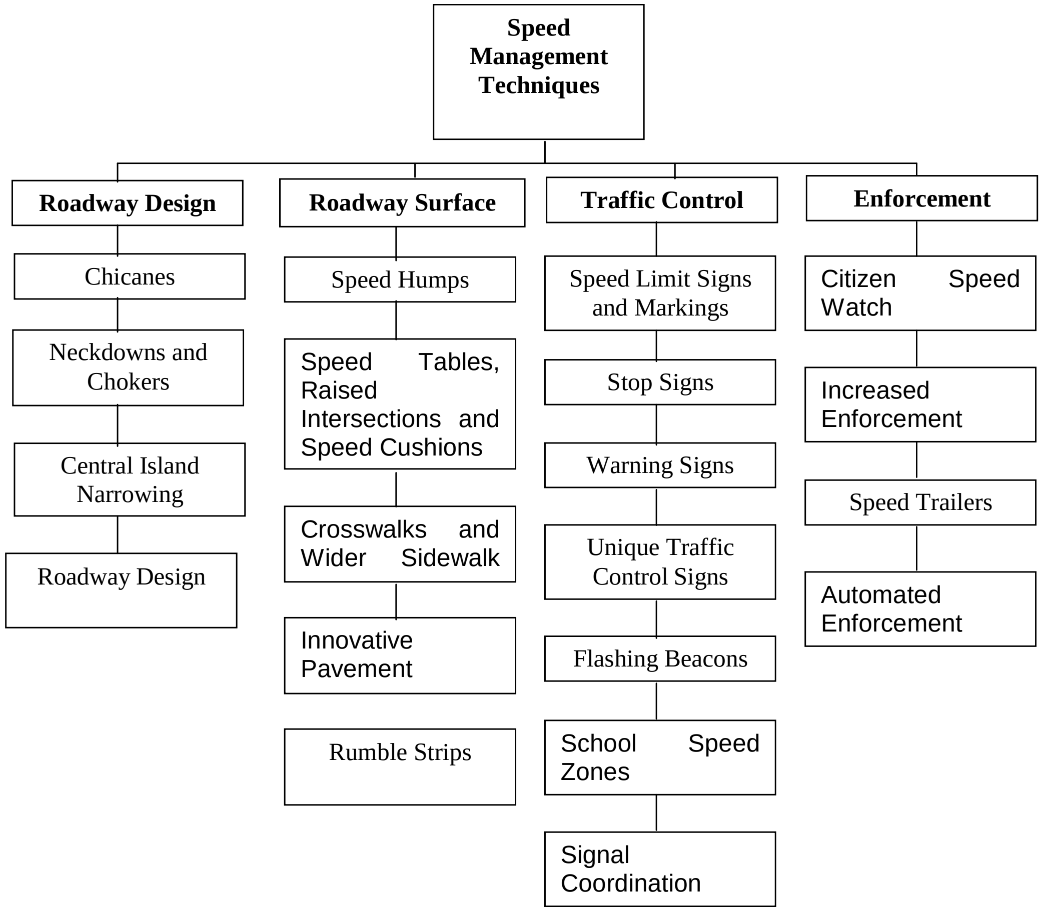

Figure 11. Speed Management Techniques[(19)]

Other enforcement techniques include: citizen speed watch programs; speed trailers; and automated enforcement. Citizen speed watch programs involved the use of local residents monitoring speeding vehicles within a community. Citizens may use a radar gun to record vehicle speeds, and using the license plates from speeding vehicles, the local police department sends letter to the registered owner of the vehicles informing them of the speed regulations and requesting their compliance. A citizen watch program was implemented in two subdivisions in Gwinett County, Georgia. The program resulted in the 85^{th} percentile speed reducing from 45 to 35 mph and the total number of vehicles exceeding 50 mph reduced from 56 to 13 daily.

Speed trailers, also known as mobile roadside speedometers and mobile radar trailers, measure and display the speed of approaching vehicles. In some applications, the driver's speed is posted next to the roadway's posted speed limit. Display boards are not used to enforce speed limits but to provide speed monitoring.

Automated Enforcement is be defined as "the use of image capture technology to monitor and enforce traffic control laws, regulations, or restrictions. Where enabling legislation authorizes the use of automated enforcement, the image capture technology negates the need for a police officer to directly witness a traffic offense" (Turner, 1998).

This enforcement strategy has been used for a variety of applications including speeding, red-light running at signalized intersections, railroad-grade crossing, ramp metering, high-occupancy vehicle lanes, lane-change and weight-restriction violations. The use of automated enforcement for speeding violations, however, is the most prevalent application.

Automated enforcement of speeding violations has been used by over 40 countries in Europe since 1970 [(20)]. Fewer applications of automated enforcement of speeds have been used in the United States. Blackburn [(20)] reports thirteen communities in Arizona, California and Utah have used automated speed enforcement equipment. Of the thirteen, six have been discontinued. The systems being used are installed in a patrol car and are operated with an officer present who makes notes on the speeding offenses photographed. Automated speed enforcement has had limited application in the United States primarily due to legislative constraints. *NCHRP Synthesis 219: Photographic Enforcement of Traffic Laws* [(20)] provides a discussion of the legal issues surrounding the use of automated speed enforcement devices and reports that many states continue to examine this strategy for use.

A study performed by the Automobile Club of Southern California investigated photo-radar and speed display boards, to determine their effectiveness in reducing speeds [(21)]. Photo-radar is one form of automated speed enforcement that uses a radar device to determine vehicle speed. If a vehicle exceeds a pre-determined speed, a photograph of the vehicle, its license plate, and possibly the driver is taken. The photographs are then used to identify registered vehicle owners through the state’s licensing agency and the owner is mailed a notice of violation. The study showed that both devices resulted in a reduction of speeds of between 3 and 4 mph and also reduced the number of vehicles traveling 10 mph or more over the posted limit. The study found that supplementing the display board with intermittent enforcement significantly increased the effectiveness of the device to reduce speeds. In addition, it was found that the display boards supplemented with enforcement provided substantial long-term effects of up to one week after the device was removed. As a result, the speed-display board was determined to be the more cost-effective of the two devices.

Flashing Beacons

Flashing beacons are used to alert drivers to conditions and potential hazards on the roadway. These beacons are typically used in conjunction with warning signs such as "Signal Ahead", "School Crossing", or some unique condition. The beacons require a power source, although solar power can be used. Flashing beacons most applicable on roadways with a high percentage of drivers unfamiliar to the roadway.

Speed Limit Signs and Markings

Speed limits that are established using an engineering study and the 85th percentile speed of vehicles on the roadway can result in driver's compliance of the speed limit. Installing the speed limit as a pavement marking on the roadway, or the use of specific words such as "Stop Ahead", can also be used to encourage speed reduction.

Speed or Radar Trailers

Speed or radar trailers, also known as speed display boards or mobile radar trailers, are mobile roadside devices that use radar to measure the speed of approaching vehicles. The speeds of approaching vehicles are displayed along side the legal speed of the roadway. Speed trailers have been shown to reduce speeds between 3 and 4 mph and can also reduce the number of vehicles traveling 10 mph or more over the posted limit. Supplementing the display board with intermittent enforcement significantly can also be used to increase the effectiveness of the speed trailer.

Rumble Strips

Rumble strips are pavement undulations placed across the driving lane, causing the vehicle to "rumble" or vibrate when crossing them. These devices, when used as a traffic calming measure, are generally placed in advance of a downstream traffic control device or hazardous or unique condition. There are primarily four types of rumble strips: milled, rolled, formed or corrugated, and raised. These types of rumble strips can either be raised or grooved into the pavement. Raised strips resemble speed humps of smaller dimensions and are constructed on existing pavement to form overlays at specified locations. Rumble strips have been used for speed control, however, the noise produced when vehicles travel over the rumble strip can create problems with residents of the community in which is placed

Traffic Calming Impacts

Although the impacts of traffic calming measures are highly dependent upon the roadway on which the traffic calming measure is implemented, there are some expected impacts of these measures. ITE's *Traffic Calming* report looked at 20 communities where traffic calming measures were implemented and based on the experience of these locations determined some expected speed impacts of traffic calming measures as shown in Table 2.

The table shows that speed humps have the greatest impact with an average reduction in the 85th percentile speed of 7.6 mph. Raised intersections, long speed tables, and traffic circles have the least impact with the average reduction in the 85th percentile speed of 3, 3.2 and 3.9 mph respectively.

Table 2. Speed Impacts Downstream of Traffic Calming Measures

		85th Percentile Speed (mph)		
Sample Measure	**Sample Size**	**Average After Calming**	**Average Change After Calming**	**Percentage Change**
12-foot humps	179	27.4 (4.0)	-7.6 (3.5)	-22 (9)
14-foot humps	15	25.6 (2.1)	-7.7 (2.1)	-23 (6)
22-foot tables	58	30.1 (2.7)	-6.6 (3.2)	-18 (8)
Longer tables	10	31.6 (2.8)	-3.2 (2.4)	- 9 (7)
Raised Intersections	3	34.3 (6.0)	- 3 (3.8)	- 1 (10)
Traffic Circles	45	30.3 (4.4)	-3.9 (3.2)	-11 (10)
Road Narrowings	7	32.2 (2.8)	-2.6 (5.5)	- 4 (22)
One-Lane slow points	5	28.6 (3.1)	-4.8 (1.3)	-14 (4)
Half-Closures	16	26.3 (5.2)	-6.0 (5.2)	-19 (11)
Diagonal Diverters	7	27.9 (5.2)	-1.4 (4.7)	- 4 (17)

Source: Ewing [2]

International Experience

Kallberg[22] reviewed the impact of urban speed-reducing traffic calming measures in different countries for a 25 year period. The speed-reducing measures considered for review in the study included: (1) reduction of speed limit; (2) roundabouts; (3) humps and speed cushions; (4) chicanes and road narrowings; (5) count-down signs and roundels; and (6) rumble strips and rumble areas. Reducing speed limits by 10 or 20 kmh had the impact of decreasing the mean speed by 1 to 5 km/h. The higher the initial speed, the greater the speed reduction after the speed limit was reduced. The conclusion, however, is that the impact of the speed limit reduction is a function of site specific features such as traffic volumes, presence of pedestrians, road geometry, and the environment. Roundabouts and mini-roundabouts had the impact of reducing speeds between 10 and 30 km/h. It was found that speed humps often reduced the speed of buses and other heavy vehicles more than they did other traffic. Where road narrowings were used, there was substantial variation in the reduction of speed. Some drivers found traveling at higher speeds through the road narrowing uncomfortable, while others seem to find it enjoyable. Count-down signs are used to warn drivers of an approaching speed zone 330, 200 and 100 meters before the speed limit begins. Roundels are elongated circles with the speed limit at the center, laid in white thermoplastic on the road surface at intervals throughout the roadway. Count-down signs did not prove to show any reduction in speeds, and roundels were found to be more effective for 40 mph rather than 30 mph roundels. Rumble strips and rumble areas were used on approaches to intersections or speed zones, to warn drivers of the changing roadway conditions. These measures were found to reduce the 85th percentile speed by an average of 5 km/h. Transverse rumble bars were more efficient in reducing speeds than transverse road markings.

Chapter III

SELECTION OF LOCATIONS FOR STUDY

Overview

One of the objectives of the research was to identify locations in New Jersey where traffic calming treatments may be beneficial to motorists, bicyclists and pedestrians. In this research, the original approach used for identifying locations for study was to perform a crash analysis to identify high pedestrian and bicycle crash locations. It became necessary to refine this approach as detailed crash analyses and field visits to high pedestrian and bicycle crash locations revealed that in many cases speeding was not always the primary cause of the pedestrian and bicycle crashes or that traffic calming would not be appropriate for the locations. The following provides a discussion of the selection process used to identify locations where traffic calming measures may be beneficial. The results of the pedestrian/crash analysis are also presented. Finally, a discussion of the locations visited and those selected for implementing traffic calming is provided.

Selection Process

As previously stated, the original approach for identifying locations for study was to perform a pedestrian and bicycle crash analysis. The crash analysis identified roadways with a high number of pedestrian and bicycle crashes over the entire length of the roadway. Using this approach, longer roadways would more likely to be identified as high crash roadways. For this reason, a secondary analysis was performed to identify specific mileposts, or one-mile segments, on the high crash roadways. In many cases the number of crashes identified at specific mileposts were very low, less than four crashes. Despite the low number of crashes at specific mileposts, the subsequent step of the process was to then perform a more detailed crash analysis identifying the conditions under which crashes at the locations occurred. Information gathered included the light condition, weather, and other characteristics for ensuring that crashes were not occurring as a result of factors not correctable using traffic calming measures. After completing this analysis, field visits were made to locations where the crash analysis indicated that speeding may be a factor contributing to pedestrian and bicycle crashes at the location.

The visits showed that many of the locations identified in the pedestrian and bicycle crash analysis were routes with substantial volumes during peak hour periods. These roadways would not be suitable for traffic calming measures based on a redesign of the roadway (e.g. speed humps/tables, center island, chicanes) as these types of measures are more appropriate for residential roadways. As a result, the process used for selecting candidate roadways was revised to include State roadways with a posted speed limit of 25 mph. These roadways were found to be treatable with traffic calming measures, and as many of these roadways were in the downtown areas of towns, pedestrians and bicycles used the roadways and would benefit from the reduced speeds obtained from the traffic calming measures.

Pedestrian and Bicycle Crash Analysis

The locations where traffic calming measures were initially considered for installation were identified through a fatal accident analysis. Crash data were evaluated to determine the nature of accidents involving pedestrians and bicycles on New Jersey roadways. Crash data from 1997 to 2001 were collected from the National Highway Traffic Safety Administration's (NHTSA's) Fatality Analysis Reporting System (FARS) database and from 1997 to 2000 for the New Jersey Department of Transportation (NJDOT) accident database. The FARS database contains data on all vehicle crashes in the United States that occur on a public roadway and involve a fatality in the crash. The database is searchable, allowing queries to be performed to obtain specific types of fatal crashes by State or for all States. NJDOT's accident database includes all reported accidents including fatal, injury or property damage for all counties and public roadways within the State.

In the FARS database, pedestrian and bicycle crashes were identified as crashes where the person type is stated as “pedestrian” or “bicyclist”. Table 3 shows the number of fatal pedestrian and bicycle crashes for 1997 to 2001 for New Jersey. On average, there were about 150 fatal crashes per year involving pedestrians and about 21 fatal crashes per year involving bicycles within the time period analyzed.

Light Conditions

As shown in Table 4, a majority of fatal pedestrian and bicycle crashes occurred during dark conditions. Thirty-six percent of fatal pedestrian and bicycle crashes occurred during daylight conditions. The remaining 64 percent occurred during “Dark”, “Dark but Lighted”, “Dawn” and “Dusk” light conditions with the largest percentage occurring during “Dark but Lighted” conditions which represent 47 percent of fatal pedestrian and bicycle crashes. A larger percentage of pedestrian crashes occurred during dark conditions when compared to bicycle crashes with fifty percent of pedestrian crashes occurring in “Dark by Lighted” conditions compared to 37 percent of bicycle crashes. Correspondingly, a higher percentage of bicycle crashes occurred during daylight conditions. Forty-five percent of bicycle crashes occurred during daylight conditions compared to 36 percent of pedestrian crashes. Although for both fatal pedestrian and

Table 3. Fatal Pedestrian/Bicyclists Crashes in NJ for 1997 – 2001

Year	Pedestrians	Bicyclists	Total
1997	146	23	169
1998	149	18	167
1999	168	25	193
2000	165	14	179
2001	133	26	159

Table 4. Percent of Fatal Pedestrian and Bicycle Crashes by Light Condition (1997 – 2001)

Light Condition	Pedestrian	Bicycles	Total
Daylight	35.9%	45.1%	35.8%
Dark	11.6%	11.5%	11.3%
Dark but Lighted	49.9%	37.2%	46.7%
Dawn	2.6%	1.8%	2.4%
Dusk	0.0%	4.4%	3.8%

Table 5. Percent of Fatal Pedestrian and Bicycle Crashes by Roadway Functional Classification (1997 – 2001)

Roadway Functional Classification	Pedestrian	Bicycles	Total
Rural Principal Arterial-Interstate	0.4%	0.0%	0.3%
Rural Principal Arterial-Other	3.5%	1.7%	3.3%
Rural Minor Arterial	1.6%	1.7%	1.6%
Rural Major Collector	1.4%	5.2%	1.9%
Rural Minor Collector	0.4%	0.0%	0.3%
Rural Local Road or Street	0.8%	2.6%	1.0%
Urban Principal Arterial-Interstate	5.6%	3.5%	5.3%
Urban Principal Arterial-Other Freeways	7.4%	0.9%	6.6%
Urban Other Principal Arterial	34.0%	35.7%	34.3%
Urban Minor Arterial	22.8%	20.9%	22.4%
Urban Collector	6.6%	7.0%	6.7%
Urban Local Road or Street	15.4%	20.9%	16.2%
Unknown Urban	0.1%	0.0%	0.1%

Table 6. Percent of Fatal Pedestrian and Bicycle Crashes by No. of Travel Lanes (1997 – 2001)

No. of Travel Lanes	Pedestrian	Bicycles	Total
1	0.7%	0.0%	0.6%
2	72.0%	82.3%	73.3%
3	14.8%	8.8%	14.1%
4	10.0%	8.0%	9.7%
5	0.9%	0.9%	0.9%
6	0.7%	0.0%	0.6%
7	0.9%	0.0%	0.8%

bicycle crashes a higher proportion of these crashes occur under dark conditions, dark conditions appear to result in a higher percentage of pedestrian crashes than bicycle crashes.

Roadway Characteristics

The majority of fatal pedestrian and bicycle crashes occur on urban roadways. Table 5 shows the functional classification of roadway on which fatal pedestrian and bicycle crashes occurred. Over 90 percent of these crashes occurred on roadways with an urban classification with the largest percentage occurring on “Urban Other Principal Arterial” which represents 34 percent of these crashes. Urban minor arterials are the functional classification with the second largest percentage of fatal pedestrian and bicycle crashes. Urban local roads or streets represent the roadway classification for 16 percent of fatal pedestrian and bicycle crashes. Fatal pedestrian crashes occur on similar functional classification roadways as fatal bicycle crashes with a few exceptions. As bicycles are not allowed on Interstates and most limited access roadways in New Jersey, little to no fatal bicycles accidents occurred on these roadways, although there are some fatal pedestrian crashes on these roadways.

The majority of fatal pedestrian and bicycle crashes occurred on dry, level roadways with two lanes. However, although 82 percent of fatal bicycle crashes occurred on roadways with two travel lanes, a lower percentage of 72 percent of fatal pedestrian crashes occurred on these roadways. As shown in Table 6, a higher percentage of fatal pedestrian crashes occur on roadways with three and four travel lanes compared to fatal bicycle crashes.

Fatal pedestrian and bicycle crashes occurred on roadways with a variety of speed limits. As shown in Table 7, the highest percentage of these crashes occurred on roadways with a speed limit of 25 mph. The next highest percentage of fatal pedestrian and bicycle

Table 7. Percent of Fatal Pedestrian and Bicycle Crashes by Speed Limit (1997 – 2001)

Speed Limit (mph)	Pedestrian	Bicycles	Total
25	35.1%	31.9%	34.6%
30	2.8%	2.7%	2.8%
35	11.6%	14.2%	11.8%
40	10.9%	9.7%	10.8%
45	8.3%	12.4%	8.8%
50	15.6%	23.9%	16.7%
55	13.6%	5.3%	12.5%
65	2.1%	0.0%	1.9%

Table 8. Top 20 Roadways with Highest Fatal Pedestrian and Bicycle Crash Frequency

Route	No. of Fatal Crashes			Speed Limit (mph)		No. of Lanes	
	Total	Pedestrian	Bicycle	Min	Max	Min	Max
US 9	31	27	4	25	55	2	4
GSP 444	22	22	0	55	65	2	5
US 30	20	13	7	35	50	2	4
US 1	19	18	1	40	55	2	4
RT 35	15	14	1	25	50	2	4
CR 501	14	14	0	25	35	2	6
RT 36	14	12	1	45	55	2	4
US 130	14	10	4	45	55	2	5
I-95	13	13	0	45	65	2	6
RT 17	13	13	0	25	55	2	3
US 46	12	11	2	30	50	2	4
US 206	11	10	1	25	50	2	3
I-78	10	10	0	55	65	2	7
I-80	10	9	1	55	65	2	7
CR 601	9	8	1	25	40	2	2
RT 18	9	8	1	35	55	2	4
RT 27	9	8	1	25	50	2	6
RT 33	9	9	1	0	55	0	4
US 322	9	8	1	45	55	2	4
US 22	8	8	0	25	55	2	3

Table 9. Top Locations with Highest Fatal Pedestrian and Bicycle Crash Frequency

Route	Roadway Name	City	County	No. of Fatal Crashes
-	12th Ave	Newark	Essex	4
CR 501	JFK Boulevard	North Bergen	Hudson	5
CR 501	Hudson Boulevard	Jersey City	Hudson	7
CR 601	Chancellor Avenue	Newark	Essex	4
-	Frelinghuysen Ave	Newark	Essex	5
RT 15	-	Wharton	Morris	5
RT 18	Memorial Highway	East Brunswick	Middlesex	6
RT 35	-	Ocean Township	Monmouth	4
RT 36	-	Hazlet	Monmouth	6
RT 440	-	Jersey City	Hudson	5
US 1	Tonnelle Avenue	North Bergen	Hudson	4
US 1	Herbert Highway	North Brunswick	Middlesex	4
US 1	-	Edison	Middlesex	5
US 30	Whitehorse Pike	Egg Harbor City	Atlantic	5
US 9	-	Marlboro	Monmouth	4
US 9	-	Old Bridge	Middlesex	4
US 9	Memorial Highway	Howell	Monmouth	5
US 9	River Road	Lakewood	Ocean	5

crashes occurred on roadways with a speed limit of 50 mph. Seventeen percent of fatal pedestrian and bicycle crashes occurred on these roadways.

Crash Locations

The top 20 roadways with the highest fatal pedestrian and bicycle crash frequency in New Jersey are shown in Table 8. The locations include three Interstate roadways, six state routes, 2 county roadways, 8 US Routes and the Garden State Parkway. US 9 and the Garden State Parkway (GSP) have the two highest fatal pedestrian and bicycle crash frequencies. The fatal pedestrian and bicycle crashes on these roadways are distributed throughout the length of the roadway. For US 9, the primary functional classification of the roadway where fatal pedestrian and bicycle crashes occur is "Urban Other Principal Arterial". For about half of the crashes, the posted speed limit of US 9 was 50 or 55 mph. Only 5 (17 percent) of the 22 fatal pedestrian/bicycle crashes on US 9 occurred on segments where the posted speed limit was 25 mph. Also provided are spot locations on a roadway with a high number of pedestrian and bicycle accidents in Table 10 and top locations with a posted speed limit of between 25 and 35 mph.

Table 10. Top 25-35 mph Locations with Highest Fatal Pedestrian and Bicycle Crash Frequency

Roadway	City	County	Speed Limit	No. of Lanes	No. of Fatal Crashes
CR 501	Jersey City	Hudson	25	2	5
US 30	Egg Harbor City	Atlantic	25	4	4
14th Ave	Newark	Essex	25	2	3
1st St	Elizabeth	Union	25	2	3
CR 501	North Bergen	Hudson	25	2	3
CR 705	Winslow	Camden	25	2	3
RT 27	Edison	Middlesex	25	2	1
	Elizabeth	Union	25	6	1
	Linden	Union	25	2	1
	Newark	Essex	25	2	1
	North Brunswick	Middlesex	25	2	1
	-	Middlesex	25	2	1
RT 36	Hazlet	Monmouth	25	2	1
	Hazlet	Monmouth	25	2	1
	Keyport	Monmouth	30	2	1
	Middletown	Monmouth	25	2	1
	Sea Bright	Monmouth	25	2	1
	Union Beach	Monmouth	25	2	1
RT 28	Plainfield	Union	30	2	1
	Cranford	Union	35	2	1
	Plainfield	Union	35	2	1
	Roselle Park	Union	35	2	1
	Somerville	Somerset	30	2	1
RT 33	Freehold	Monmouth	25	1	1
	East Windsor	Mercer	25	2	1
	Freehold	Monmouth	25	2	1
	Trenton	Mercer	-	-	1
	-	Mercer	25	2	1
RT 35	Perth Amboy	Middlesex	25	2	1
	Eatontown	Monmouth	25	2	1
	Ocean Township	Monmouth	25	2	1
	Perth Amboy	Middlesex	25	2	1
	Woodbridge	Middlesex	35	2	1
RT 17	Lodi	Bergen	35	2	1
	Lyndhurst	Bergen	25	2	1
	North Arlington	Bergen	25	2	1

Roadway	City	County	Speed Limit	No. of Lanes	No. of Fatal Crashes
	Wood Ridge	Bergen	25	2	1
RT 18	East Brunswick	Middlesex	25	2	1
	Old Bridge	Middlesex	25	2	1
	East Brunswick	Middlesex	35	2	1
	Old Bridge	Middlesex	25	2	1
RT 49	Millville	Cumberland	25	2	1
	Pennsville	Salem	35	2	1
	Salem	Salem	30	2	1
	-	Cumberland	25	2	1

Field Visit of High Crash Locations

Using the results from the pedestrian/bicycle crash analysis, locations for implementing traffic calming measures were initially identified. Of the locations identified, State routes were further studied to determine whether traffic calming may be appropriate in reducing the number of accidents. Some of the routes studied include: Route 27 (Middlesex County), Route 501 (Hudson County); Routes 33, 35, and 36 (Monmouth County); Route 28 (Union County) and Routes 18 and 35 (Middlesex County). Using the NJDOT crash database, which includes not just fatal crashes, but all property damage and injury crashes, a crash analysis was performed to ensure that neither lighting nor weather was the primary contributing factor to crashes at each location.

Field visits were then made to these locations to gather geometric and land-use information and to determine whether the locations were appropriate for traffic calming. The visits showed that many of the locations identified in the crash analysis were routes with substantial volumes during peak hour periods and higher speeds during off-peak periods. These roadways were determined not be suitable for using "traditional" traffic calming measures based on a redesign of the roadway (e.g. speed humps/tables, center island, chicanes) as these types of measures are more appropriate for residential roadways.

State Roadways with 25mph Speed Limit

Identifying locations for implementing traffic calming measures using a crash analysis did not ensure that speeding was a contributing factor in the crashes. For this reason, an alternative approach was taken to identify locations for implementing traffic calming measures. The approach involved identifying State Routes with a posted speed limit of 25 mph and not zoned as school zones. Table 10 shows these roadways identified using the "State Road Speed Limits" website found on the NJDOT web pages. Locations identified using this approach were deemed appropriate for traffic calming as

Table 11. State Routes Posted at 25 mph

Route	Roadway Name	City	County	MP From	MP To	No. of Lanes	Functional Classification	Pavement Width	Number of Signalized Intersections
N.J. 27	Nassau Street	Princeton	Mercer	0.00	0.81	2	Urban Principal Arterial	44 - 52	6
N.J. 28	North Avenue	Westfield	Union	19.45	20.12	4-5	Urban Principal Arterial	40-60	4
N.J. 28	North Avenue	Cranford	Union	21.97	22.62	2	Urban Principal Arterial	36-40	5
N.J. 49	W. Broad Way	Salem	Salem	8.87	9.3	2	Urban Principal Arterial	45-56	2
N.J. 49	Main Street	Millville	Cumberland	36.02	36.78	2	Urban Principal Arterial	24-48	5
Route 54	12th Street/ Bellevue Avenue	Hammonton Town	Atlantic	10.318	10.988	2	Urban Minor Arterial	34-48	3
Route N.J. 57	Morris and Essex Tpk.	Washington	Warren	10.52	11.01	2	Urban Principal Arterial	48	2
Route 67	Palisades Ave/ Lemoine Ave	Fort Lee	Bergen	0.0	1.86	4	Urban Minor/ Principal Arterial	30-56	4
Route 71	Eight Street/	Belmar	Monmouth	5.41	5.56	2	Urban Minor Arterial	25-60	4

Table 11. State Routes Posted at 25 mph

Route	Roadway Name	City	County	MP From	MP To	No. of Lanes	Functional Classification	Pavement Width	Number of Signalized Intersections
	Main Street								
Route 88	Main Street	Lakewood	Ocean	0.00	0.20	2	Urban Minor Arterial	30-44	2
N.J. 94	WWII 94th Hwy.	Newton	Sussex	22.22	22.42	2	Urban Minor Arterial	27-42	0
Route 161	Clifton Ave	Clifton	Passaic	0.00	0.20	4	Urban Minor Arterial	34-68	1
Route 166	Main Street	Dover	Ocean	1.08	1.48	2	Urban Minor Arterial	34-44	2
Route 172	George Street/ Clifton Avenue	New Brunswick	Middlesex	0.00	0.81	2-4	Urban Minor Arterial	24-60	3
U.S. 206	Disabled Amer. Vet. Hwy.	Trenton	Mercer	44.50	45.01	2-4	Urban Principal Arterial	30-48	4
U.S. 206	Disabled Amer. Vet. Hwy.	Princeton	Mercer	53.94	54.28	3	Urban Principal Arterial	30	2
U.S. 206	Disabled Amer. Vet. Hwy.	Newton	Sussex	108.30	109.32	2-6	Urban Principal Arterial	30-72	3

these roadways, although having high volumes, are intended to be low speed roadways. The following provides a discussion of each of these roadways.

Route 27 (Nassau Street)

Figure 12. Route 27, Princeton, NJ

The study roadway, shown in Figure 12, is Route 27(Nassau Street), located in the town of Princeton in Mercer County. Nassau Street is a two lane roadway with parking provided on both sides of the roadway. The roadway is located adjacent to the Princeton University campus in the heart of the business district. During peak periods, there is congestion with long queues existing at signalized intersections and occasional double-parked vehicles. There is a substantial amount of pedestrian activity with bicyclists also using the roadway. Striped crosswalks are provided at all signalized intersections, with several mid-block crosswalks included. High speeds are not as critical during the peak periods because of the high levels of congestion, however, the use of mid-block pedestrian crossings, suggest that there may be a need for additional treatments to the roadway to ensure safe pedestrian movement on the roadway.

Table 12 shows the crash statistics for all vehicular crashes on the 25-mph segment of the Route in 2003. Compared to the entire route, the 25-mph segment of the route has higher crash rates with one of the five fatal crashes that occurred in 2003 on this route occurring within the 25-mph roadway segment. The crash statistics indicate crash activity that may be treatable using traffic calming measures.

Table 12. Crash Statistics for all Vehicles on Route 27 (0.0 - 0.81)

MP From	MP To	Section Length	AADT	Total Accidents	Fatals	Injury	Prop Dam	Wet Weather	Acc Rate
0.00	0.20	0.20	19,270	25		3	22	5	17.77
0.20	0.40	0.20	19,270	25		6	19	8	17.77
0.40	0.60	0.20	19,270	18		3	15	6	12.80
0.60	0.80	0.20	19,270	14		3	11	4	9.95
0.80	1.06	0.26	19,270	3	1		2		1.64
1.06	1.26	0.20	11,721	9		1	8	3	10.52
Total	Route	37.15	20,783	2,093	5	709	1379	606	7.43

Route 28 (North Avenue)

Figure 13. Route 28, Westfield, NJ

The study roadway, shown in Figure 13, is Route 28 (North Avenue), located in the towns of Westfield and Cranford Township. Both cities are located in Union County. In Westfield, North Avenue is a four-lane roadway located in the city's downtown business district. Parking is not provided on much of North Avenue, with parking provided in large municipal lots located adjacent to the roadway. The field study showed that the poles for the parking meters were still in place, suggesting that metered parking was available on the roadway and had been recently removed. There is some pedestrian movement and bicycling in the area. The pedestrian movement, however, seems to be in the area of the municipal parking lots. The town's NJ Transit station is located within this 25 mph speed zone and suggests that pedestrian and bicycling activity may be high during the AM and PM peak period. The roadway has high volumes and for this reason speeding may not be a predominant cause for motor vehicle crashes in this area.

A Lord and Taylor's retail store is located on Route 28 in a 30 mph speed zone several hundred feet away from the 25 mph speed zone. A mid-block pedestrian crossing is provided at this location for pedestrians crossing Route 28 to access the store. This location may be a good location for implementing traffic calming.

Table 13 shows the crash statistics for all vehicular crashes on the 25-mph segment of the Route in 2003. Compared to the entire route, the 25-mph segment has significantly higher crash rates. The crash statistics indicate crash activity that may be treatable using traffic calming measures.

Table 13. Crash Statistics for all Vehicles on Route 28 (MP 19.45 - MP 20.12)

MP From	MP To	Section Length	AADT	Total Accidents	Fatals	Injury	Prop Dam	Wet Weather	Acc Rate
19.40	19.56	0.16	10,165	8		2	6	3	13.48
19.56	19.63	0.07	10,165	21		2	19	4	80.86
19.63	19.72	0.09	10,165	2		1	1		5.99
19.72	19.92	0.20	10,165	16		6	10	2	21.56
19.92	20.06	0.14	10,165	14		2	12	2	26.95
20.06	20.26	0.20	10,165	5		2	3		6.74
Total	Route	21.77	14,126	885	3	274	608	198	7.88

Figure 14. Route 28, Cranford, NJ

The second location studied on Route 28 is the 25 mph speed zone in Cranford Township, shown in Figure 14. The roadway has two travel lanes with parking provided on both sides of the roadway. Parking, in some locations is angled. At this location, North Avenue has several horizontal curves restricting sight distance to vehicles as they approach the traffic signals located in the area. There is a significant amount of pedestrian and bicycling activity in this area. This is due, in part, to the recent completion of a Streetscapes Project in this area, the location of several businesses, and the presence of the town's train station at this location. The field visit identified about 20 bicycles parked at the train station indicating that bicycling is a significant portion of the peak period traffic in this location. The high number of pedestrians and bicyclists and the potential problems with limited sight distance make this a good location for studying the potential of traffic calming to reduce motor vehicle crashes.

Table 14. Crash Statistics for all Vehicles on Route 28 (MP 21.97 - MP 22.62)

MP From	MP To	Section Length	AADT	Total Accidents	Fatals	Injury	Prop Dam	Wet Weather	Acc Rate
21.67	21.70	0.03	10,165	2		1	1		17.97
21.70	21.90	0.20	13,034						
21.90	22.10	0.20	13,034						
22.10	22.30	0.20	13,034	7		7		3	7.36
22.30	22.50	0.20	13,034	2		2		2	2.10
22.50	22.70	0.20	13,034	2		2			2.10
Total	Route	21.77	14,126	885	3	274	608	198	7.88

Table 14 shows the statistics for all vehicular crashes on the 25-mph segment of the Route in 2003. Compared to the entire route, the 25-mph segment has generally similar or lower crash rates. The low number of crashes on the route does not support major safety improvements for the route and traffic calming may not be entirely appropriate for this location.

Route 57 (Morris and Essex Turnpike)

Figure 15. Route 57, Washington, NJ

The study roadway, shown in Figure 15, is Route 57 (Morris and Essex Turnpike) located in Washington Borough in Warren County. The roadway runs through the downtown section of Washington with several small businesses and residences on the outskirts of Route 57. The roadway has one travel lane in each direction with parking allowed on both sides of the roadway. During the field visit, there were few pedestrians using the roadway. One roadway sign stating "No bicycle riding on the sidewalk from this point on" prohibited bicycle riding on the sidewalk in the downtown area. This regulation restricts bicyclists to the travel lanes of Route 57 which was observed to be narrow and heavily traveled. Volumes on Route 57 are high with long queues observed at the signalized intersections within the study area. As a result of heavy volumes, speeding was not observed and may not be a factor except during off-peak periods.

Table 15 shows the crash statistics for all vehicular crashes on the 25-mph segment of the Route in 2003. Compared to the entire route, the 25-mph segment has slightly higher crash rates. The low number of crashes on the route does not support major safety improvements for the route and traffic calming may not be entirely appropriate for this location.

Table 15. Crash Statistics for all Vehicles on Route 57 (MP 10.52 - MP 11.01)

MP From	MP To	Section Length	AADT	Total Accidents	Fatals	Injury	Prop Dam	Wet Weather	Acc Rate
10.41	10.65	0.24	17,792	8		2	6	2	5.13
10.65	10.85	0.20	15,877	5			5	1	4.31
10.85	11.01	0.16	15,877	9		1	8	3	9.71
Total	Route	21.10	13,286	205	1	66	138	57	2.00

Route 67 (Palisades Avenue/Lemoine Avenue)

Figure 17. Route 67, Fort Lee, NJ

Figure 16. Route 67, Fort Lee, NJ

The study roadway, shown in Figures 16 and 17, is Route 67 (Palisades Avenue/Lemoine Avenue) located in Fort Lee in Bergen County. The roadway has four travel lanes with parking provided on most portions of the roadway. The segment where the speed limit is 25 mph is long, extending for over a 1.5 miles. Within this 1.5 mile long segment, the roadway characteristics and the area type changes. Portions of the roadway are located in mostly urban residential areas with large apartment complexes, to downtown business areas. The roadway crosses the toll plaza to the George Washington Bridge and, as a result, there can be substantial levels of congestion during peak periods. For this reason, speeding may not be observered during the peak period, however, the presence of police vehicles monitoring the roadway during the field visit indicates that speeding may be a factor during off-peak periods. Fort Lee High School is also located on the roadway and for this reason, Route 67 should be considered for implementing traffic calming.

Table 16 shows the crash statistics for all vehicular crashes on the 25-mph segment of the Route in 2003. Compared to the entire route, the 25-mph segment of the route has similar crash rates. Based on the crash statistics, traffic calming may not be entirely appropriate, however, coupled with field visits to the location which indicated a speed problem does exist during off-peak hours, this location should be considered for further study.

Table 16. Crash Statistics for all Vehicles on Route 67 (MP 0.00 - MP 1.86)

MP From	MP To	Section Length	AADT	Total Accidents	Fatals	Injury	Prop Dam	Wet Weather	Acc Rate
0	0.2	0.20	20,190	6		3	3	2	4.07
0.2	0.4	0.20	20,190	9		2	7	3	6.11
0.4	0.55	0.15	20,190	6		2	4	1	5.43
0.55	0.75	0.20	20,190	8		3	5	4	5.43
0.75	1.01	0.26	20,190	10		1	9	4	5.22
1.01	1.13	0.12	20,190	11		2	9	3	12.44
1.13	1.29	0.16	20,190	1		1			0.85
1.4	1.6	0.20	20,190	13		5	8	5	8.82
1.6	1.78	0.18	20,190	6		3	3	3	4.52
1.78	1.86	0.08	20,190	2			2	1	3.39
Total	Route	1.75	20,190	72		22	50	26	5.58

Route 94 (WWII 94th Highway)

Figure 18. Route 94, Newton, NJ

The study roadway, shown in Figure 18, is Route 94 (WWII 94th Highway) located in the town of Newton in Sussex County. The 25 mph speed zone is relatively short extending from milepost 22.25 to milepost 22.42. Within the study area, there is one travel lane in each direction with residences located off of the study roadway. Route 94 combines with Route 206 in Newton Township with significant volumes. No pedestrian or bicycling activity was seen on the Route 94 section. However, in the downtown portion of Route 94/U.S. 206 location, several pedestrians were observed.

Table 17. Crash Statistics for all Vehicles on Route 94 (MP 22.22 - MP 22.42)

MP From	MP To	Section Length	AADT	Total Accidents	Fatals	Injury	Prop Dam	Wet Weather	Acc Rate
22.16	22.36	0.20	5,665	7			7	1	16.93
22.36	22.47	0.11	5,665	4		1	3	1	17.59
Total	Route	43.07	7,665	372		95	277	115	3.09

Table 17 shows the crash statistics for all vehicular crashes on the 25-mph segment of the Route in 2003. Compared to the entire route, the 25-mph segment has higher crash rates. The short segment of roadway impacted by the 25-mph speed limit, and the relatively lower number of crashes in this area does not suggest that this roadway be considered for treatment using traffic calming.

Route 161 (Clifton Avenue)

Figure 19. Route 161, Clifton, NJ

The study roadway, shown in Figure 19, is Route 161 (Clifton Avenue) located in the town of Clifton and in Passaic County. The roadway has four travel lanes with parking prohibited on both sides of the roadway. The 25 mph speed zone at this location is relatively short extending from milepost 0.00 to 0.18 (950 feet). Much of this segment of the roadway is the approach/departure lane to a major intersection at Route 161 (Clifton Avenue) and Allwood Road. The roadway is located adjacent to the Richfield Shopping Center and a large apartment complex. The presence of a mid-block crossing connecting the shopping center to one section of the apartment complex, suggests pedestrian activity between the two areas, although during the field visit no pedestrians were seen using the crosswalk. Vehicles approaching and departing the intersection of Clifton Avenue and Allwood Road appeared to be traveling above the 25 mph speed zone. Coupled with possible pedestrian activity in this are, Route 161 has good potential for a traffic calming measure to be effective in improving the safety of the roadway.

Table 18. Crash Statistics for all Vehicles on Route 161 (MP 0.00 - MP 0.20)

MP From	MP To	Section Length	AADT	Total Accidents	Fatals	Injury	Prop Dam	Wet Weather	Acc Rate
0	0.05	0.05	15,587						
5	0.25	0.2	15,587	1			1		0.88
Total	Route	1.10	15,587	14		2	12	8	2.24

Table 18 shows the crash statistics for all vehicular crashes on the 25-mph segment of the Route in 2003. Only one crash occurred within the 25-mph roadway segment of this route in 2003. For this reason, Route 161 is not being considered for treatment using traffic calming.

Route 172 (George Street)

Figure 20. Route 172, New Brunswick, NJ

The study roadway, shown in Figure 20, is Route 172 (George Street) located in New Brunswick in Middlesex County. George Street is located adjacent to the Rutgers University New Brunswick campus. The roadway has between two and four travel lanes with no parking allowed on either side of the roadway. Currently, "Yield to Pedestrian" stantions are located in the roadway along with signing indicating that vehicles are approaching the dormitories. The portion of the roadway zoned at 25 mph, and under the jurisdiction of NJDOT, is located between the dormitories and the main campus area. The location of the roadway, coupled with the low volume, suggests that speeding may be a concern and that it is critical that vehicles maintain the 25 mph speed limit on this roadway.

Table 19 shows the crash statistics for all vehicular crashes on the 25-mph segment of the Route in 2003. Compared to the entire route, the 25-mph segment of the route has similar crash rates. The short segment of roadway impacted by the 25-mph speed limit, and the relatively lower number of crashes in this area does not suggest that this roadway be considered for treatment using traffic calming. The roadway, however, is located adjacent to the a dormitory on the Rutgers campus and field observations indicate the potential for speeding in this area. For this reason this location is being considered for treatment using traffic calming.

Table 19. Crash Statistics for all Vehicles on Route 172 (MP 0.00 - MP 0.81)

MP From	MP To	Section Length	AADT	Total Accidents	Fatals	Injury	Prop Dam	Wet Weather	Acc Rate
0.00	0.20	0.20	14,567	2			2		1.88
0.20	0.36	0.16	14,567	1		1		1	1.18
0.36	0.55	0.19	14,567						
0.55	0.81	0.26	14,567	3			3	2	2.26
Total	Route	0.81	14,567	6		1	5	3	1.39

U.S. 206

The study roadway, shown in Figures 21 and 22, is U.S. 206 at three locations including: Trenton (Mercer County), Princeton (Mercer County) and Newton (Sussex). In the 25 mph speed zone in Trenton, the roadway has between two and four travel lanes. A portion of this roadway segment, is under municipal control and is not considered for traffic calming measures in this study. The portion under NJDOT jurisdiction, from milepost 44.5 to milepost 45.14, includes a traffic circle connecting U.S. 206 and Route 1. Traffic calming will not be considered around the circle, although it is recognized that vehicle speeds in and around the circle exceed 25 mph and during

Figure 22. Route 206, Newton, NJ

Figure 21. Route 206, Trenton, NJ

the field visit one pedestrian was seen attempting to walk around the circle. The area of concern in the segment under study is a stop-controlled intersection that appears to be complex and would make pedestrian movement at this intersection unsafe. The intersection will be studied to determine design treatments that may improve safety for pedestrians and bicyclists.

The second segment of U.S. 206 under study is located in Princeton (Mercer County). This segment is located on a grade with three travel lanes and one of those lanes a two-way left-turn lane. The roadway has large traffic volumes with significant queuing from vehicles traveling through the U.S. 206 and Route 27 (Nassau Street) intersection. Vehicles traveling away from the intersection, which is on the downgrade portion of the roadway, may exceed the 25 mph speed zone. There was little evidence of pedestrian or bicycle activity in this area. The potential for high speeds on the downgrade segment of the roadway, however, warrants that further study be performed to determine the effectiveness of traffic calming in reducing speeds at this location.

The third segment of U.S. 206 under study is located in the town of Newton in Sussex County. The segment with a speed limit of 25 mph extends from milepost108.30 to milepost 109.32. Within this one-mile segment, U.S. 206 runs through a residential neighborhood outside of the downtown section which has one travel lane in each direction. In the downtown area, U.S. 206 is combined with Route 94, circulating on one-way streets around the town center. Several pedestrians were observed in the downtown area and because of heavy volumes and higher speeds, pedestrians were forced to use existing marked crosswalks. The heavy volumes and speed of vehicles in the area indicate that pedestrian safety could be impacted if pedestrians chose to cross outside of the marked crosswalks.

Tables 20, 21 and 22 show the crash statistics for all vehicular crashes on the 25-mph segment of the Route in 2003. Compared to the entire route, the 25-mph segment has higher crash rates. The short segment of roadway impacted by the 25-mph speed limit, and the relatively lower number of crashes in this area does not suggest that this roadway be considered for treatment using traffic calming.

Table 20. Crash Statistics for all Vehicles on Route 206 (MP 44.50 - MP 45.01)

MP From	MP To	Section Length	AADT	Total Accidents	Fatals	Injury	Prop Dam	Wet Weather	Acc Rate
44.5	44.75	0.25	9,661	18		5	13	4	20.42
44.75	45.01	0.26	12,020	12		1	11	4	13.09
45.01	45.08	0.07	12,020	14		4	10	4	45.59
Total	Route	114.50	15,983	2,332	6	667	1,659	640	3.49

Table 21. Crash Statistics for all Vehicles on Route 206 (MP 53.94 - MP 54.28)

MP From	MP To	Section Length	AADT	Total Accidents	Fatals	Injury	Prop Dam	Wet Weather	Acc Rate
53.94	54.01	0.07	22,799	13		5	8	4	22.32
54.01	54.21	0.20	22,799	8		3	5	3	4.81
54.21	54.47	0.26	22,799	11		4	7	4	5.08
Total	Route	114.50	15,983	2,332	6	667	1,659	640	3.49

Table 22. Crash Statistics for all Vehicles on Route 206 (MP 108.30 - MP 109.32)

MP From	MP To	Section Length	AADT	Total Accidents	Fatals	Injury	Prop Dam	Wet Weather	Acc Rate
108.30	108.33	0.03	12,318	1			1	1	7.41
108.33	108.53	0.20	12,318	6		2	4		6.67
108.53	108.66	0.13	12,318	2			2		3.42
108.66	108.86	0.20	12,318	2			2	2	2.22
108.86	109.01	0.15	12,318	1		1			1.48
109.01	109.19	0.18	22,489	8		2	6	1	5.41
109.19	109.25	0.06	21,894	11		1	10	4	22.94
109.25	109.26	0.01	21,894						
109.26	109.46	0.20	21,894	29		9	20	5	18.14
Total	Route	114.50	15,983	2,332	6	667	1,659	640	3.49

Chapter IV

HUMAN FACTORS STUDY

Overview

To determine the effectiveness, suitability and potential of the traffic calming treatments to reduce speeds, a human factors was performed as part of this research. The use of human factors studies to determine the impact of traffic calming measures on speeds has primarily been performed through the use of field studies where the traffic calming measure is implemented and a before and after study performed. In a laboratory setting, human factors studies on the impact of traffic calming measures are limited to the use of a driving simulator. Driving simulators, in general, have the ability to replicate actual driving conditions in a controlled laboratory environment.

A driving simulator was not proposed for use in this research due to the high costs and time that would be associated with the development of this tool. Instead, field studies performed by others were used to determine the potential speed and crash reduction associated with various traffic calming measures. Field studies where an actual traffic calming measure was installed, and before and after speeds taken, is an effective approach to determine the impact of a traffic calming measure for a particular roadway. To gather information on the preference and acceptability of the measure by the community, the human factors study also included a visual preference survey.

Meta-Analysis

Much has been reported on the impacts of traffic calming measures on speed reduction. The speed reduction achieved for a particular traffic calming measure varies depending on differences in drivers, roadway and environmental conditions associated with the roadway where the traffic calming measure was implemented. One approach that can be used to better summarize the findings of previous studies on the impact of traffic calming measures is through the use of a meta-analysis. A meta-analysis is defined as a statistical analysis of a large collection of analysis results from individual studies for the purpose of integrating the findings. Compared with a traditional literature review, existing knowledge in a meta-analysis is summarized in a more systematic and statistical way. Quantitative rules for selecting and reviewing the literature is used and effect size measures, such as speed reduction, are coded for a dependent study-outcome variable. The analysis summarizes study results weighting studies with greater validity.

Elvik (2000) performed a meta-analysis of 33 studies to determine the safety effects for area-wide urban traffic calming schemes. The studies were identified by first reviewing research reports from road safety research institutes, journals, and conference proceedings. Studies were then selected only if it provided information about the number of accidents on which study conclusions were based. The 33 studies found were then coded identifying: year of publication, country of origin, study design, data on traffic volume, accident severity and type of road to which results referred. A study effect was determined for each study as the odds ratio, ratio of the percent change in the calmed area over the percent change in a comparison area. Statistical analysis are then performed to determine the variability of the study effect and each study then ranked for its validity. The study showed that area wide traffic calming reduces the number of accidents by about 15% for both the main road and local roads.

A meta-analysis was performed in this research to identify potential speed reductions associated with different traffic calming measures. The results of the meta-analysis are presented in Table 23 and show the expected range of speed reduction if the measure were to be implemented.

Visual Preference Survey

Past experience of local Departments of Transportation implementing traffic calming measures has shown that the success of these programs is highly dependent upon input from the communities in which the traffic calming measure will be implemented. Gwinett County in Georgia reported a successful speed hump installation program as a result of getting the public involved in initiating the implementation of the traffic calming measure as well as in determining where the speed hump would be placed (Bretherton, 2001). The City of Concord in California, on the other hand, demonstrated that traffic calming measures need to be community-driven and without it the traffic calming measure will fail (Templeton, 2001).

The residents of Lambertville, New Jersey, have had criticisms of a plan to turn Route 29, which is a four-lane roadway, into a two-lane roadway (Coughlan, 2002). This plan is being implemented in response to concerns over speeding cars and trucks mixing with pedestrians and bicyclists. Although there are mixed reactions to the plan from the community, a public outreach effort may have allowed engineers involved with the project to determine transportation alternatives that may have been better received.

Involving the local community in the design and selection of the traffic calming measure can be accomplished through a variety of techniques. Some of the traditional techniques include (Taylor, 1997):

1. Questionnaires;
2. Household face-to-face interviews;
3. Group discussions;
4. Residents liaison groups;
5. Public meetings; and
6. Public exhibitions.

Additional techniques are available that go beyond the non-traditional approaches in some cases the techniques are designed to help citizens visualize design alternatives. Some of these techniques include (Ewing, 1999):

Table 23. Expected Speed Reduction for Traffic Calming Strategies

TRAFFIC CALMING MEASURE	DESCRIPTION	SPEED REDUCTION
VERTICAL CONTROL MEASURES		
Speed Humps	Rounded raised areas placed across the roadway.	+ 0.3% to – 42% [35.5 to 35.6 & 37.5 to 21.9 mph]
Split Speed Bump	Two halves of a 22-foot speed hump separated by a long enough distance than an emergency vehicle can travel through at 20 mph.	+ 13.6% to – 17.6% [22 to 25 mph & 34 to 28 mph]
Speed Tables	Modified speed hump with a flat-top design to allow the wheelbase of a passenger car to rest on top.	-23.6% [38 to 29 mph]
Enhanced Speed Humps	The enhanced speed hump is a combination traffic-calming feature that includes four key traffic-calming elements: Vertical deflection, horizontal deflection, change in texture and color, and landscaping.	-(30 to 32)% [31 to 21 mph & 33 to 21 mph]
HORIZONTAL MEASURES		
Traffic Circles	Raised islands placed in intersections around which traffic circulates and prevent drivers from speeding through intersections.	- 5.7% to – 21.6% [38 to 35.8 mph & 37 to 29 mph]
Roundabouts	Roundabouts are similar to traffic circles, but are larger than traffic circles and are used on roadways with higher volumes.	-
Chicanes	Curb extensions that create an S-shaped curve on a street.	-
ROAD NARROWINGS		
Center Island Narrowing	Raised islands along the centerline of a street that narrow the travel lanes at that location.	- (2 to 5 mph)
Chokers	Used to reduce the travel way for vehicles. Can take the form of pedestrian peninsulas where the travel width	-

Table 23. Expected Speed Reduction for Traffic Calming Strategies

TRAFFIC CALMING MEASURE	DESCRIPTION	SPEED REDUCTION
	between the peninsular is one or two travel lanes.	
Bulbouts	Creates extra space for benches, landscaping, tables, chairs, etc. also makes it safer for drivers to see pedestrians waiting to cross the street.	+ 14% to – 45%
Street Narrowings	It provides a flexible way to take backspace from the street for non-motor vehicle uses.	+ 3.8% to – 14.2% [26 to 27 mph & 35 to 30 mph]
PSYCHO-PERCEPTION CONTROLS		
Edge lines	Edge lines located several feet from the pavement edge can have the effect of visually narrowing the roadway.	+ 3.8% to – 2.6% [32.9 to 34.2 & 39.7 to 38.7 mph]
Transverse Markings	High-contrast painted or thermoplastic strips placed across a driving lane, horizontal to the direction of travel.	- (3 to 4 mph)
SPEED MANAGEMENT TECHNIQUES		
Increased Enforcement (Speed Watch)	Use of public safety officers, citizen speed watch programs, speed trailers, and automated enforcement to encourage compliance of speed limits.	- 5% [42 to 39 mph]
Flashing Beacons	Used in conjunction with warning signs to alert drivers to conditions and potential hazards on the roadway.	-
Speed Limit Signs and Markings	Speed limit signs state the statutory speed limit on the roadway. The speed limit can also used as a pavement marking on the roadway.	Little or no effect
Speed or Radar Trailers	Mobile roadside devices that use radar to measure the speed of approaching vehicles. The speeds of approaching vehicles are displayed along side the legal speed of the roadway.	-
Rumble Strips	Pavement undulations placed across the driving lane, causing the vehicle to "rumble" or vibrate when crossing	-

Table 23. Expected Speed Reduction for Traffic Calming Strategies

TRAFFIC CALMING MEASURE	DESCRIPTION	SPEED REDUCTION
	them.	
Diverters	Roadway modifications which restrict one or more vehicle movements through the intersection	- (7 to 8 mph)
Stop Signs	Stop signs show which motorist has the right of way and ensures that the traffic flows smoothly and predictably	+ 7.1% to + 13.3% [28 to 30 mph & 30 to 34 mph]

Speed Hump **Speed Table**

Median Divider **Median with Breakpoint for pedestrians**

Figure 23. Traffic Calming Measures Surveyed

1. Guided tours of traffic calming sites;
2. Computer imaging;
3. Visual preference surveys;Design charrettes;
4. Focus groups;
5. Neighborhood traffic committees.

To assess the preference and acceptability of various traffic calming measures, a visual preference survey was administered to various road user groups, including motorists, pedestrians and bicyclists, from the communities where the traffic calming measures are proposed to be implemented. The survey gathered the following information:

- Reason for coming to this area
- Age of Respondent

- Number of times respondent is a pedestrian in the area
- Number of times respondent is a bicyclist in the are
- Perception of safety for pedestrians or bicyclists
- Reasons for perceived lack of safety
- Preferred roadway travel speed
- Rating of traffic calming measure for pedestrian/bicyclist safety
- Rating of traffic calming measure for driver convenience
- Rating of traffic calming measure for aesthetics.

The four traffic calming measures assessed in the survey are shown in Figure 23, and include a speed hump, speed table, median divider, and median with a breakpoint for pedestrians. Surveys were performed over a two week period at five locations in Cranford, Westfield, New Brunswick, and Princeton.

Table 24. Survey Respondent Information

City	Number of Respondents	Percentage of Total Respondents
Westfield	42	23.6%
Cranford	45	25.3%
ForLee	27	15.2%
New Brunswick	33	18.5%
Princeton	31	17.4%
Total	178	

As shown in Table 24, a total of 178 surveys were collected. The following provides a discussion of the results of the survey.

Reason for Coming to Area

Figure 24 shows the results of the question "Indicate your reason for coming to this area" for each of the locations studied and for the entire survey. The results show that overall, most of the respondents (54 percent) were residents of the area. The study areas in New Brunswick and Princeton had different characteristics with only 36 percent of the respondents in New Brunswick living in the area and 31 percent living in the area for Princeton. For New Brunswick, the highest percentage of respondents categorized their purpose for being in the area as "Other" (55 percent). As the study location was in the Rutgers University campus and adjacent to one of the University's dormitories, many of the respondents from this location is expected to be students. In Princeton, forty-one percent of the respondents indicated that they worked in the area. This survey was also administered adjacent to the Princeton University campus and captured many workers in the area.

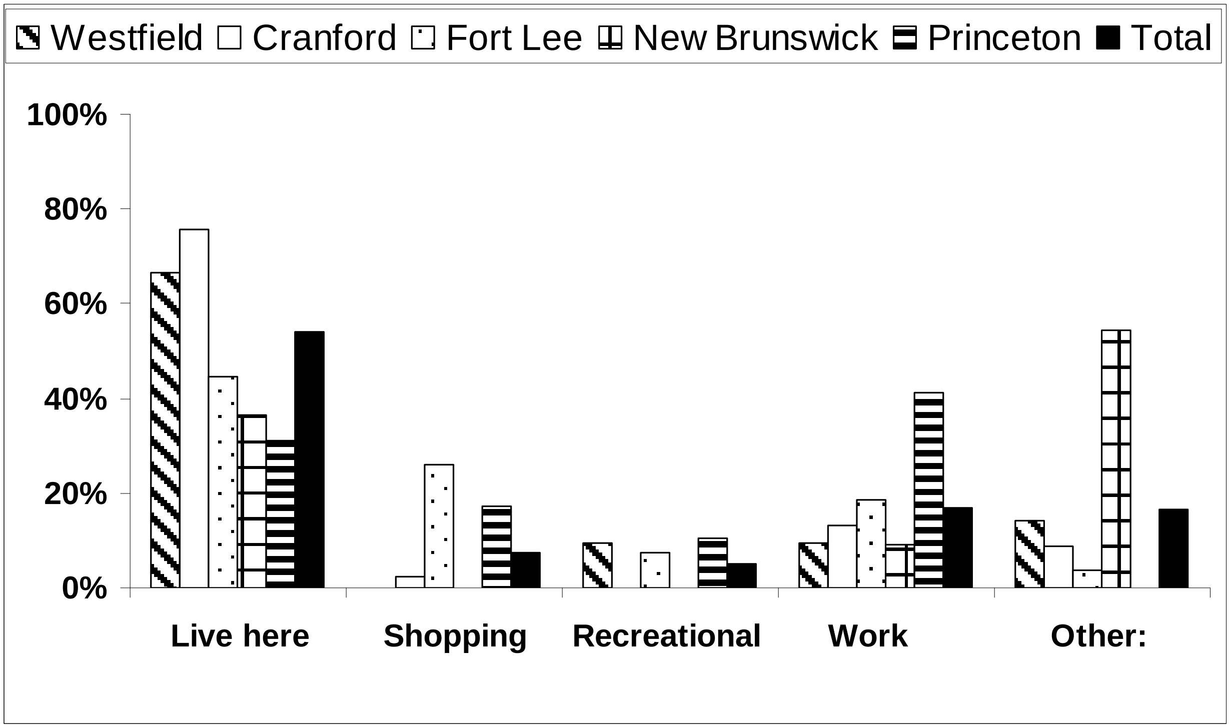

Figure 24. Reason for Coming to Area

Age of Respondents

Figure 25 shows the age of the respondents to the survey for each of the study locations and for the entire survey. Overall, the largest percentage of respondents (51 percent) fell in the age category between 31 and 64 years. A large portion of the respondents (41 percent) fell within the age range of 18 to 30 years. These characteristics differed by location of the study. Westfield and Cranford had a higher percentage of respondents falling within the 31 to 64 age range, compare to the overall average. Seventy-six percent and 69 percent of respondents fell within the 31 to 64 age group for Westfield and Cranford, respectively. On the other hand, New Brunswick had a significantly higher percentage of respondents falling in the 18 to 30 age range, compare to the overall average with 91 percent of respondents falling within this range. Princeton also had a higher percentage of respondents falling within this category compared to the overall average with 53 percent of respondents falling in the 18 to 30 age range. Few respondents fell in the 65 or older age range, and no respondents were under 18 years old.

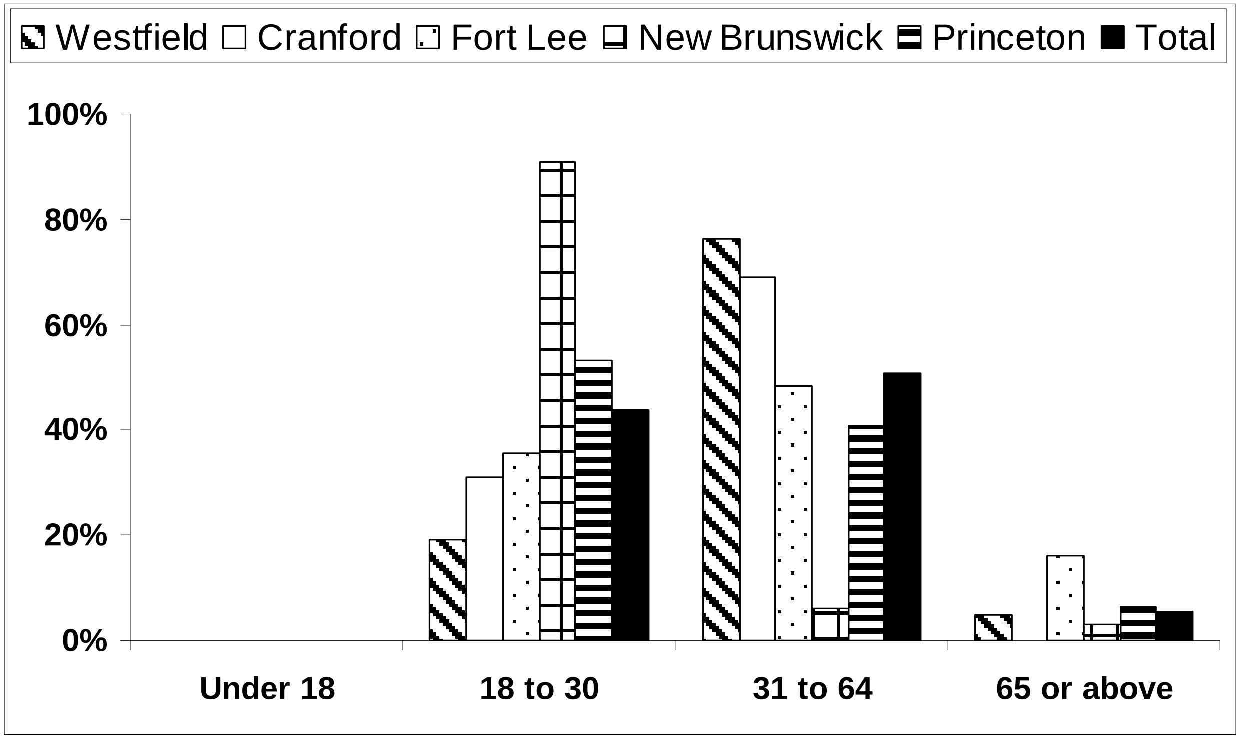

Figure 25. Age of Respondent

Primary Mode of Transportation

Figure 26 shows the primary mode of transportation for respondents for each study location and for the total survey. Overall, all of the modes are utilized as primary modes for respondents of the survey. Bicycling has the highest percentage with 24 percentage of respondents using this as their primary mode of transportation. Thirty-percent of respondents also chose “Other” as the primary mode of transportation. This category is assumed to be those respondents using transit as their primary mode. The smallest percentage of respondents (15 percent) include “Driving” as their primary mode. These results indicate that the communities where the surveys were performed have walking and bicycling as a primary mode with less dependence on driving. One exception to this conclusion is at the New Brunswick location, where although the highest percentage of respondents indicate walking (45 percent) as the primary mode, a high percentage (41 percent) also indicate walking as the primary mode.

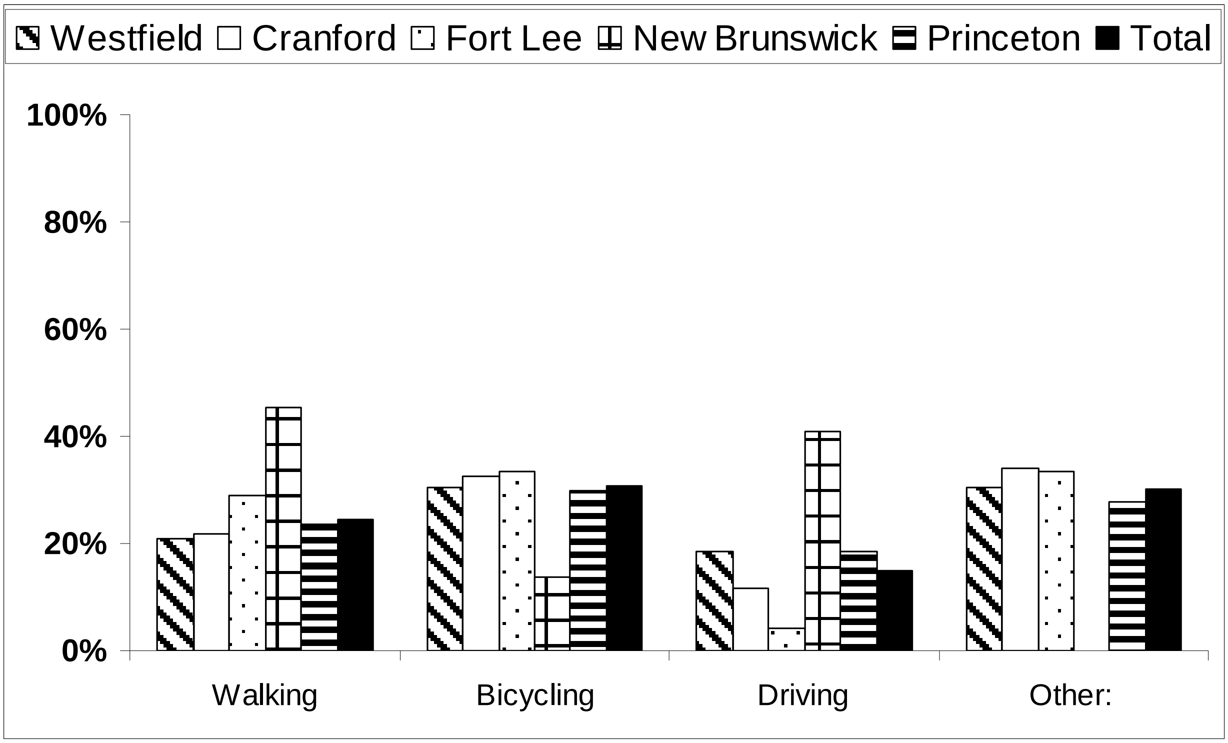

Figure 26. Primary Mode of Transportation

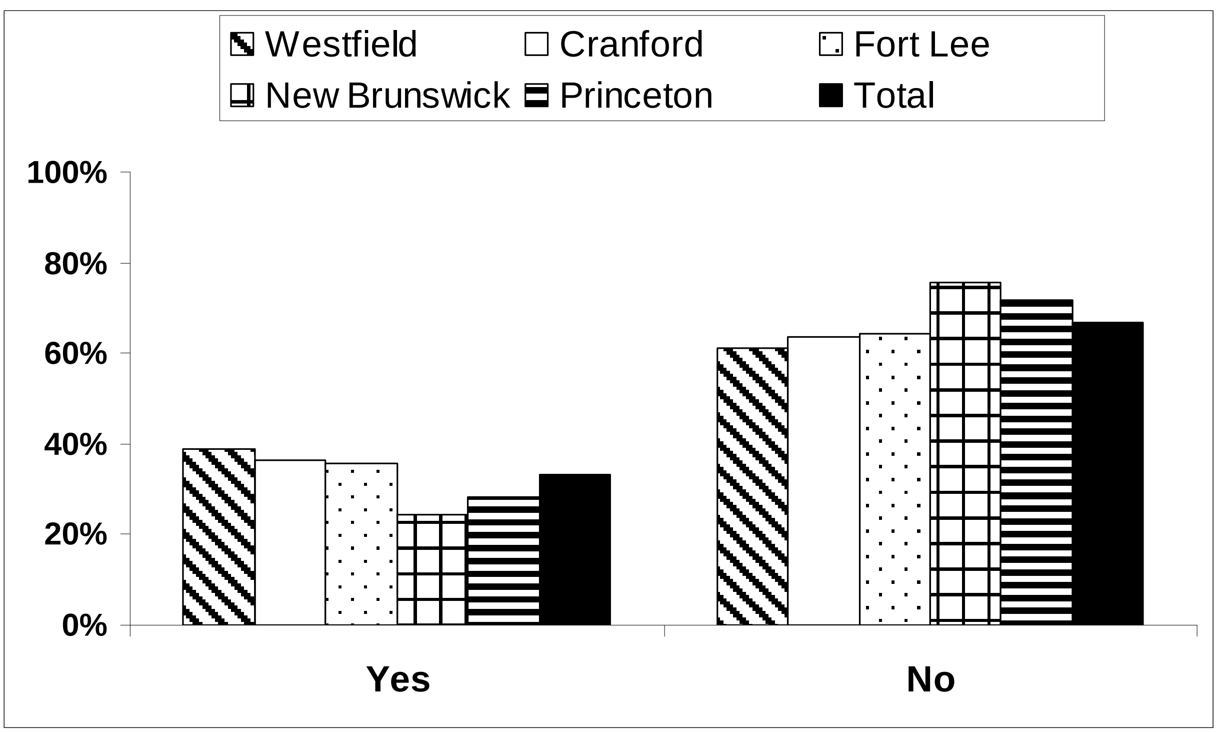

Figure 27. Response to "Is Your Street Safe for Pedestrians and Bicycles?"

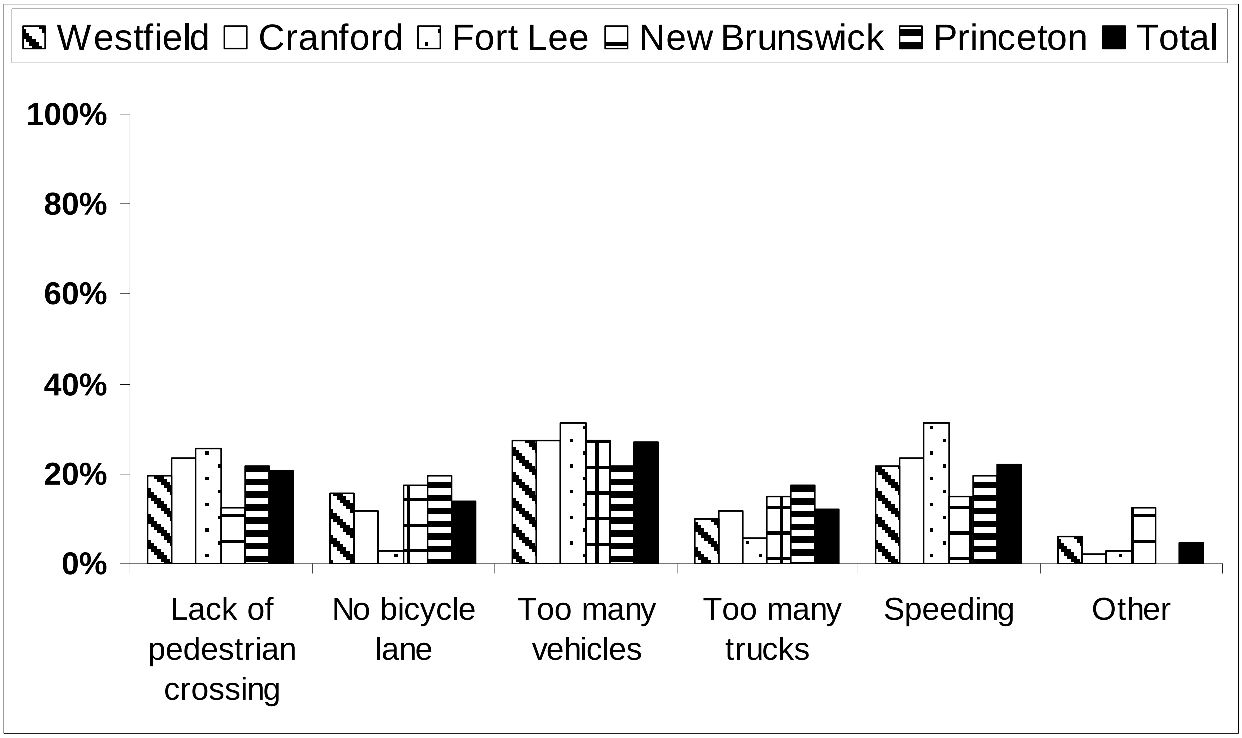

Figure 28. Reasons For Unsafe Roadway

<u>Perception of Roadway Safety for Pedestrians and Bicycles</u>

Figure 27 shows the response to the question “Is your street safe for pedestrians and bicycles?” for each of the study locations and for the total survey. Overall, sixty-seven percent of respondents stated that they did not believe that their street was safe for pedestrians and bicycles. This type of response was similar for all of the locations studied, with New Brunswick showing the highest percentage (76 percent) of respondents stating that the roadway was not safe.

Respondents stating “No” were then asked to specify a reason why the roadway was unsafe. Figure 28 shows the response to these questions for each of the study locations and for the total survey. Overall, “Too many vehicles” had the highest percentage of respondents with twenty-seven percent. “Speeding” and “Lack of pedestrian crossing” were the next highest reasons stated with 22 percent and 21 percent, respectively.

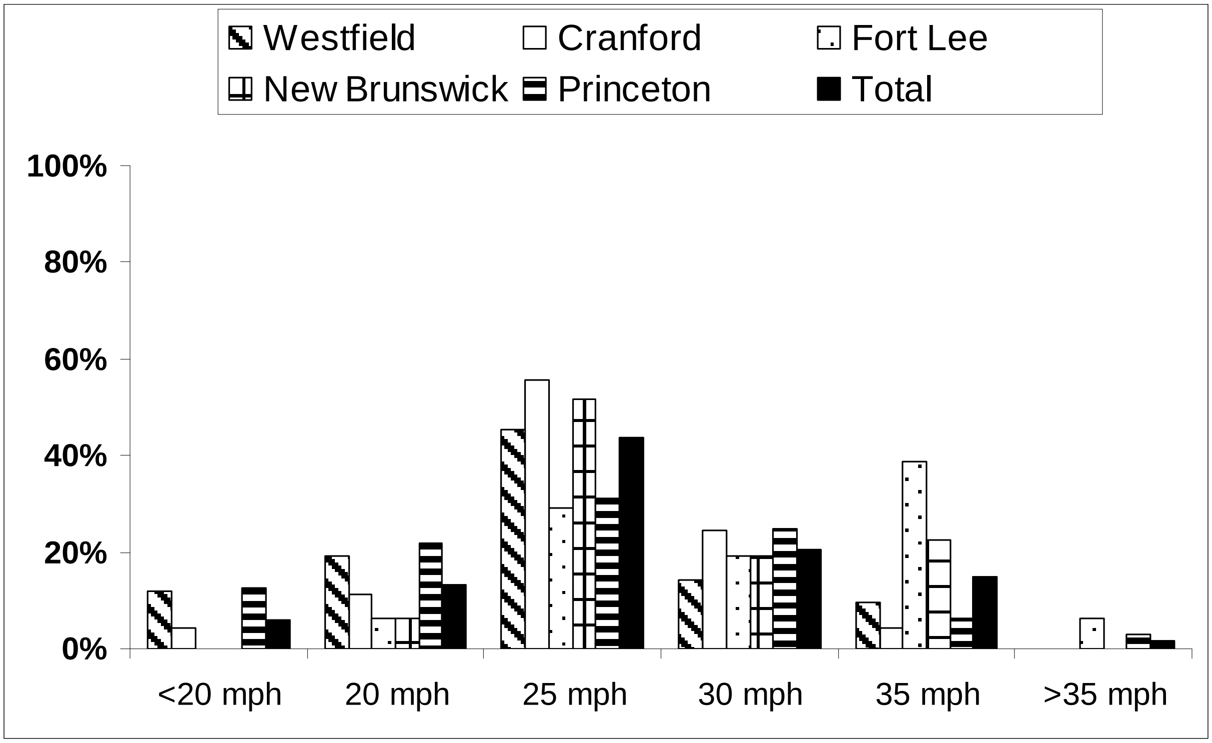

Figure 29. Safe Speed of Roadway

Safe Speed for Roadway

Figure 29 shows the preferred speed for the roadway selected by respondents at each of the study locations and for the total survey. Forty-four percent of respondents stated that “25 mph” was a safe speed for the roadway. Twenty percent selected “30 mph” and 15 percent selected “35 mph”. FortLee had different characteristics with 39 percent of respondents stating “35 mph” was a safe speed for the roadway and 29 percent stating “25 mph” as a safe speed.

Traffic Calming Measure Rating

Respondents were asked to rate each of the four traffic calming measures studied for three aspects include: the ability of the measure to improve safety for pedestrians; the inconvenience the measure would have on drivers; and the aesthetics of the measure. Figures 30, 31 and 32 show the results from respondents for the total survey. For the ability of the measure to improve safety for pedestrians and bicycles, speed humps and speed tables show similar ratings and these ratings are lower than the ratings for the

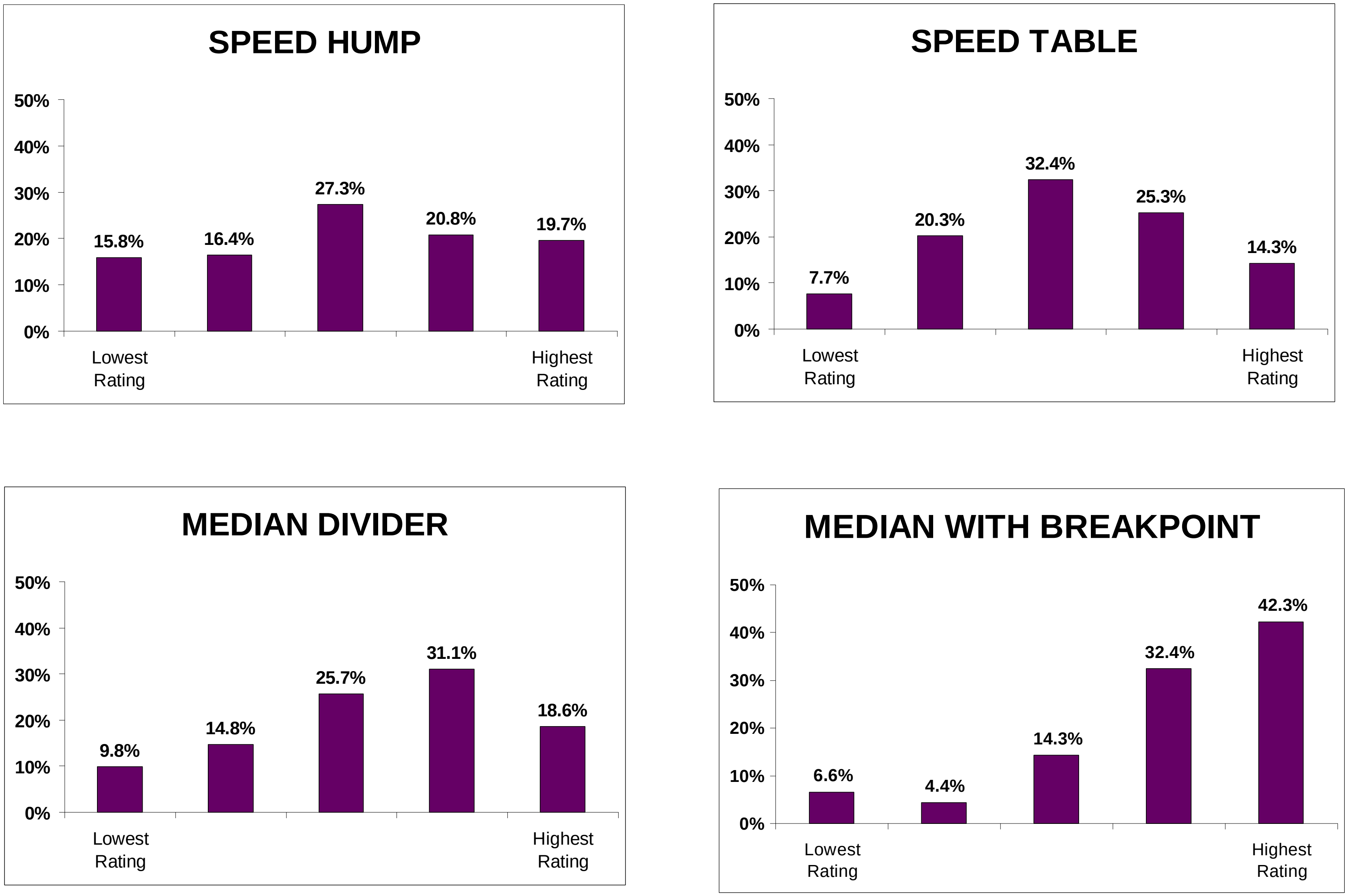

Figure 30. Pedestrian/Bicycle Safety Rating

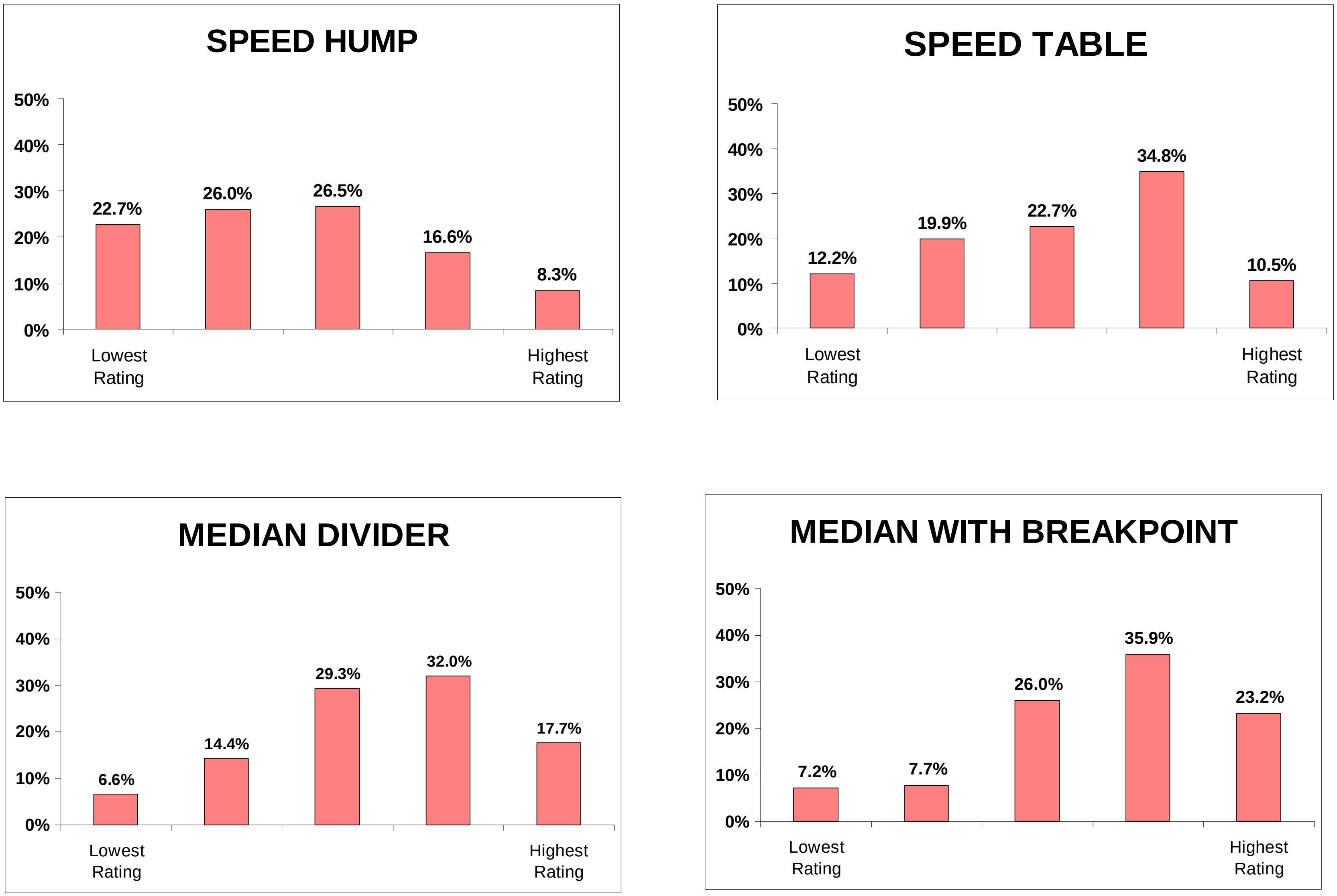

Figure 31. Driver Convenience Rating

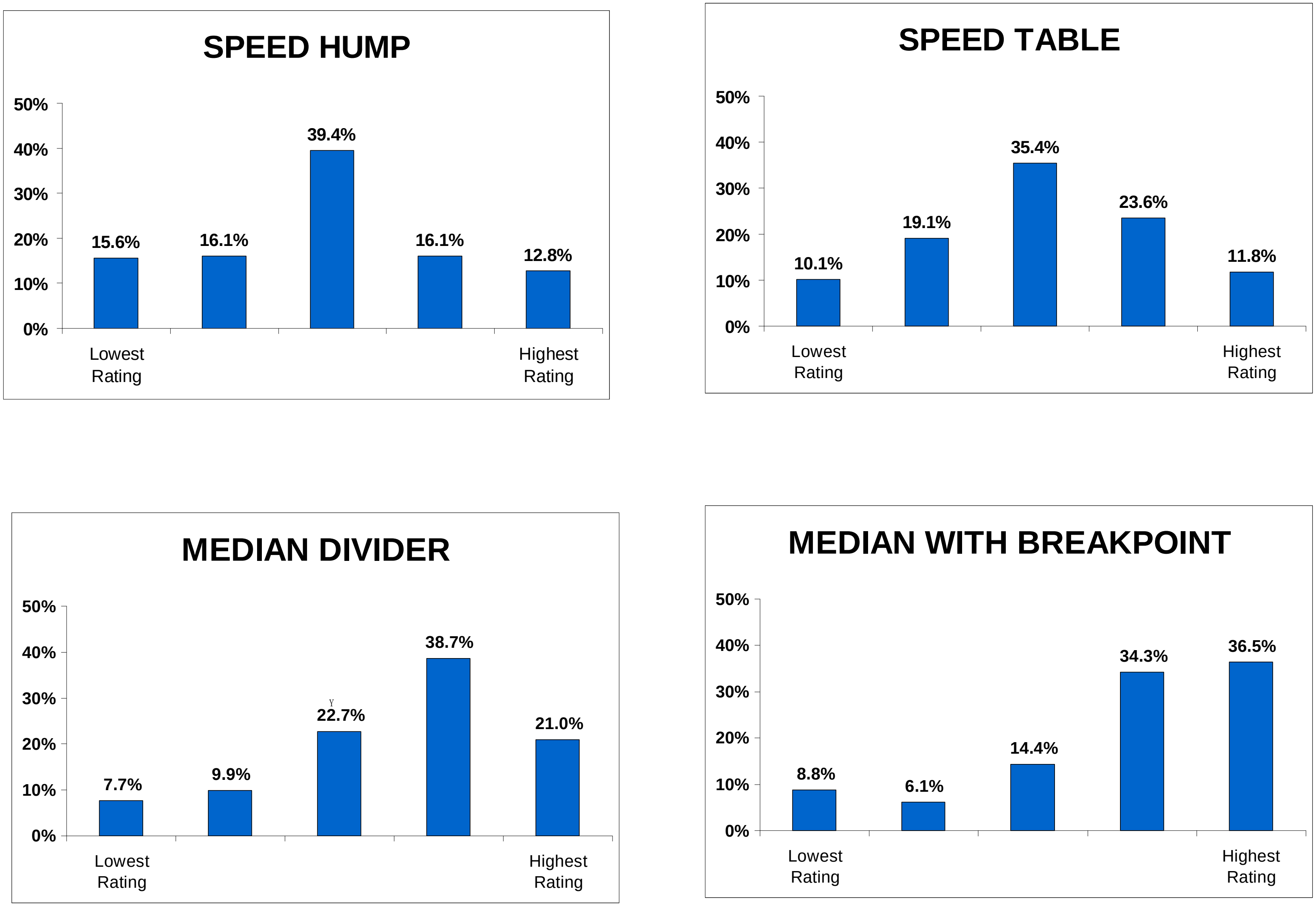

Figure 32. Aesthetic Rating

Table 25. Overall Rating of Traffic Calming Measures

	Pedestrian/Bicyclist Safety	Driver Convenience	Aesthetic
Speed Hump	3.12	2.62	2.94
Speed Table	3.18	3.12	3.08
Median Divider	3.34	3.40	3.55
Median with Breakpoint	3.99	3.60	3.83

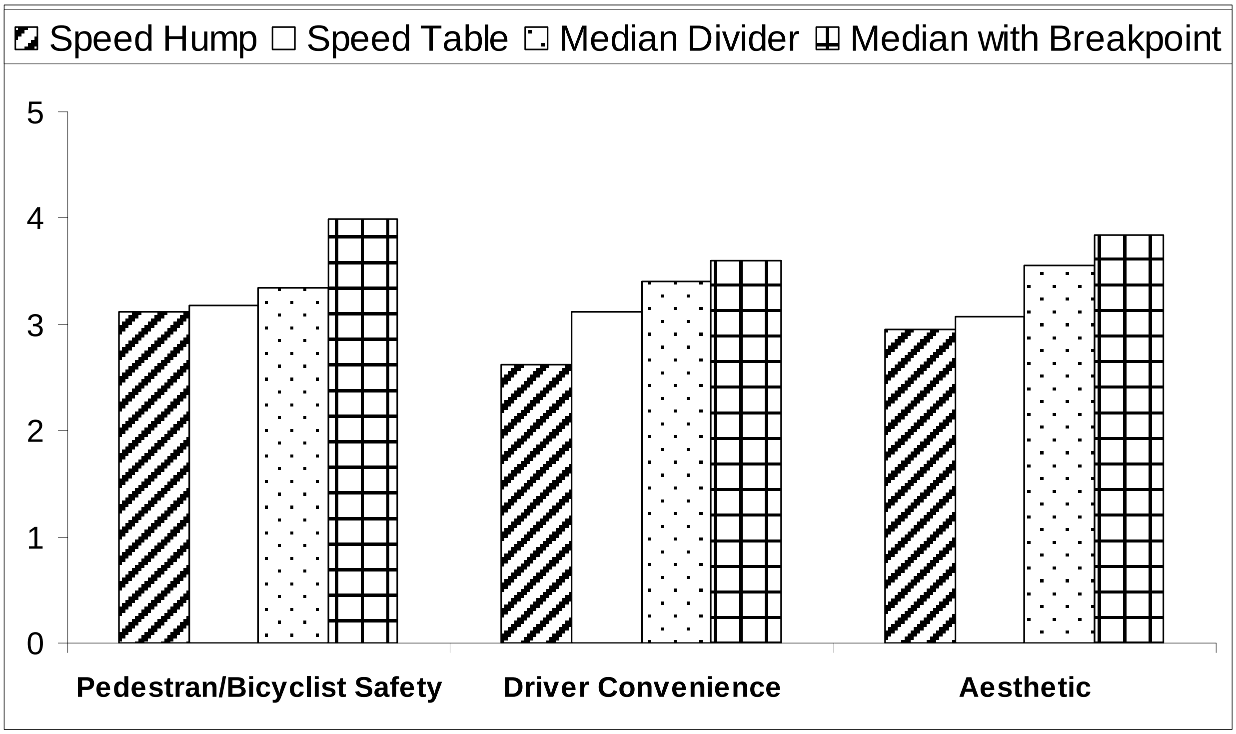

Figure 33. Overall Rating of Traffic Calming Measures

median divider and for the median with a breakpoint for pedestrians.

An overall rating was determined for each traffic calming measure by applying a value of 1 through 5 for the lowest to the highest rating, respectively. A weighted average was then determined by summing the product of the percentage of respondents selecting one of the five ratings and the value assigned to that rating. Using this procedure the overall rating for the four measures was determined and shown in Table 25 and Figure 33. As the Table and figure shows, the median with the breakpoint had the highest overall rating for improving safety for pedestrians and bicycles.

The ratings for the impact of the measure on driver convenience, as well as the ratings for the aesthetics of the measure showed similar results with the median with the breakpoint having the highest rating and the speed hump the lowest rating.

Chapter V

IMPLEMENTATION AND EVALUATION PLAN

Overview

An evaluation and implementation plan was developed for each of the study locations where traffic calming is proposed for implementation. The intent of the implementation and evaluation plan is to be able to provide an assessment on the effectiveness of traffic calming measure to reduce speeds and improve safety. A thorough assessment of the traffic calming measure includes several components including: speed measurements at the entrance and within the traffic calmed roadway; crash analyses before and after the installation of the measure; collecting traffic counts before and after the installation of the measure; observing driver, cyclist and pedestrian behavior adjacent to the measure; survey of residents, road users, local authorities; and noise measurements. The following provides some discussion on performing the assessment and then provides the implementation plan for installing the traffic calming measure in the five study locations.

Evaluation Plan

Speed Study

To assess the effectiveness of the traffic calming measure on the reduction of speed, a before-after speed study should be performed at the location where the measure is installed. Speeds should be collected during similar days of week and times of day before and after the installation. The “After” speed data should be collected some time after the installation of the measure to avoid capturing a “novelty effect” or measuring speeds while drivers and roadway users are still becoming familiar with the device. Speed data should be collected at various distances upstream and downstream from the traffic calming measure. The exact distances will vary by location as the locations upstream and downstream should have similar geometric and volume characteristics so that the reduction in speed can be attributable solely to the traffic calming measure.

In some study locations, more than one measure may be needed to reduce speeds on the roadway. Speed data collected at these types of locations cannot be used to determine the impact of one traffic calming measure, but of the impact of the speed reduction plan.

Speeds can be collected using a variety of techniques including a radar gun, laser gun, and through the use of electronic devices, such as Nu-Metric classifiers. Radar and laser guns provide spot speed data and can allow for speeds to be observed at various distances upstream and downstream of the measure. Nu-Metric classifiers are devices which are installed in the middle of the travel lane and provide a count and speed of each vehicle that passes over the device. These devices can be used to collect speed data for all vehicles traveling in the lane. Using multiple devices, data from all lanes and at different locations upstream and downstream of the measure can be obtained. One concern with using these types of devices is because of the technology being used, vehicles stopping over, due to congested conditions, or vehicles traveling at very slow speeds can result in some errors in the speed data. For this and other reasons, speed data should be obtained during the off-peak period, to capture vehicles traveling at free-flow conditions and unimpeded by other vehicles on the roadway.

Crash Analysis

A crash analysis should also be performed comparing crash statistics before and after the installation of the traffic calming measure. The crash analysis should include a comparison of crash frequency, crash rates, and types of crashes for the section of the roadway impacted by the traffic calming measure. To calculate the crash rates, the vehicle-miles traveled (VMT) on the roadway should be determined using either the annual average daily traffic (AADT) or if this is unknown, the volume on the roadway should be collected to calculate the VMT.

Observation of Road Users

Before and after pedestrian, cyclist and motorist behavior at the traffic calming measure should be gathered. Pedestrians and cyclists should be observed to see if they are navigating the traffic calming measure correctly. Gender and age of the pedestrians and cyclists should be determined as this may impact behavior at the traffic calming measure. Motorists will be observed to see how the traffic calming measure influences not only their speed, but whether any erratic maneuvers are made in the vicinity of the measure.

Survey of Community

A survey of pedestrians, bicyclists and motorists impacted by the traffic calming measure should be administered to gather qualitative information on the effectiveness of the measure and its impact on speeds and perception of safety. Some of the types of questions that should be asked include:

- Has the traffic calming measure increased motorist awareness of traveling speeds?
- Has the traffic calming measure increased safety for road users?
- Are motorists more likely to reduce their speeds at the traffic calming measure?
- Are motorists more likely to reduce/increase their speeds on other sections of the roadway?
- Are pedestrians and cyclists more likely to use the roadway since the installation of the traffic calming measure?

- Are motorists more likely to find alternative routes as a result of the traffic calming measure?
- Do road users understand how to travel through the traffic calming measure?

A sample of individuals from various Citizen Groups should be included in the survey. The survey can be administered at the Citizen Group meeting or through focus groups or a mail-out survey. Where possible, motorists' will also be surveyed at parking areas adjacent to study area.

Implementation Plan

Route 27 (Nassau Street)

Description of Location

As described in Chapter III, Nassau Street is a two lane roadway located adjacent to the Princeton University campus. During the peak periods the roadway experiences congestion resulting in lower vehicular speeds. However, high pedestrian and bicycling activity, suggests that the mid-block crossings on the roadway should be treated to improve safety for both pedestrians and bicyclists.

Selection of Traffic Calming Measure

The visual preference survey, previously described in Chapter IV, assessed the type of traffic calming measure preferred by road users on Route 27. The study determined that over 70 percent of road users believed Route 27 to not be safe for pedestrians and bicyclists suggesting the need for additional treatment on the roadway. Although 31.3 percent of respondents believed 25 mph was a safe speed for the roadway, 34 percent believed the safe speed on the roadway to be less than 25 mph. Table 26 shows the overall rating for each of the four traffic calming measures surveyed. A median with a breakpoint opening for pedestrians was identified as the most preferred traffic calming device for its ability to improve the safety for pedestrians and bicyclists, for driver convenience and for aesthetics.

Table 26. Overall Rating of Traffic Calming Measures – Route 27

	Pedestrian/Bicyclist Safety	Driver Convenience	Aesthetic
Speed Hump	3.12	2.62	2.94
Speed Table	3.18	3.12	3.08
Median Divider	3.34	3.40	3.55
Median with Breakpoint	3.99	3.60	3.83

Placement Location

Field visits indicate that potential locations for placing the traffic calming measure are at the mid-block crossing located adjacent to Palmer Square. This location is identified in Figure 34.

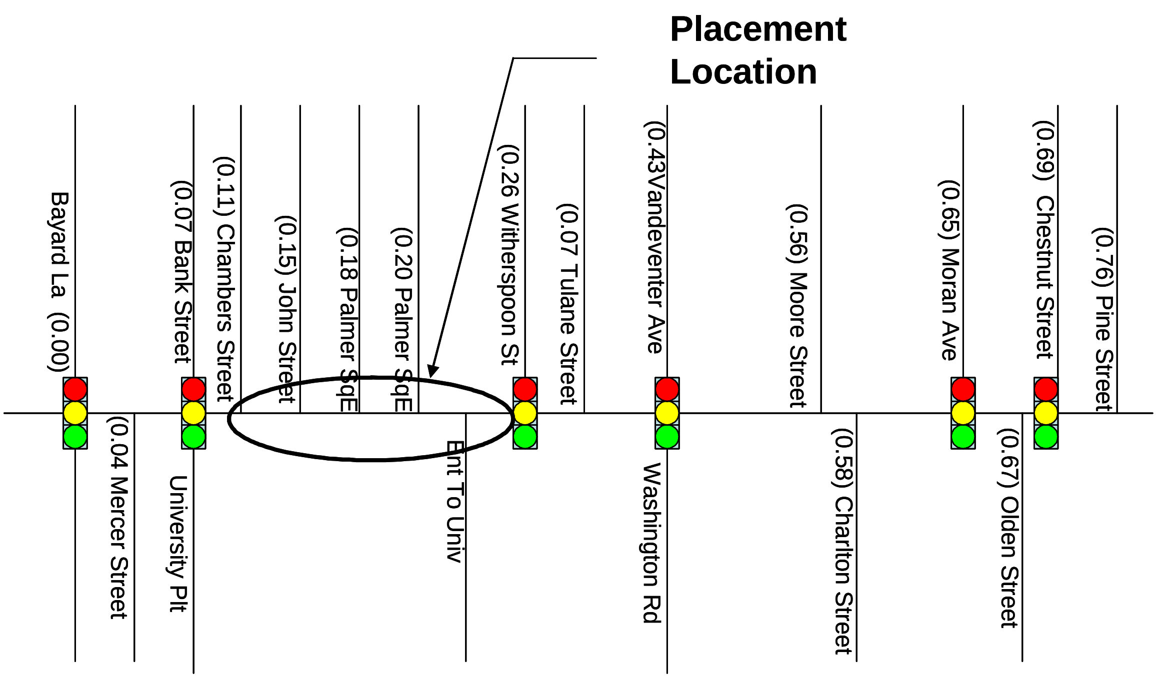

Figure 34. Placement Location - Route 27

Route 28 (Westfield)

Description of Location

As described in Chapter III, North Avenue in Westfield is a four-lane roadway with some pedestrian and bicycling activity. High roadway volumes indicate that speeding is not a critical factor in crashes on North Avenue. The field visit indicated parking was in the process of being removed, which may lead to less congested conditions, and in turn speeding on the roadway.

Selection of Traffic Calming Measure

The visual preference survey determined that over 60 percent of road users believed Route 28 to not be safe for pedestrians and bicyclists suggesting the need for additional treatment on the roadway with 45 percent indicating that 25 mph was a safe speed for the roadway. Table 27 shows the overall rating for each of the four traffic calming measures surveyed. A median with a breakpoint opening for pedestrians was identified

Table 27. Overall Rating of Traffic Calming Measures – Route 28(Westfield)

	Pedestrian/Bicyclist Safety	Driver Convenience	Aesthetic
Speed Hump	3.26	2.79	3.31
Speed Table	3.19	3.24	3.05
Median Divider	3.21	3.57	3.52
Median with Breakpoint	4.07	3.71	3.76

as the most preferred traffic calming device for its ability to improve the safety for pedestrians and bicyclists, for driver convenience and for aesthetic value.

Placement Location

Field visits indicate that potential locations for placing the traffic calming measure are between East Broad Street and Central Avenue. This location is identified in Figure 35.

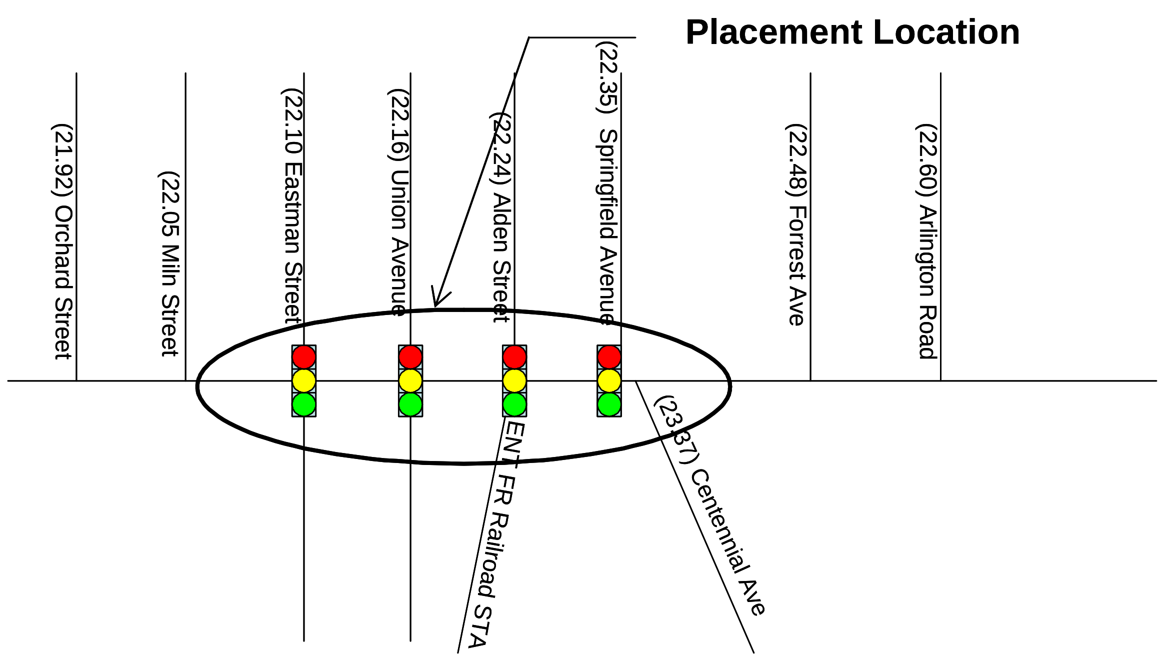

Figure 35. Placement Location - Route 28 (Westfield)

Route 28 (Cranford)

Description of Location

As described in Chapter III, North Avenue in Cranford has two travel lanes with parking provided on both sides of the roadway. There is a significant amount of pedestrian and bicycling activity in this area. The curvature of the roadway, coupled with the high pedestrian and bicycling activity indicates that traffic calming would improve the safety to these road users.

Selection of Traffic Calming Measure

The visual preference survey determined that over 64 percent of road users believed Route 28 to not be safe for pedestrians and bicyclists suggesting the need for additional treatment on the roadway with 55 percent indicating that 25 mph was a safe speed for the roadway. Table 28 shows the overall rating for each of the four traffic calming measures surveyed. A median with a breakpoint opening for pedestrians was identified as the most preferred traffic calming device for its ability to improve the safety for pedestrians and bicyclists, for driver convenience and for aesthetic value.

Table 28. Overall Rating of Traffic Calming Measures – Route 28(Cranford)

	Pedestrian/Bicyclist Safety	Driver Convenience	Aesthetic
Speed Hump	3.20	2.64	2.86
Speed Table	3.00	3.25	3.26
Median Divider	3.16	3.33	3.44
Median with Breakpoint	4.02	3.81	4.00

Placement Location

Field visits indicate that potential locations for placing the traffic calming measure are between Eastman Street and Centennial Avenue. This location is identified in Figure 36.

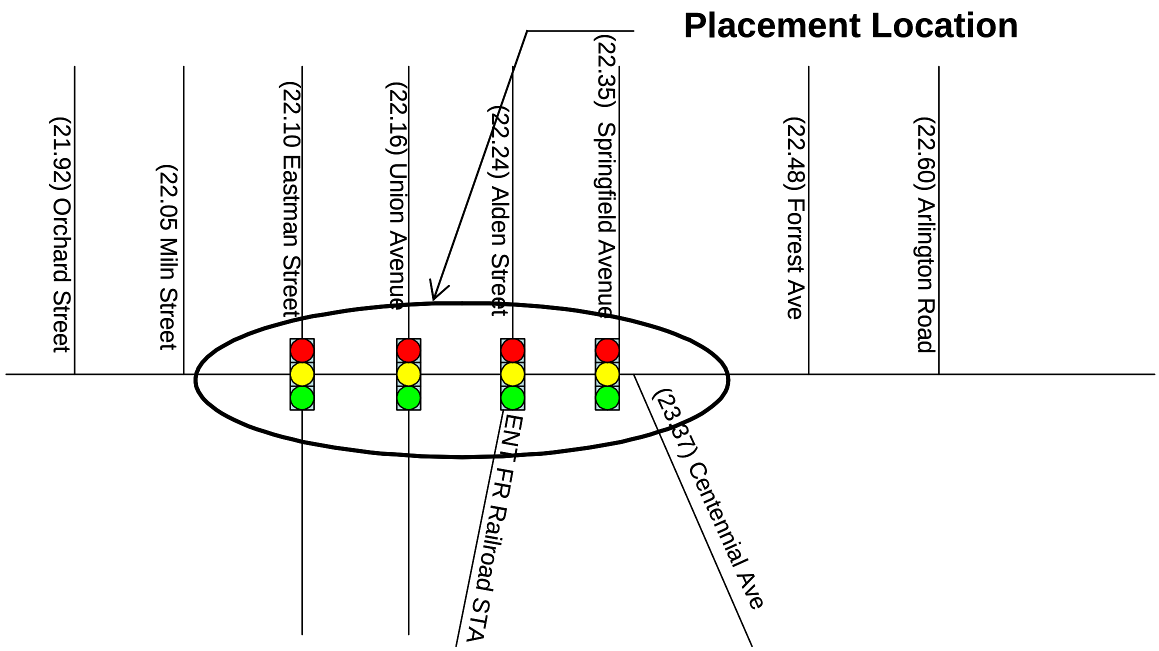

Figure 36. Placement Location - Route 28(Cranford)

Route 67 (Fort Lee)

Description of Location

As described in Chapter III, Route 67 (Palisades Avenue/Lemoine Avenue) has four travel lanes with parking. At the portion of the roadway where it crosses the George Washington Bridge toll plaza, speeding is not a factor in pedestrian and bicycle crashes. Speeding may be a factor at locations outside of the toll plaza area, based on the lower volumes and wider roadway.

Selection of Traffic Calming Measure

The visual preference survey determined that over 64 percent of road users believed Route 67 to not be safe for pedestrians and bicyclists suggesting the need for additional treatment on the roadway with only 29 percent indicating that 25 mph was a safe speed for the roadway. Almost 65 percent of respondents believed the safe speed for the roadway to be greater than 25 mph, with 39 percent stating that the 35 mph to be a safe speed. Table 29 shows the overall rating for each of the four traffic calming measures surveyed. A median with a breakpoint opening for pedestrians was identified as the most preferred traffic calming device for its ability to improve the safety for pedestrians and bicyclists, for driver convenience and for aesthetic value.

Table 29. Overall Rating of Traffic Calming Measures – Route 67

	Pedestrian/Bicyclist Safety	Driver Convenience	Aesthetic
Speed Hump	2.81	2.42	2.48
Speed Table	3.26	3.10	3.00
Median Divider	3.23	3.16	3.48
Median with Breakpoint	3.65	3.35	3.61

Placement Location

Field visits indicate that potential locations for placing the traffic calming measure are between Virginia Avenue and Riverdale Drive. This location is identified in Figure 37.

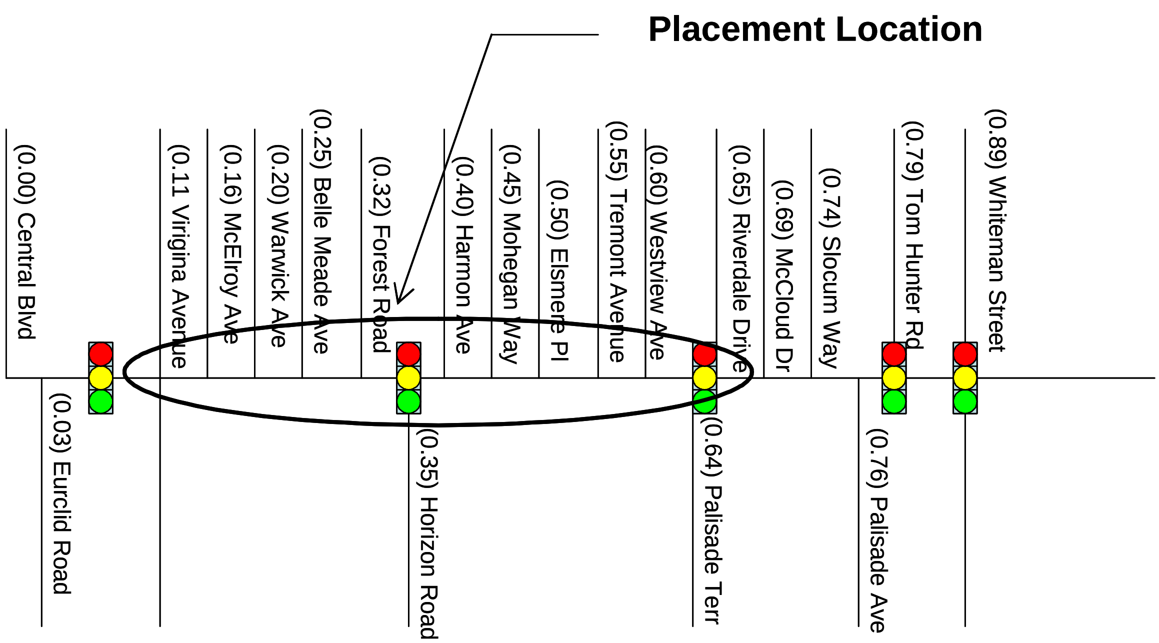

Figure 37. Placement Location (Route 67)

<u>Route 172 (George Street)</u>

Description of Location

As described in Chapter III, Route 172 (George Street) has between two and four travel lanes with no parking allowed on either side of the roadway. George Street is located adjacent to the Rutgers University New Brunswick campus and runs between the dormitories and the main campus area. The location of the roadway, coupled with the low volume, suggests that speeding may be a concern and traffic calming may be warranted for this roadway.

Selection of Traffic Calming Measure

The visual preference survey determined that over 75 percent of road users believed Route 172 to not be safe for pedestrians and bicyclists suggesting the need for additional treatment on the roadway. Over half of the respondents, 51.6 percent, indicated that 25 mph was a safe speed for the roadway, with 42 percent indicating a speed higher than 25 mph to be a safe speed. Table 30 shows the overall rating for each of the four traffic calming measures surveyed. A median with a breakpoint opening for pedestrians was identified as the most preferred traffic calming device for its ability to improve the safety for pedestrians and bicyclists, for driver convenience and for aesthetic value.

Table 30. Overall Rating of Traffic Calming Measures – Route 172

	Pedestrian/Bicyclist Safety	Driver Convenience	Aesthetic
Speed Hump	3.48	2.72	3.22
Speed Table	3.50	3.16	3.09
Median Divider	3.70	3.82	3.82
Median with Breakpoint	4.18	3.73	4.09

Placement Location

Field visits indicate that potential locations for placing the traffic calming measure are between Commercial Avenue and Chapel/Nichol Avenue. This location is identified in Figure 38.

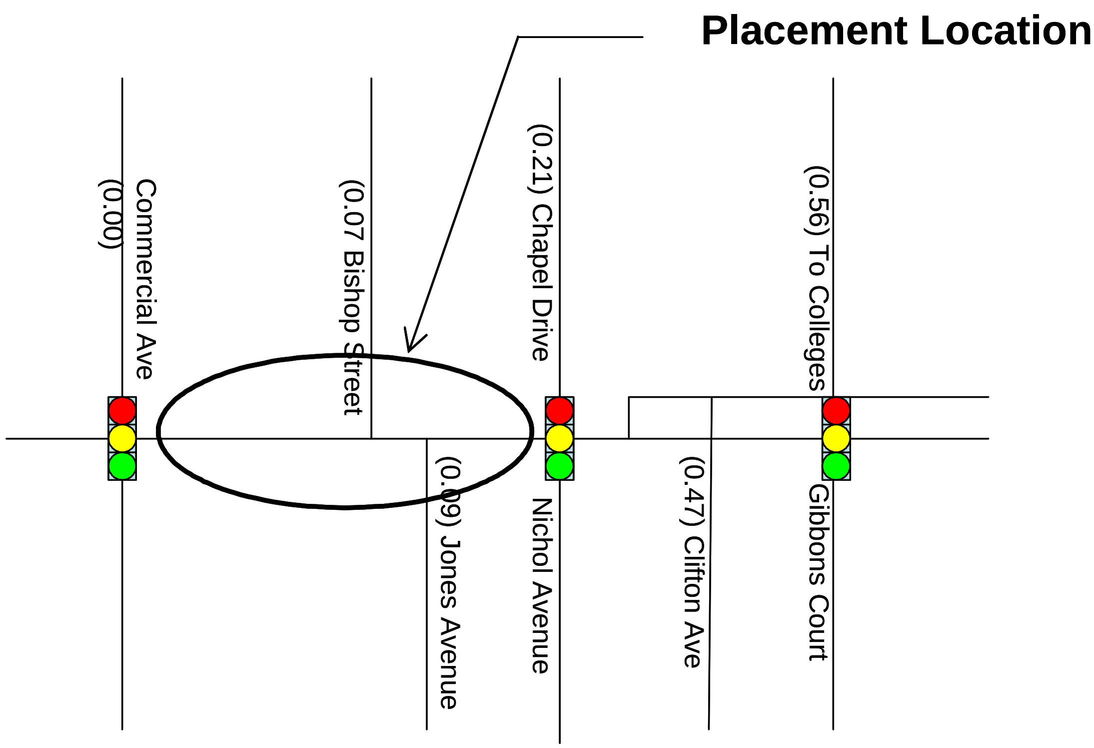

Figure 38. PLacement Location (Route 172)

Evaluation Plan Budget

The cost for performing an evaluation of the effectiveness of the selected traffic calming measure was developed. The cost is based on performing an evaluation at each of the five study locations and does not include the costs associated with installing the traffic calming measure. As described in the evaluation plan, the costs cover the four types of evaluation:

- Before/After speed study
- Crash analysis of study area
- Before/After observational analysis of pedestrians, cyclists and motorists
- Survey of Community

The evaluation can be completed in 18 months, assuming a three month period for installing the traffic calming measure and another two months after the measure has been installed for users of the roadway to become familiar with the measure. The time schedule for completing the evaluation is shown in Table 31.

Table 31. Time Schedule for Performing Evaluation

Evaluation Plan	Time (Months)																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Before Speed Study	■	■	■	■														
Crash Analysis			■	■	■													
Before Observational Study				■	■	■												
Installation of Measure							■	■	■	■	■							
After Speed Study												■	■	■				
After Observational Study														■	■	■		
Survey of Community																■	■	
Report																		■

Based on this 18-month evaluation time schedule, the budget for monitoring conditions before and after the implementation of a traffic calming measure was determined and is shown in Table 31. As the table shows, the overall cost is approximately $140,000 for the five study locations. The costs include personnel costs of about $90,000, fringe benefits of $16,000, travel costs of $1,500, equipment and supplies of $4,500, and other costs including overhead and student tuition of $26,000. Personnel costs include costs for a senior traffic engineer, one entry level engineer and data collectors. The equipment to be purchased includes speed data collection equipment. Travel funds will be used to travel to and from the study locations. An indirect rate of 10% was used.

Table 32. Budget for Monitoring Performance of Traffic Calming Measures

			Total Amount
A. Salary and Wages			
Staff Time and Wages			
	Subtotal	**$**	**90,733.33**
B. Fringe Benefits (%)			
	Subtotal	**$**	**16,288.33**
C. Direct Costs			
Tuition		$	15,000.00
Supplies		$	500.00
Travel		$	1,500.00
Consultants		$	-
Miscellaneous		$	-
	Subtotal	**$**	**17,000.00**
D. Other Direct Costs:			
Equipment		$	4,000.00
	Subtotal	**$**	**4,000.00**
E. Modified Total Direct Cost		$	-
	Subtotal	**$**	**-**
F. Overhead/Indirect Costs		$	11,302.17
	Subtotal	**$**	**11,302.17**
Total Costs		**$**	**139,323.83**

Chapter VI

CONCLUSIONS

OVERVIEW

This research focused on design solutions for reducing vehicle speeds in business and residential areas. The research focused on treatments to improve the safety of motorists, while maintaining and or improving the safety of pedestrians and bicyclists. A literature search was performed covering the state-of-the-practice of traffic calming in the United States. State Routes with a posted speed limit of 25 mph were identified as possible locations for evaluating the potential benefits for implementing traffic calming. A human factor study to determine the effectiveness, suitability and potential of the traffic calming treatments to reduce speeds was conducted. Finally, a plan for evaluating the traffic calming measures after its implementation, as well as implementation plans for these measures was also developed.

SUMMARY

Research has shown that one prevalent factor associated with motor vehicle crashes is speeding. The use of traffic calming measures to reduce speeds and volumes to acceptable levels has shown to hold potential. A literature review was performed covering: (1) the state-of-the practice of traffic calming in the United States and abroad; (2) experience of local and state Departments of Transportation using various traffic calming measures; and (3) the legal and political concerns governing the installation of traffic calming measures on New Jersey roadways. New Jersey is cited as one of the first locations where traffic calming was implemented in the United States. Since that time, traffic calming programs have been implemented in hundreds of jurisdictions across the country.   Traffic calming measures can be divided into three categories: vertical measures, horizontal measures, and road narrowings. Vertical measures use forces of vertical acceleration to discourage speed. Horizontal measures use forces of lateral acceleration to discourage speed. Road narrowing uses a psycho-perceptive sense of enclosure to discourage speed.

Locations in New Jersey where traffic calming treatments may be beneficial to motorists, bicyclists and pedestrians were identified. Field visits of state roadways with a posted speed limit of 25 mph were visited and suitability for traffic calming was determined. Five locations were identified for further study including: Route 28 (Westfield and Cranford), Route 67 (Fort Lee), Route 172 (New Brunswick) and Route 27 (Princeton). A visual preference survey was performed at these locations to determine the effectiveness, suitability and potential of the traffic calming treatments to reduce speeds.

The survey gathered the following information:

- Reason for coming to this area
- Age of Respondent
- Number of times respondent is a pedestrian in the area
- Number of times respondent is a bicyclist in the are
- Perception of safety for pedestrians or bicyclists
- Reasons for perceived lack of safety
- Preferred roadway travel speed
- Rating of traffic calming measure for pedestrian/bicyclist safety
- Rating of traffic calming measure for driver convenience
- Rating of traffic calming measure for aesthetics.

Four traffic calming measures were assessed in the survey including speed humps, speed tables, median dividers, and medians with a breakpoint for pedestrians. The median with the breakpoint received the highest overall rating for improving safety for pedestrians and bicycles, for its driver convenience, as well as for the aesthetics of the measure. Speed humps received the lowest rating.

An evaluation and implementation plan was developed for each of the study locations where traffic calming is proposed for implementation. The intent of the implementation and evaluation plan is for use in assessing the effectiveness of traffic calming measures to reduce speeds and improve safety. Several components should be included in the evaluation plan including: speed measurements; crash analyses before and after the installation of the measure; traffic counts; observations; and a survey of residents, road users, local authorities; and noise measurements.

Conclusions

The overall objective of this research was to evaluate the effectiveness of various traffic calming treatments on motorist's speeds. The literature review identified various traffic calming treatments that have been demonstrated to reduce motorist’s speeds. Previous studies have demonstrated the potential impact of these treatments on speeds. The specific reduction, however, does vary from location to location depending on the roadway geometry and volume conditions. For this reason, further research is needed to better estimate the impact of traffic calming on speeds. Given the volume levels and geometric conditions on the roadway, speed models can be used to better determine the potential impacts of various traffic calming measures on operating speeds.

Locations in New Jersey where traffic calming treatments may be beneficial to motorists, bicyclists and pedestrians were identified. The research focused on design solutions for reducing speeds on State routes. Although the research identified locations on State routes where design solutions would be appropriate for reducing speeds, these types of roadways tend to have higher volumes and truck volumes that may limit the applicability of design solutions for reducing speeds. In addition to design solutions, traffic control measures should also be included as elements in the safety plan for these roadways. The research demonstrated that crash analyses, by themselves, are not a good indication of whether traffic calming would be appropriate for a location. Further research is needed to develop a procedure for identifying locations where traffic calming would be warranted and be beneficial in reducing speeds.

The human factors study performed included a visual preference survey which gathered information on the acceptability and preferences of various road uses. The survey found that despite the widespread use of speed humps, this measure was selected as the least preferred traffic calming measure by road users in this study. The median with the breakpoint had the highest overall rating for its ability to improve safety, for imposing the least driver inconvenience, and this measure had the highest aesthetic value. Study results suggest that road users may need to be educated on the effectiveness of various traffic calming measures to reduce speeds and improve safety for bicyclists and pedestrians. More research is needed to better understand the preference of road users in the selection of these measures and to understand the factors that impact road users' perception of road safety.

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Appendix I

Crash Statistics for State Routes

Table 33. Crash Statistics for all Vehicles on Route 49 (MP 8.87 - MP 9.30)

MP From	MP To	Section Length	AADT	Total Accidents	Fatals	Injury	Prop Dam	Wet Weather	Acc Rate
8.86	9.05	0.19	12,030						
9.05	9.25	0.20	12,643	2			2	1	2.17
9.25	9.45	0.20	12,643	1		1			1.08
Total	Route	53.76	8,629	524	7	174	343	136	3.09

Table 34. Crash Statistics for all Vehicles on Route 49 (MP 36.02 - MP 36.78)

MP From	MP To	Section Length	AADT	Total Accidents	Fatals	Injury	Prop Dam	Wet Weather	Acc Rate
35.91	36.13	0.22	11,705	17		6	11	7	18.09
36.13	36.40	0.27	24,315	32		10	22	8	13.35
36.40	36.60	0.20	11,070	25		5	20	5	30.94
36.60	36.80	0.20	11,070	6		3	3		7.42
Total	Route	53.76	8,629	524	7	174	343	136	3.09

Table 35. Crash Statistics for all Vehicles on Route 54 (MP 10.318 - MP 10.988)

MP From	MP To	Section Length	AADT	Total Accidents	Fatals	Injury	Prop Dam	Wet Weather	Acc Rate
10.21	10.41	0.20	7,092						
10.41	10.61	0.20	7,092	1			1		2.58
10.61	10.83	0.22	7,092	7		4	3	3	13.52
10.83	11.03	0.20	7,092	5			5	1	9.66
Total	Route	11.86	9,533	144	1	44	99	46	3.49

Table 36. Crash Statistics for all Vehicles on Route 71 (MP 5.41 - MP 5.56)

MP From	MP To	Section Length	AADT	Total Accidents	Fatals	Injury	Prop Dam	Wet Weather	Acc Rate
5.42	5.49	0.07	14,920	1			1		2.62
5.49	5.77	0.28	14,920	8		2	6	1	5.25
Total	Route	16.46	14,309	419		131	288	108	4.87

Table 37. Crash Statistics for all Vehicles on Route 88 (MP 0.00 - MP 0.20)

MP From	MP To	Section Length	AADT	Total Accidents	Fatals	Injury	Prop Dam	Wet Weather	Acc Rate
0	0.11	0.11	11,277	6		1	5	2	13.25
0.11	0.31	0.20	11,277	18		4	14	6	21.87
Total	Route	9.81	15,477	421		136	285	154	7.60

Table 38. Crash Statistics for all Vehicles on Route 166 (MP 1.08 - MP 1.48)

MP From	MP To	Section Length	AADT	Total Accidents	Fatals	Injury	Prop Dam	Wet Weather	Acc Rate
1.05	1.13	0.08	26,076	2			2	1	2.63
1.13	1.33	0.2	26,076	35		5	30	14	18.39
1.33	1.53	0.2	26,076	14		6	8	5	7.35
Total	Route	3.73	21,957	250		74	176	81	8.36

Appendix II

Visual Preference Survey

New Jersey Institute of Technology is conducting a study of *(Street Name)* between *(Cross Streets)*. The study is being conducted for the New Jersey Department of Transportation to better understand public acceptance of various roadway design treatments.

1. Please indicate your reason for coming to this area

   ☐ You live here ☐ Shopping ☐ Recreational ☐ Work
   ☐Other__________________

2. Please indicate your age:

   ☐ Under 20 ☐ 21 to 30 ☐ 31 to 64 ☐ 65 or above

3. How often do you cross *(Your Street)* as a pedestrian?

   ☐ At least once a day ☐ At least once a week ☐ At least once a month ☐ Never

4. How often do you bicycle on *(Your Street)*?

   ☐ At least once a day ☐ At least once a week ☐ At least once a month ☐ Never

5. Do you believe *(Your Street)*, between *(Cross Streets)*, is safe for a pedestrian or a bicyclist to cross?

   - ☐ Yes
   - ☐ No, Please specify the reasons:
     - ☐ Lack of pedestrian crossing
     - ☐ No bicycle lane
     - ☐ Too many vehicles
     - ☐ Too many trucks
     - ☐ Speeding
     - ☐ Other (please specify) _________________

6. How fast do you believe vehicles on *(Your Street)* should be allowed to travel to improve safety for pedestrians and bicycles?

   ☐ <20 mph ☐ 20 mph ☐ 25 mph ☐ 30 mph ☐ 35 mph ☐ >35 mph

7. One way to force drivers to travel at a particular speed is through the design of the roadway. The following shows several pictures of possible roadway designs that can be used to force drivers to travel at a particular speed and to improve safety for pedestrians and bicycles. Rate these designs for their safety, driver convenience and aesthetics, on a scale of 1 to 7, where 1 is the least preferred design for *(Your Street)*, and 5 is the most preferred design for *(Your Street)*.

Speed Hump	**Pedestrian/Bicyclist Safety Rating:** 1 2 3 4 5 Least Preferred … Most Preferred
	**Driver Convenience Rating:** 1 2 3 4 5 Least Preferred … Most Preferred
	Aesthetic Rating: 1 2 3 4 5 Least Preferred … Most Preferred

Speed Table	**Pedestrian/Bicyclist Safety Rating:** 1 2 3 4 5 Least Preferred … Most Preferred
	**Driver Convenience Rating:** 1 2 3 4 5 Least Preferred … Most Preferred
	Aesthetic Rating: 1 2 3 4 5 Least Preferred … Most Preferred

Median Divider	**Pedestrian/Bicyclist Safety Rating:** 1 2 3 4 5 Least Preferred … Most Preferred
	**Driver Convenience Rating:** 1 2 3 4 5 Least Preferred … Most Preferred
	Aesthetic Rating: 1 2 3 4 5 Least Preferred … Most Preferred

Median with Breakpoint for Pedestrians	**Pedestrian/Bicyclist Safety Rating:** 1 2 3 4 5 Least Preferred … Most Preferred
	**Driver Convenience Rating:** 1 2 3 4 5 Least Preferred … Most Preferred
	Aesthetic Rating: 1 2 3 4 5 Least Preferred … Most Preferred

Thank you for your assistance with this survey.

Appendix III

Results of Visual Preference Survey for Each Study Location

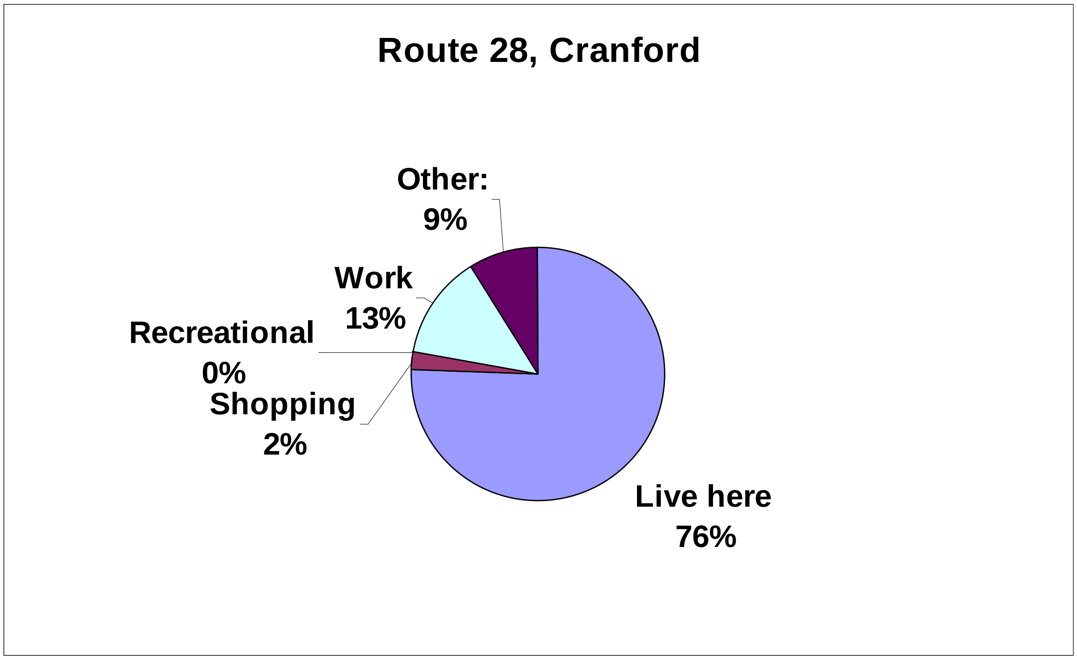

Figure 39. Purpose for Trip - Route 28, Cranford

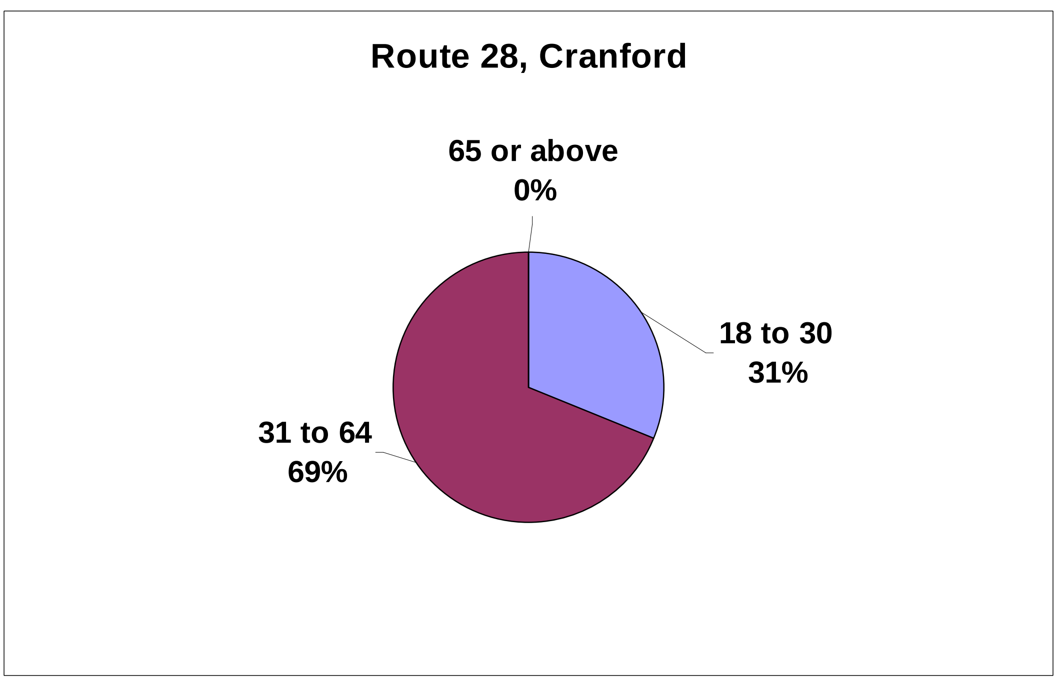

Figure 40. Age of Respondent – Route 28, Cranford

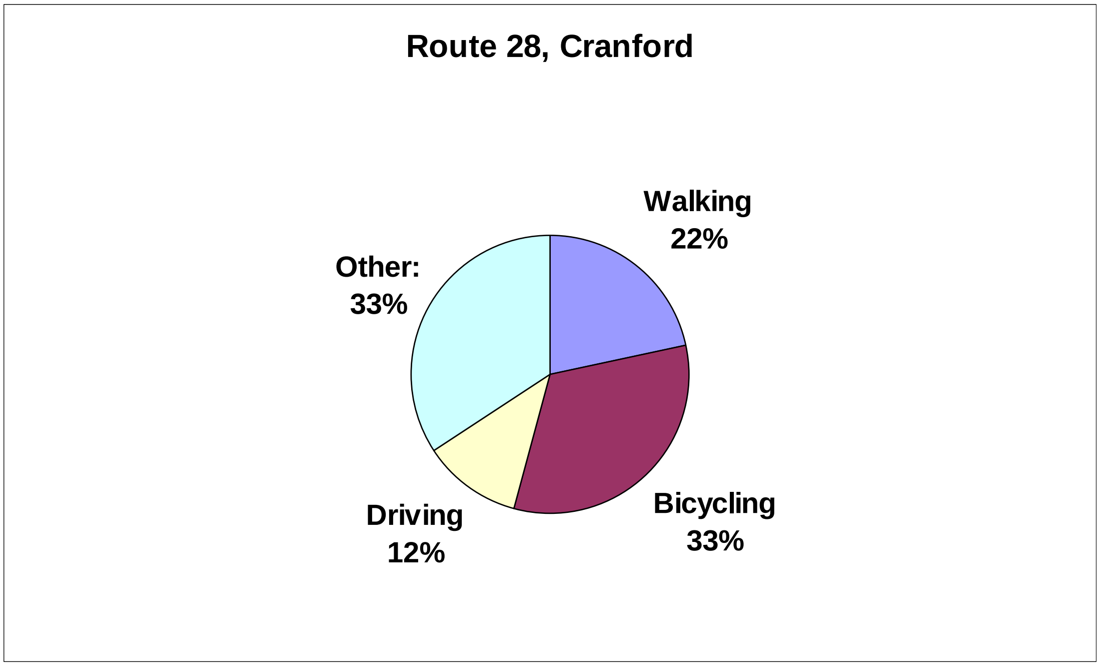

Figure 41. Primary Mode of Transportation - Route 28, Cranford

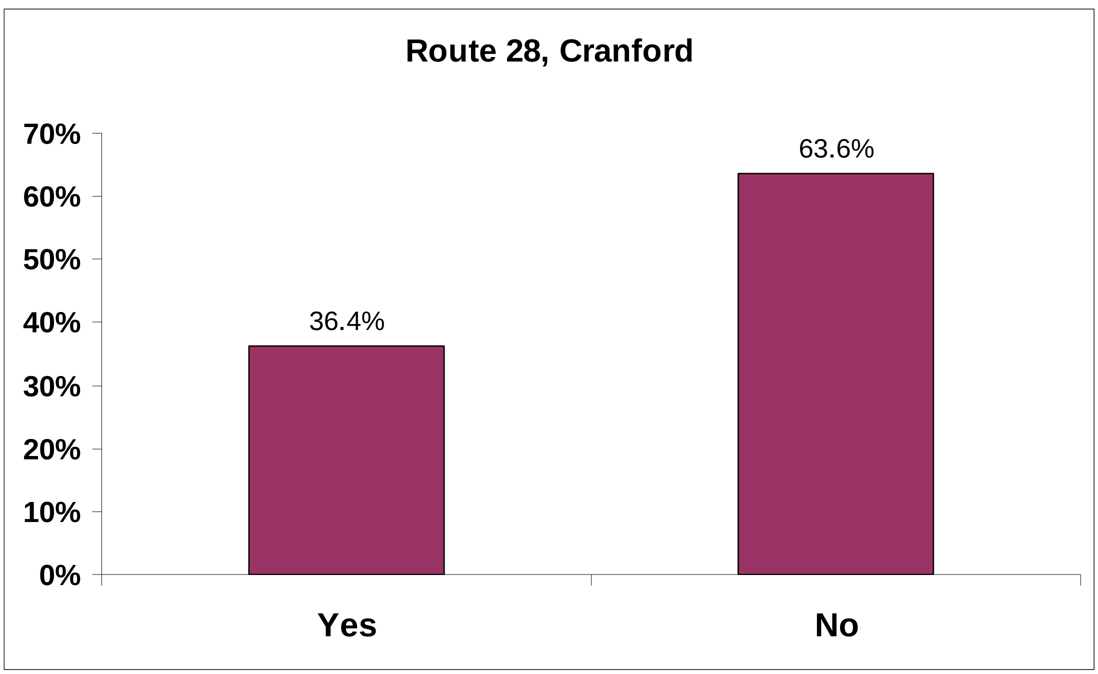

Figure 42. Safety of Roadway - Route 28, Cranford

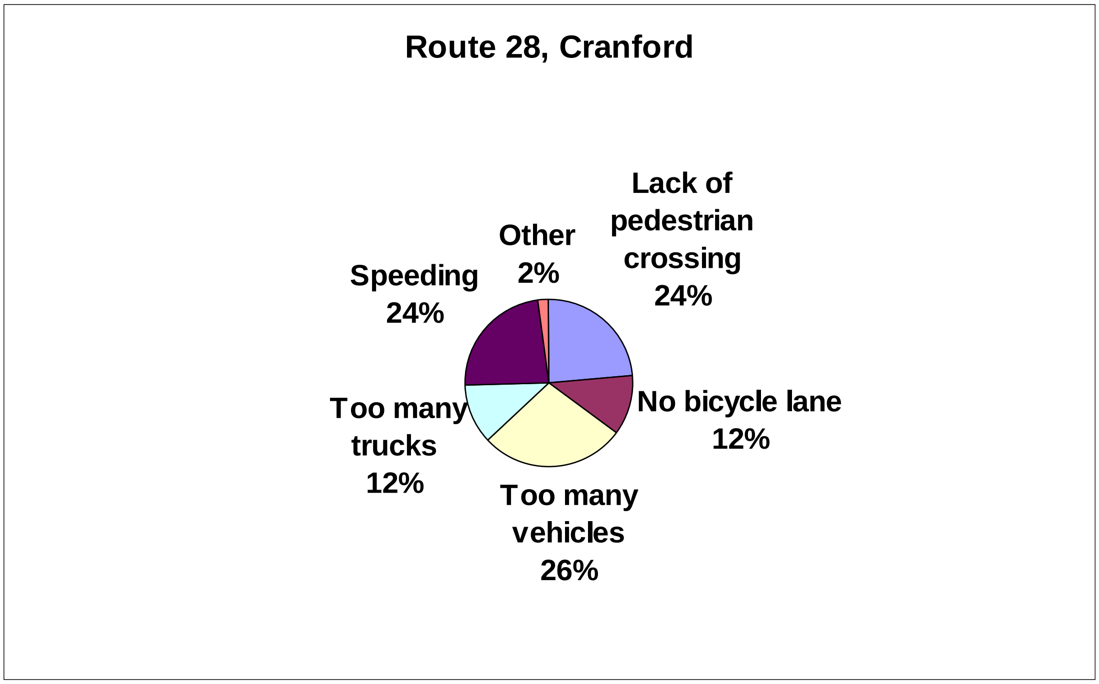

Figure 43. Reasons Why Street is Unsafe - Route 28, Cranford

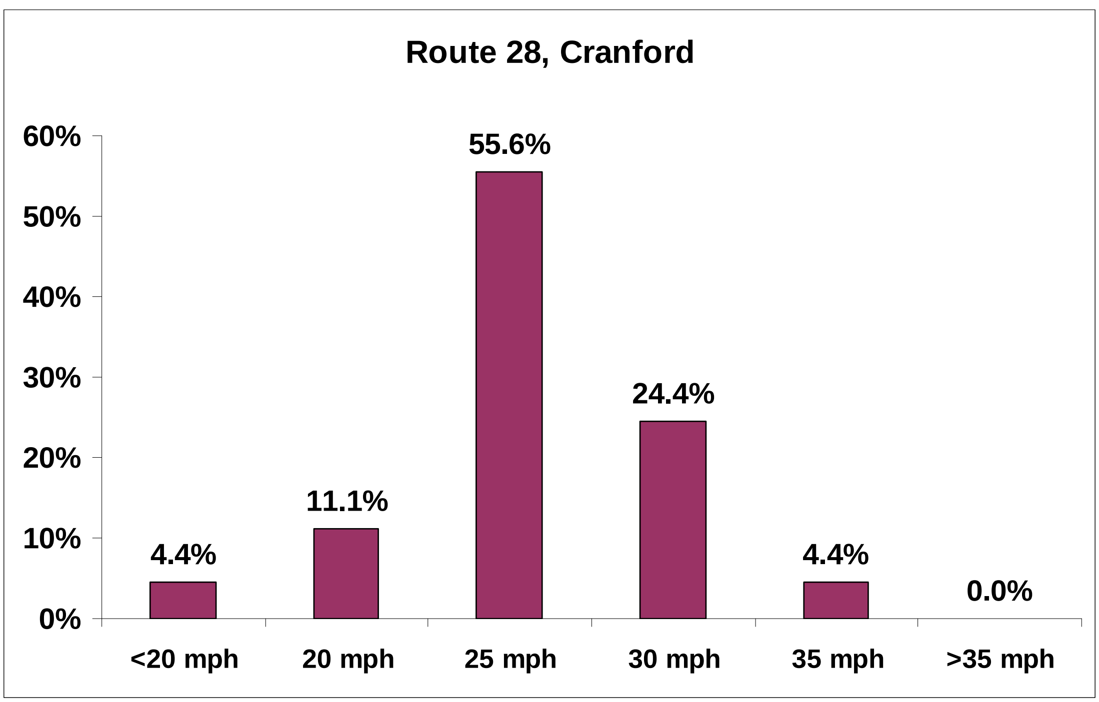

Figure 44. Safe Speed of Roadway - Route 28, Cranford

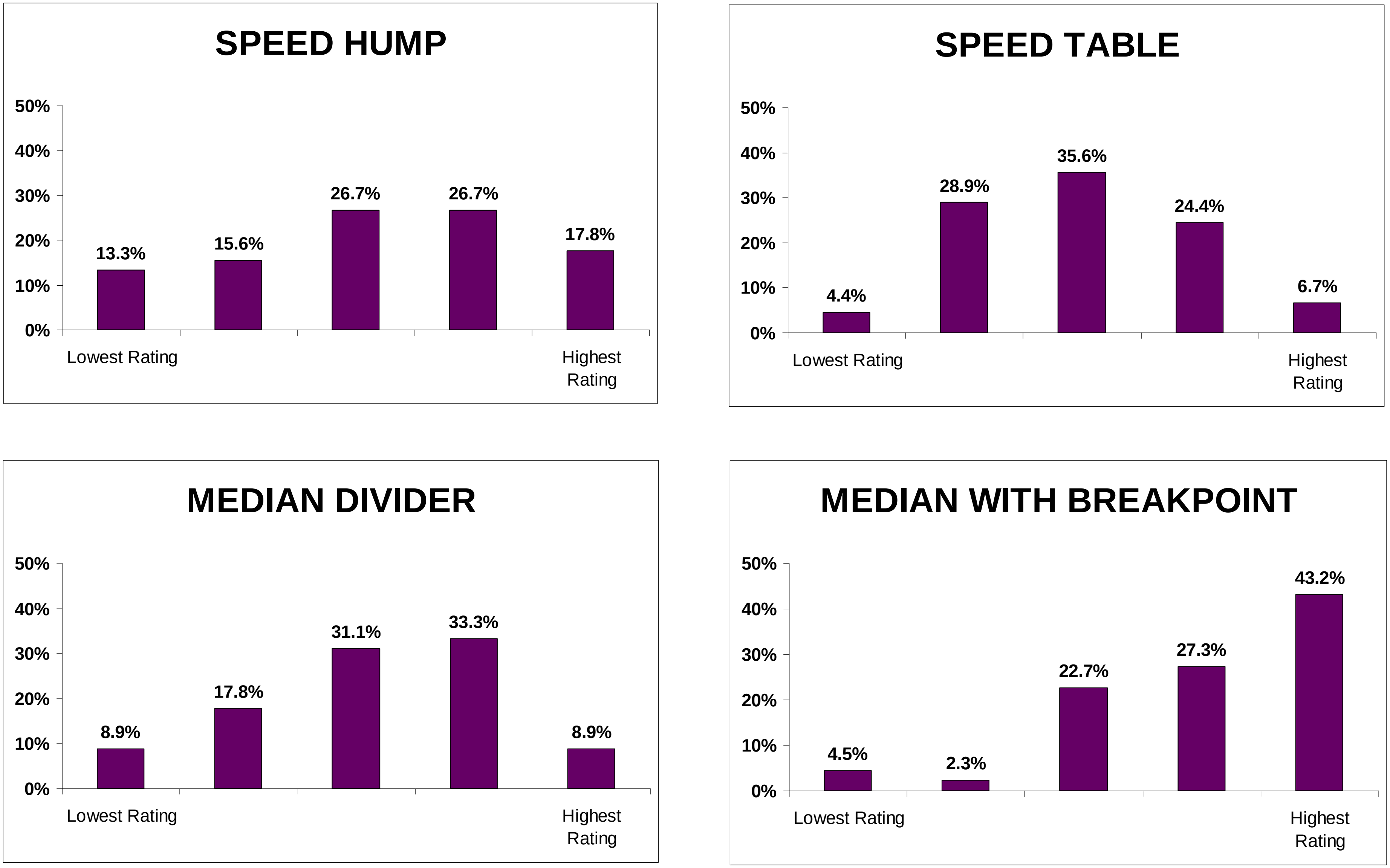

Figure 45. Pedestrian/Bicyclists Safety Rating – Route 28, Cranford

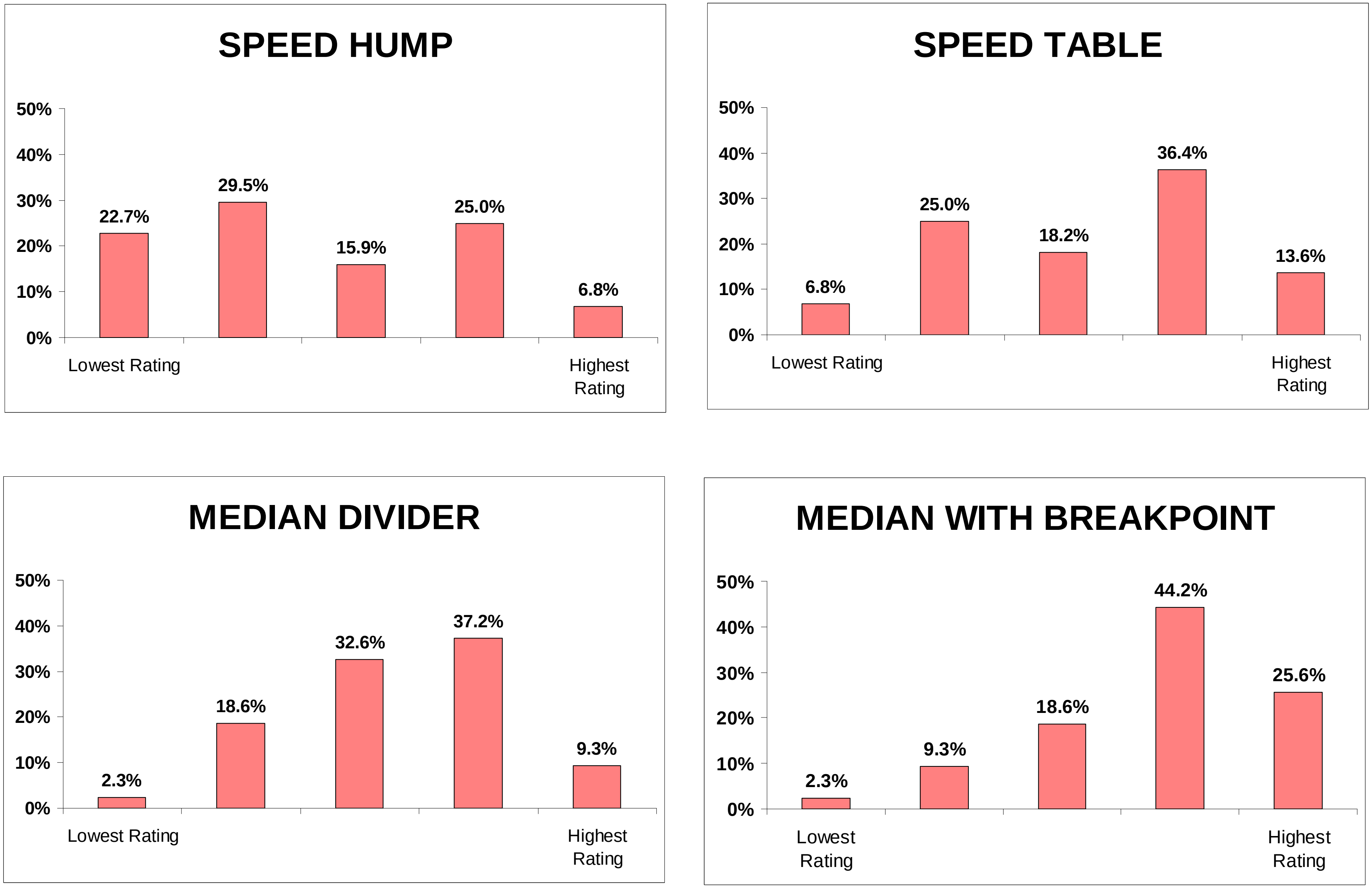

Figure 46. Driver Convenience Rating – Route 28, Cranford

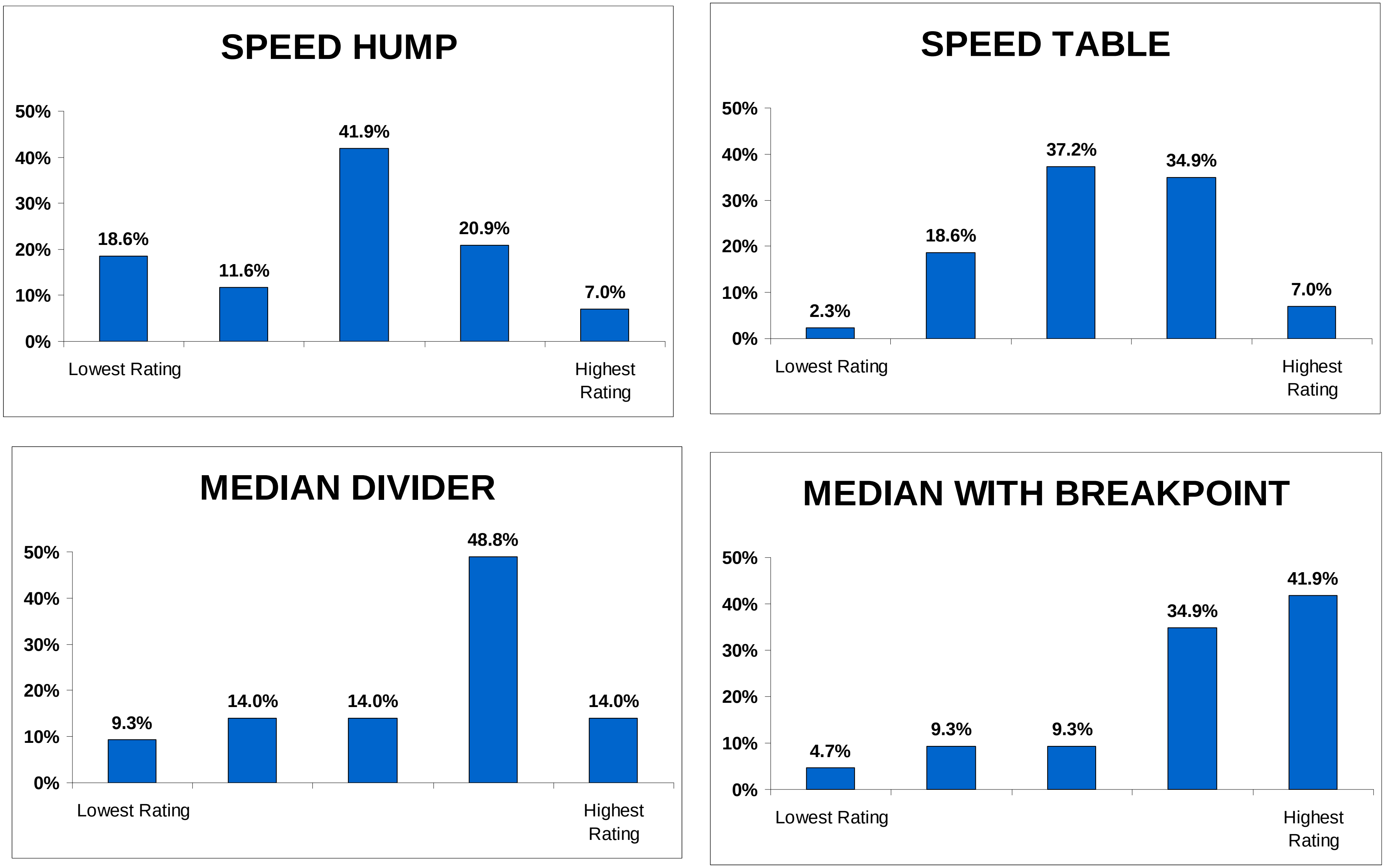

Figure 47. Aesthetic Rating - Route 28, Cranford

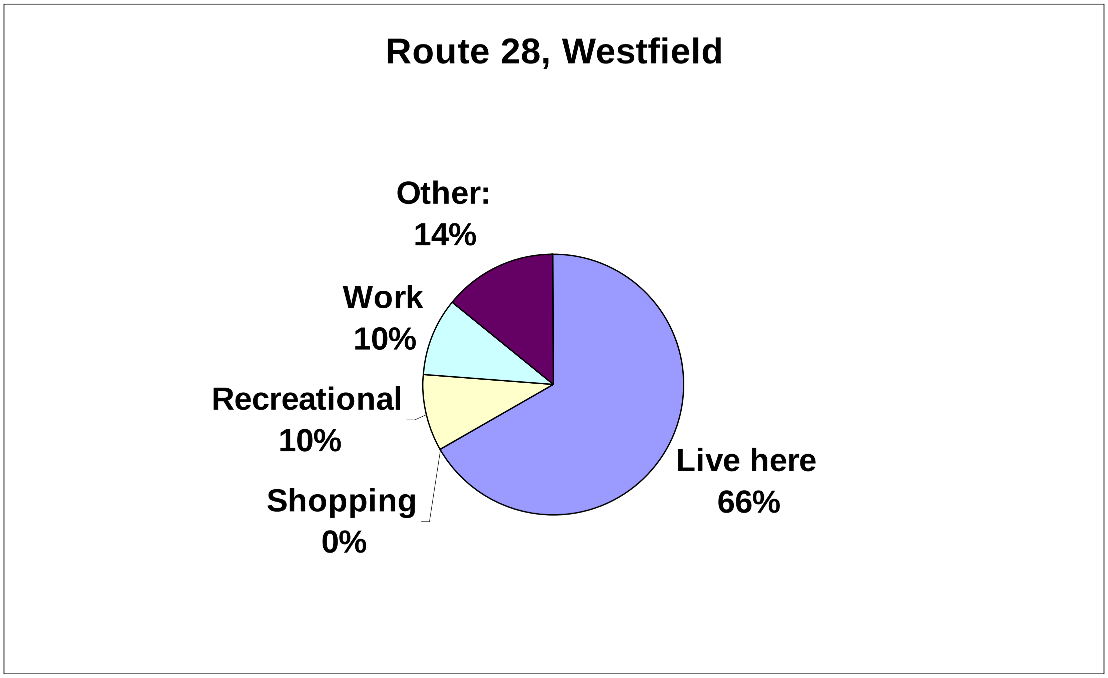

Figure 48. Purpose for Trip – Route 28, Westfield

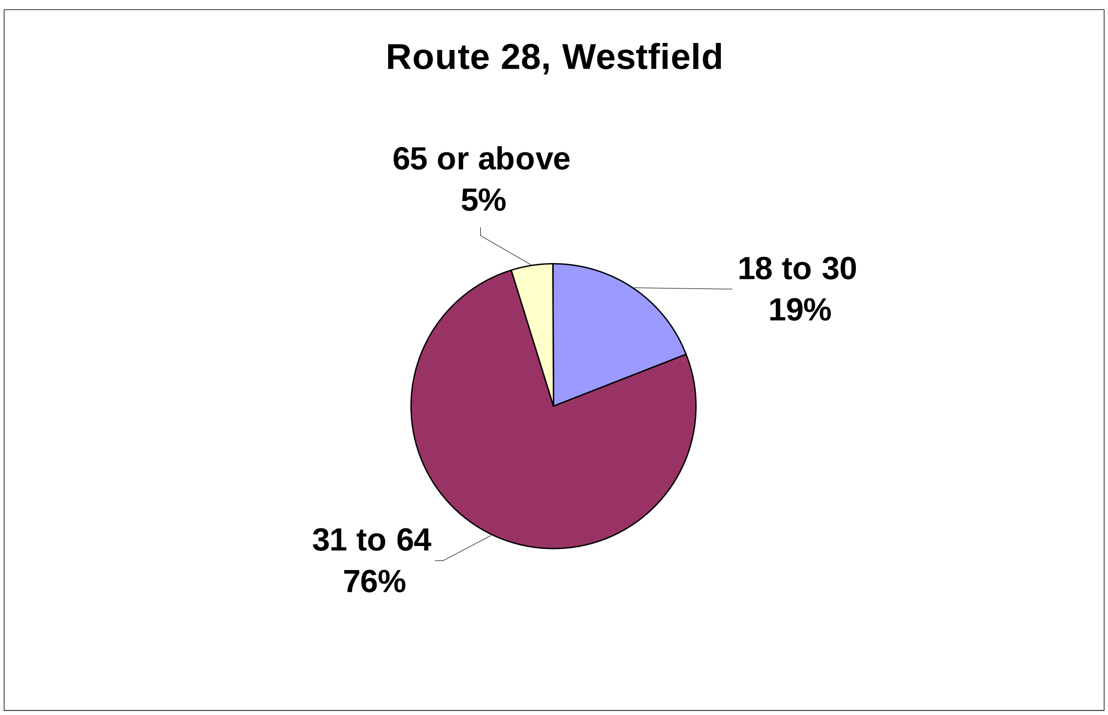

Figure 49. Age of Respondent – Route 28, Westfield

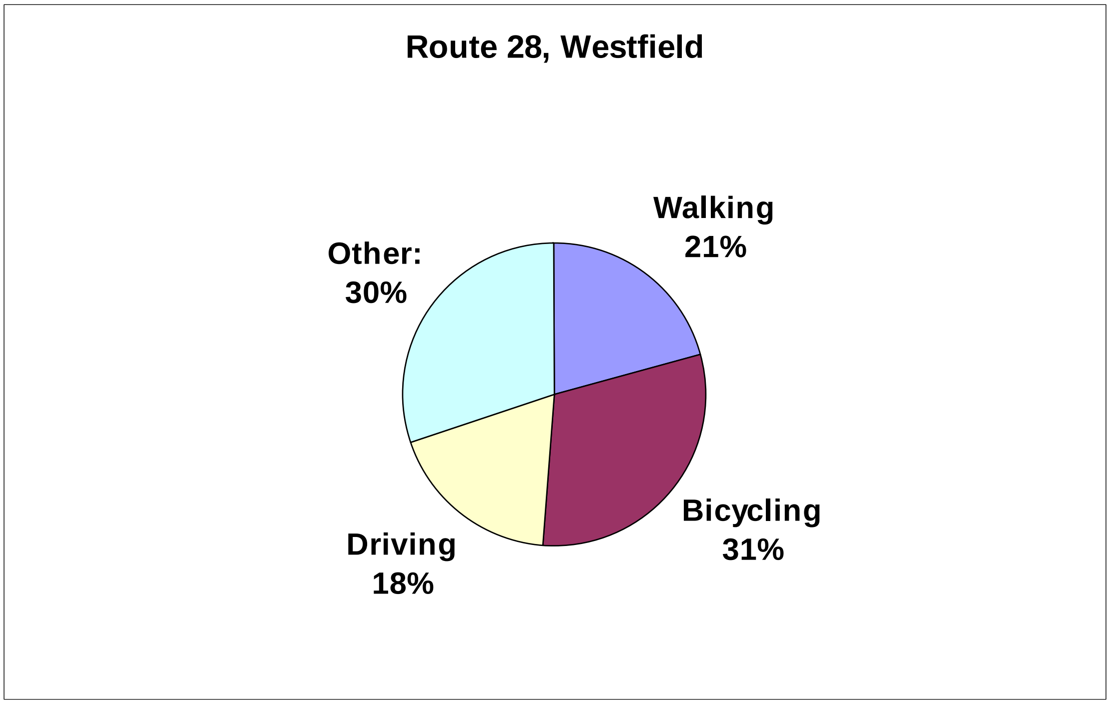

Figure 50. Primary Mode of Transportation – Route 28, Westfield

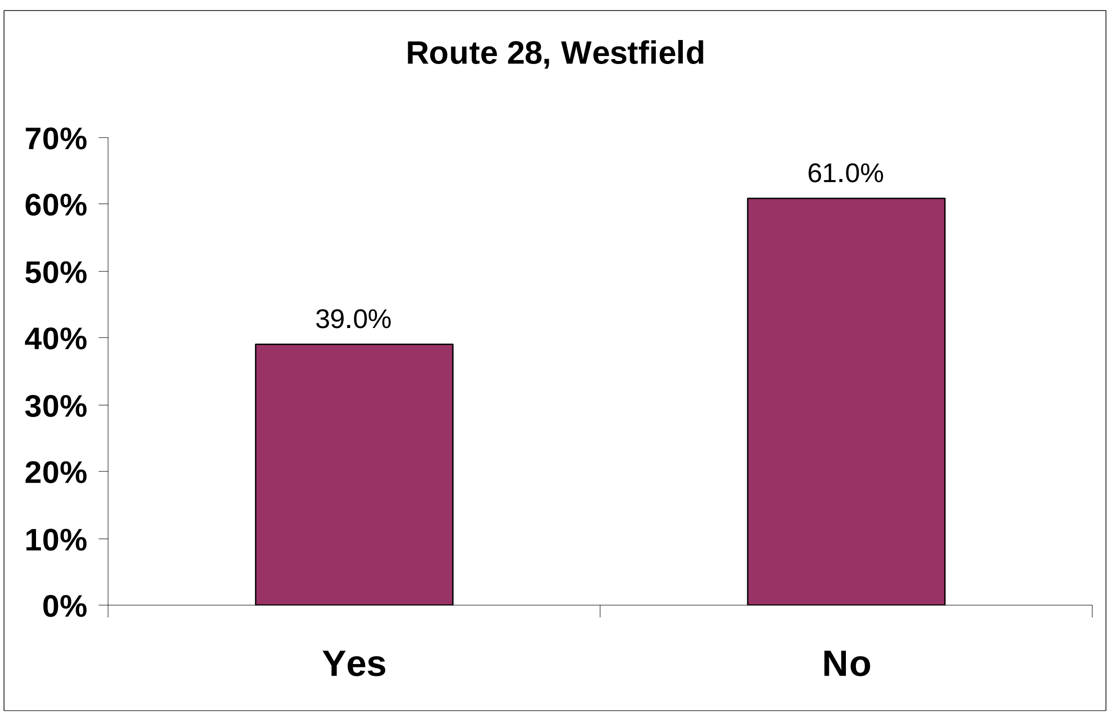

Figure 51. Safety of Roadway – Route 28, Westfield

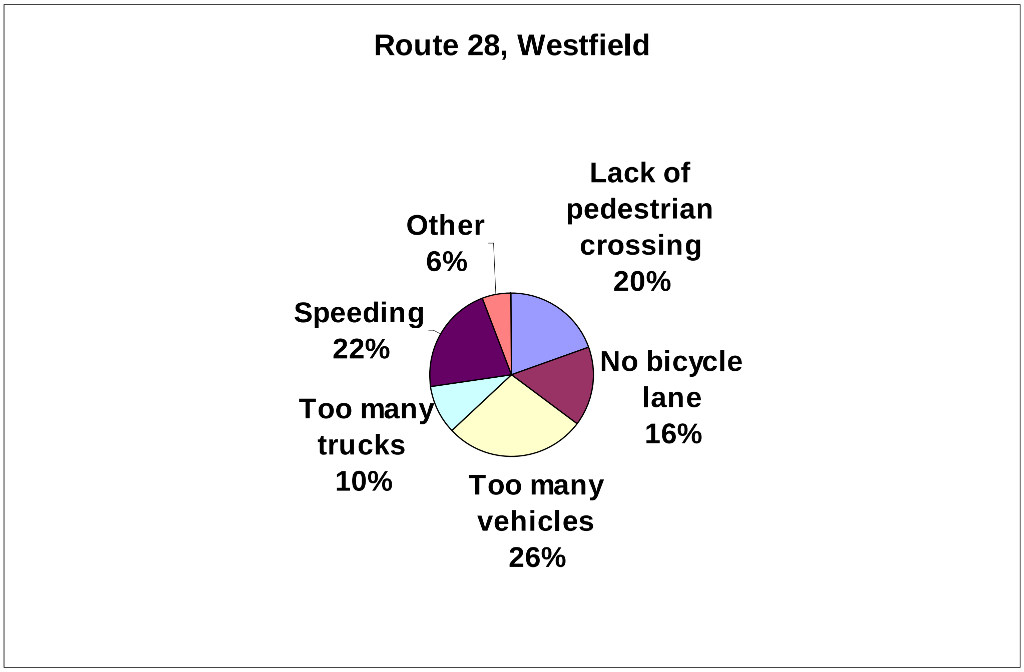

Figure 52. Reasons Why Roadway Unsafe – Route 28, Westfield

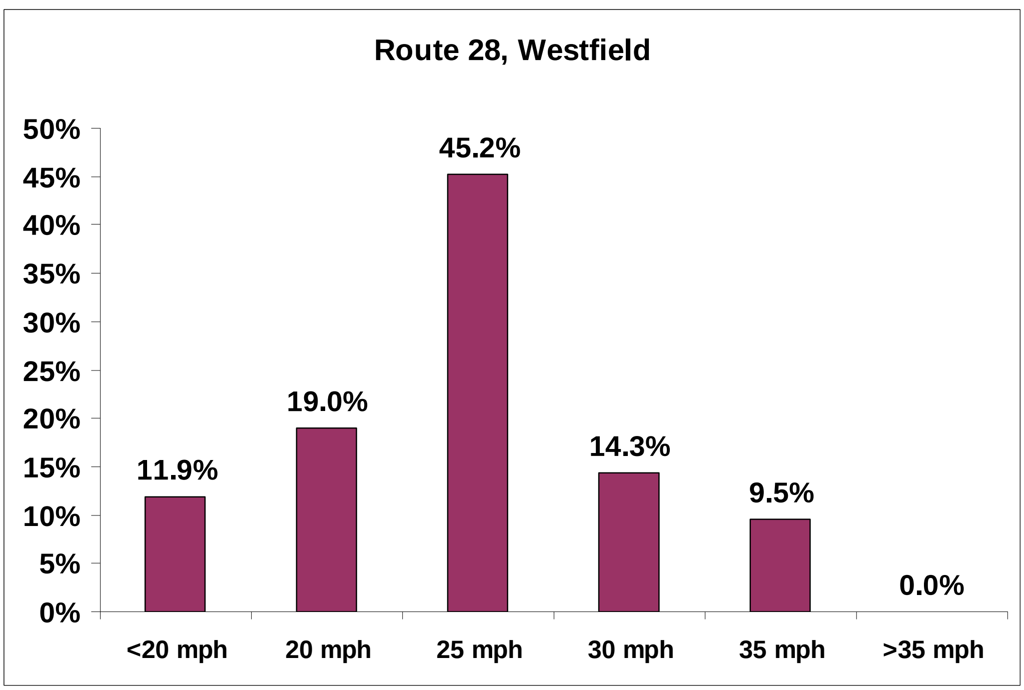

Figure 53. Safe Speed for Roadway – Route 28, Westfield

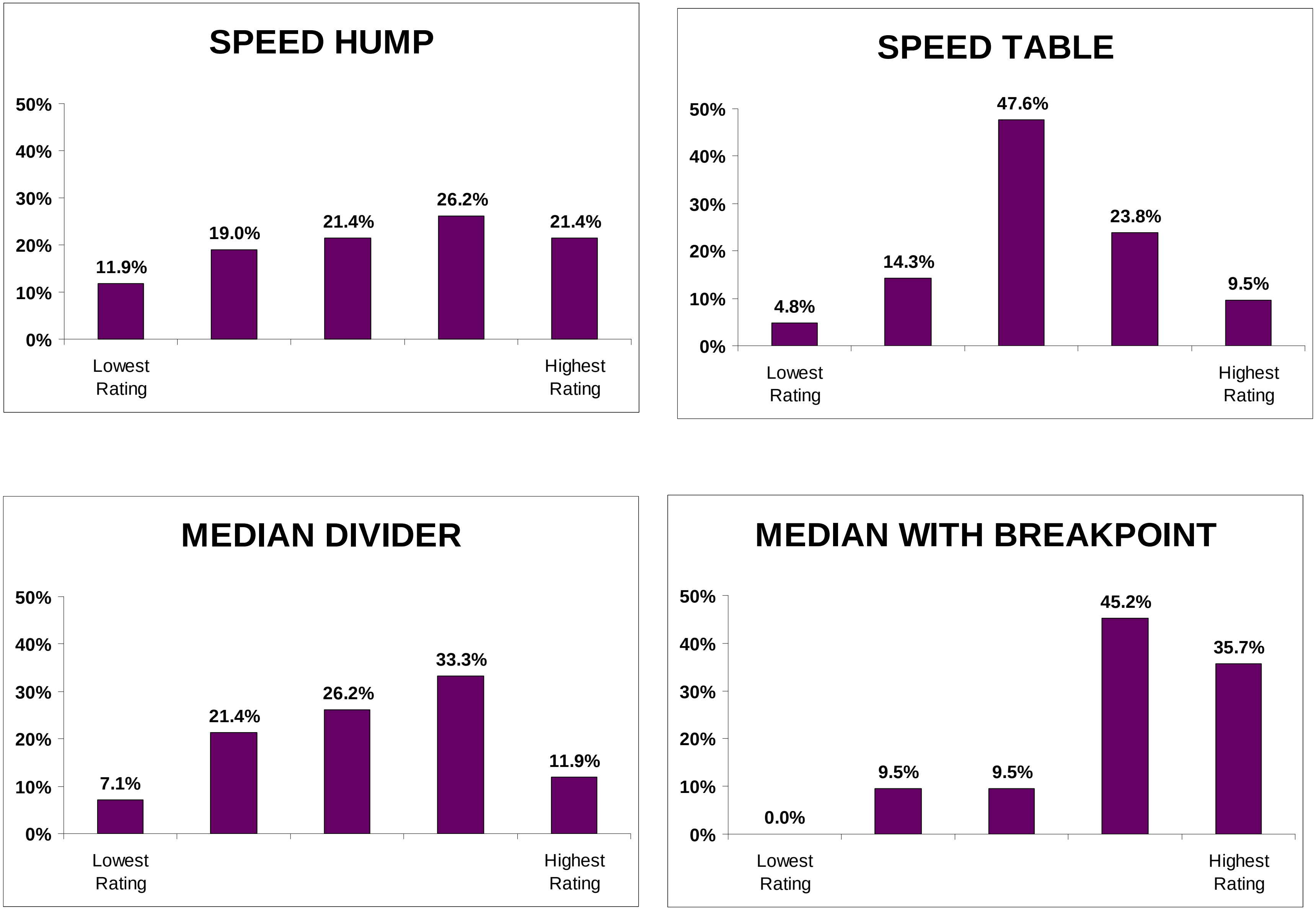

Figure 54. Pedestrian/Bicycle Safety Rating – Route 28, Westfield

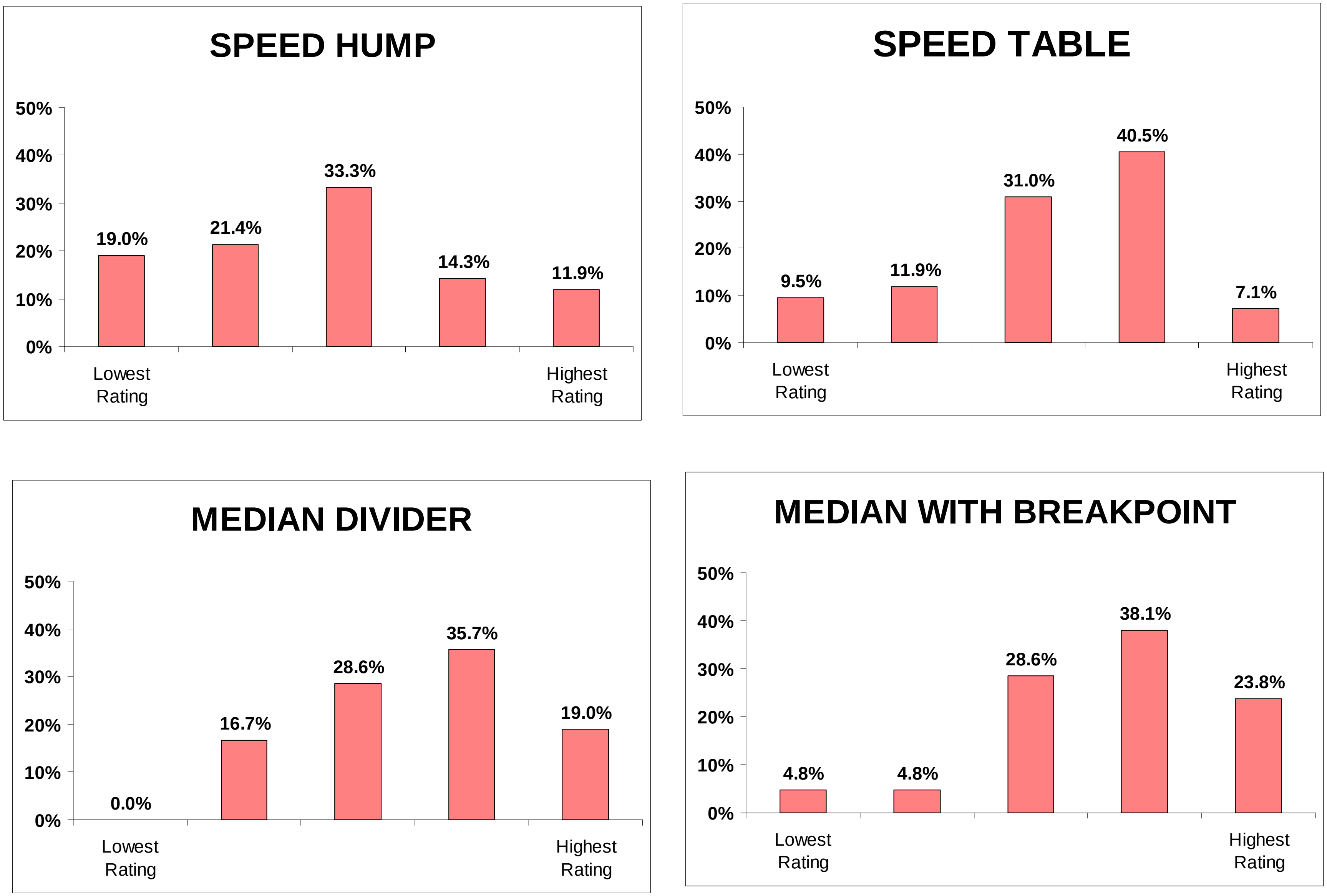

Figure 55. Driver Convenience Rating – Route 28, Westfield

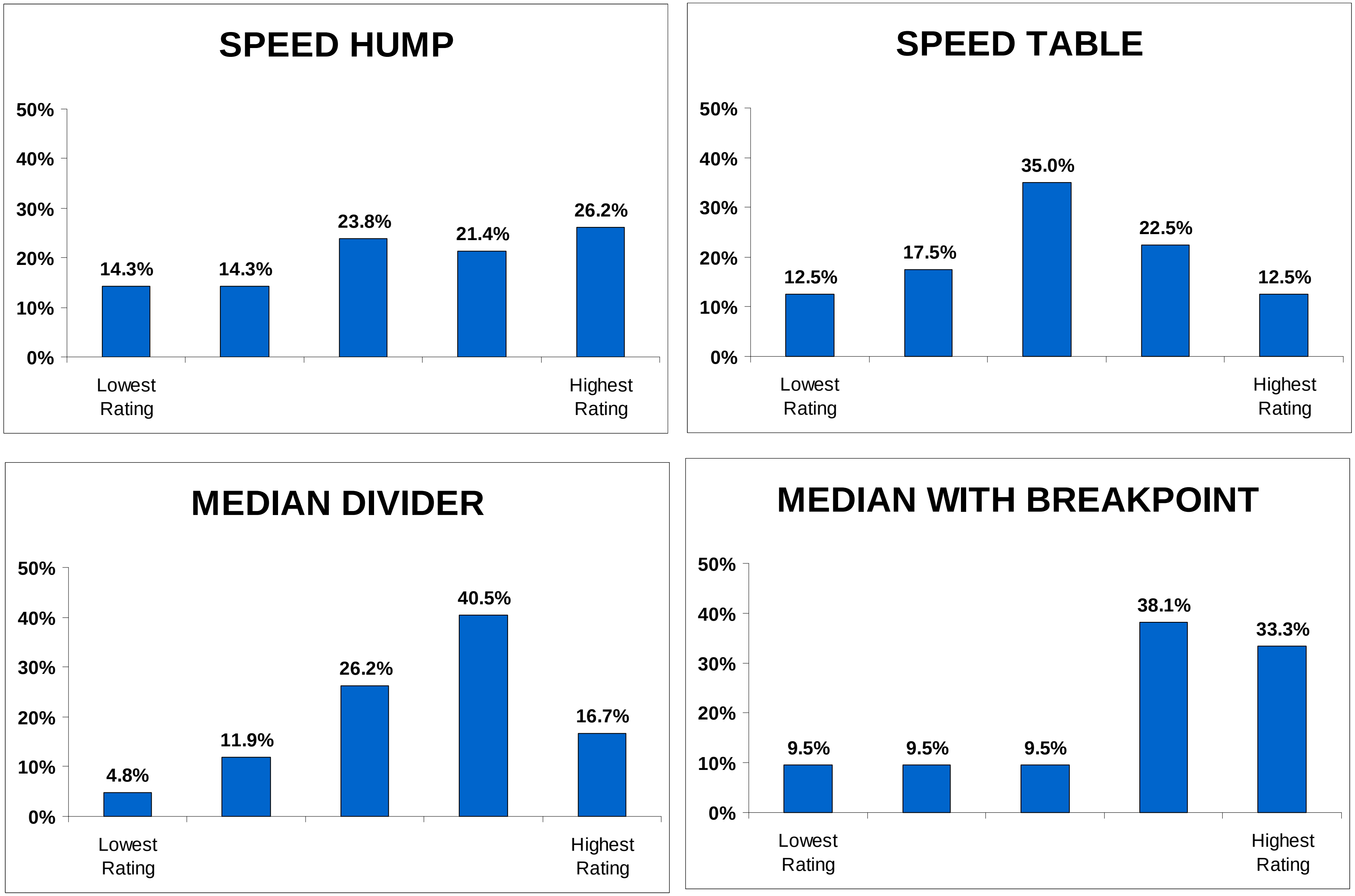

Figure 56. Aesthetic Rating – Route 28, Westfield

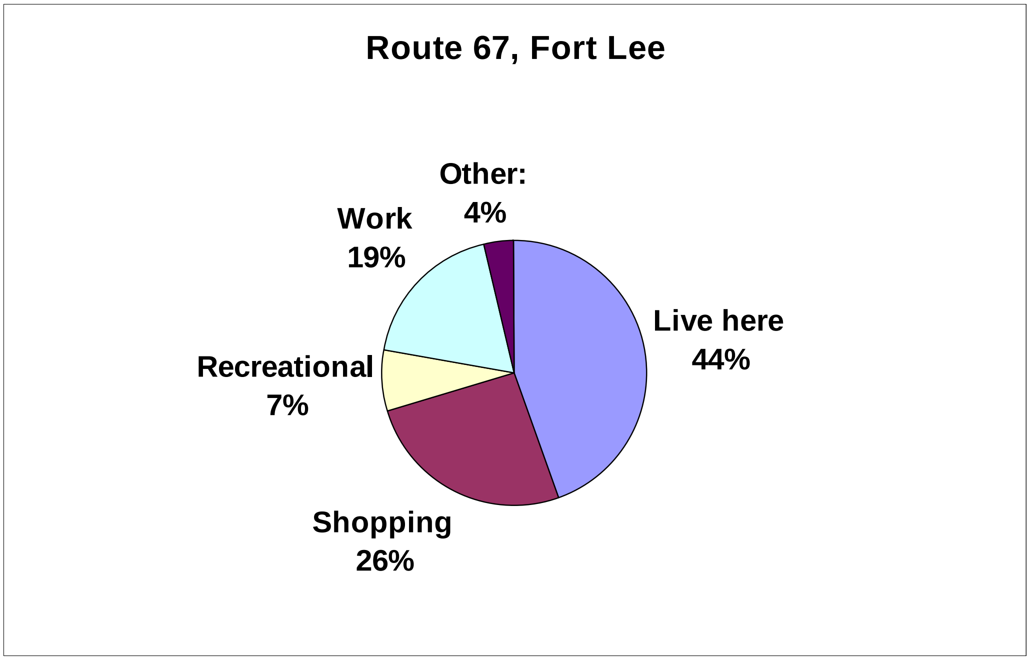

Figure 57. Purpose of Trip - Route 67, Fort Lee

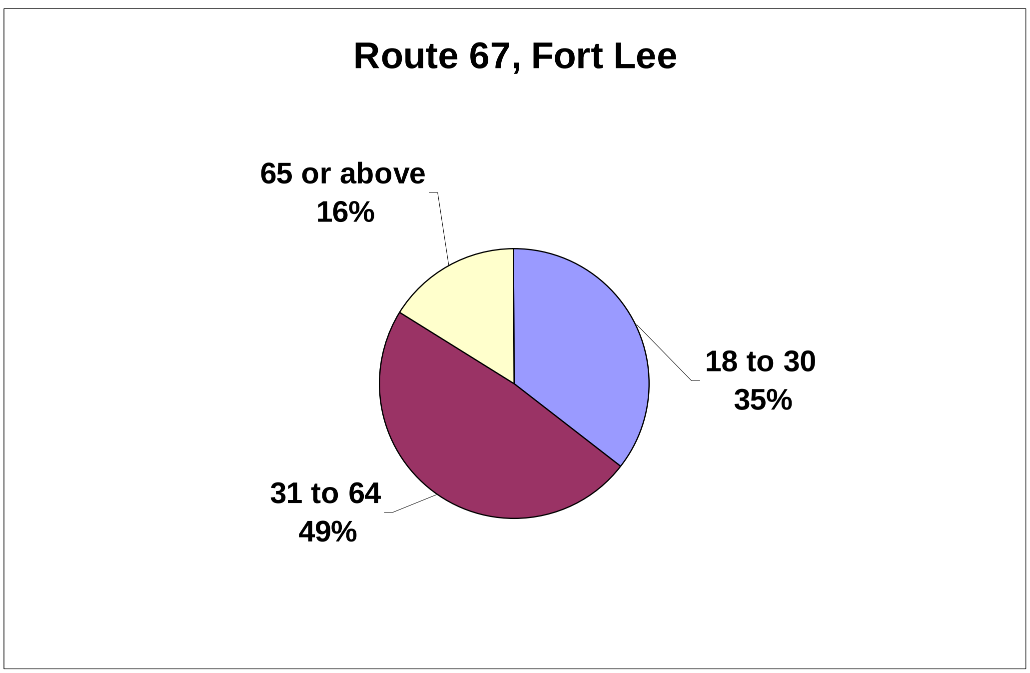

Figure 58. Age of Respondent - Route 67, Fort Lee

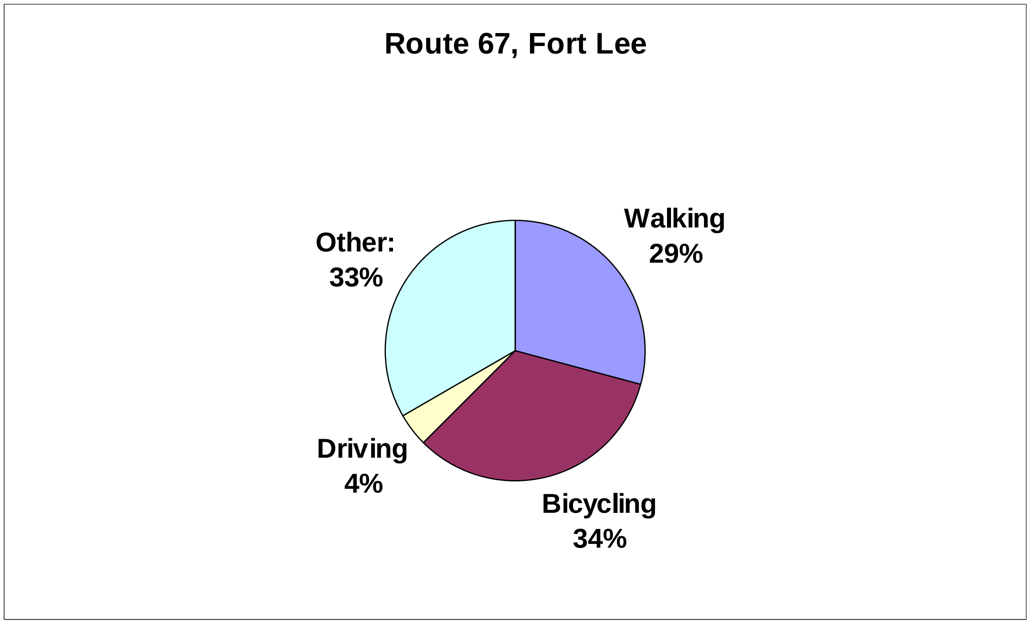

Figure 59. Primary Mode of Transportation - Route 67, Fort Lee

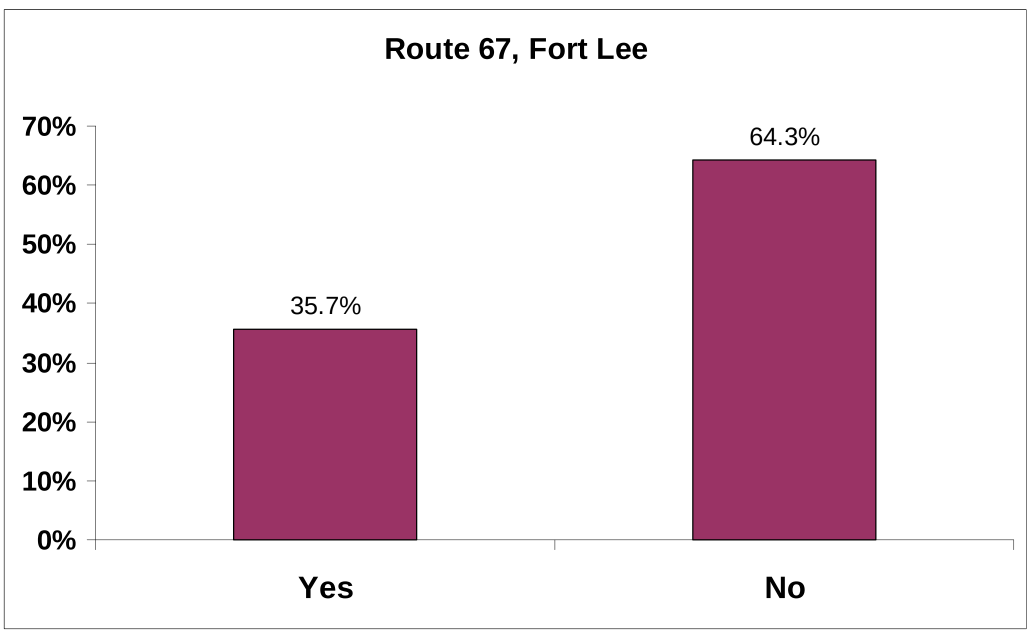

Figure 60. Safety of Roadway - Route 67, Fort Lee

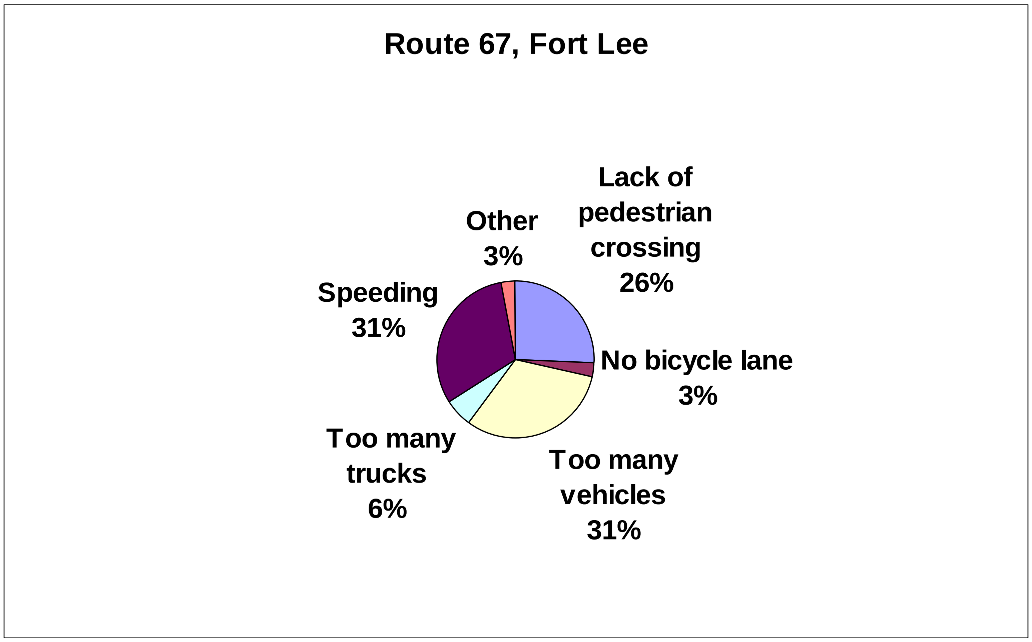

Figure 61. Reasons Why Roadway Unsafe - Route 67, Fort Lee

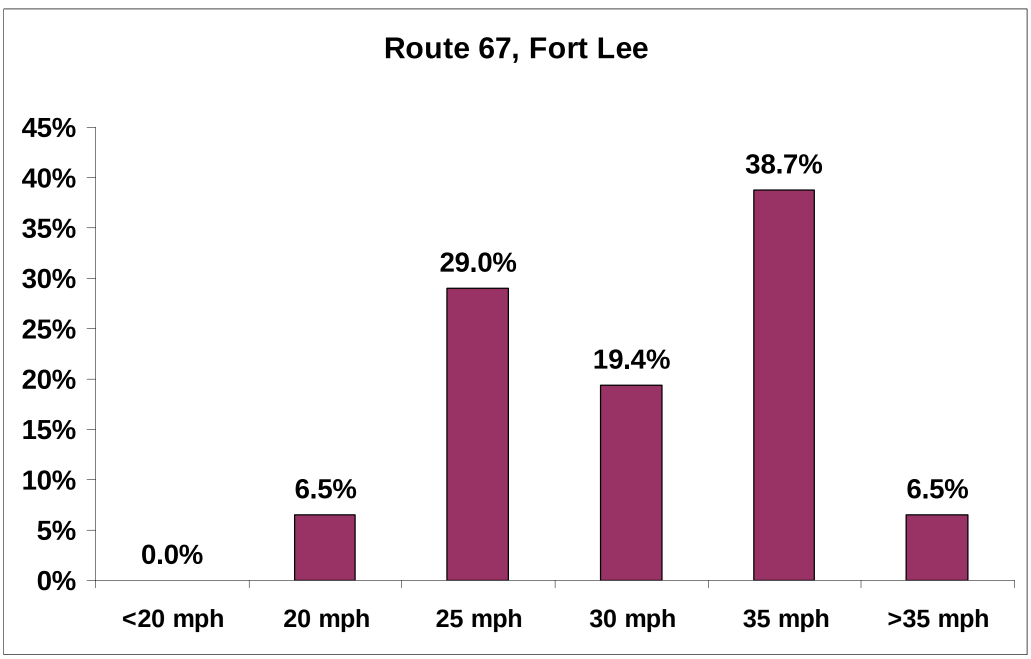

Figure 62. Safe Speed for Roadway - Route 67, Fort Lee

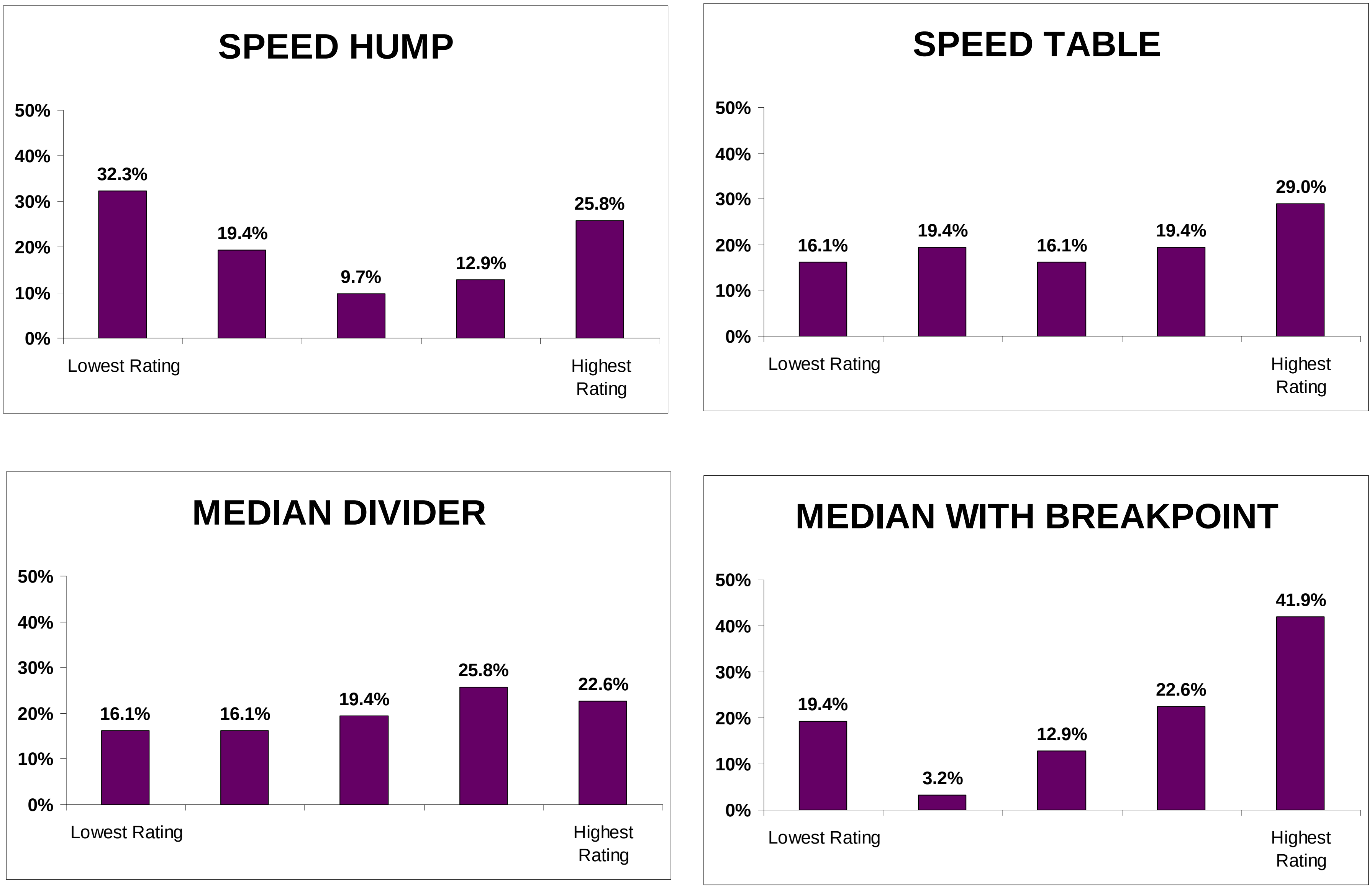

Figure 63. Pedestrian/Bicyclists Safety Rating - Route 67, Fort Lee

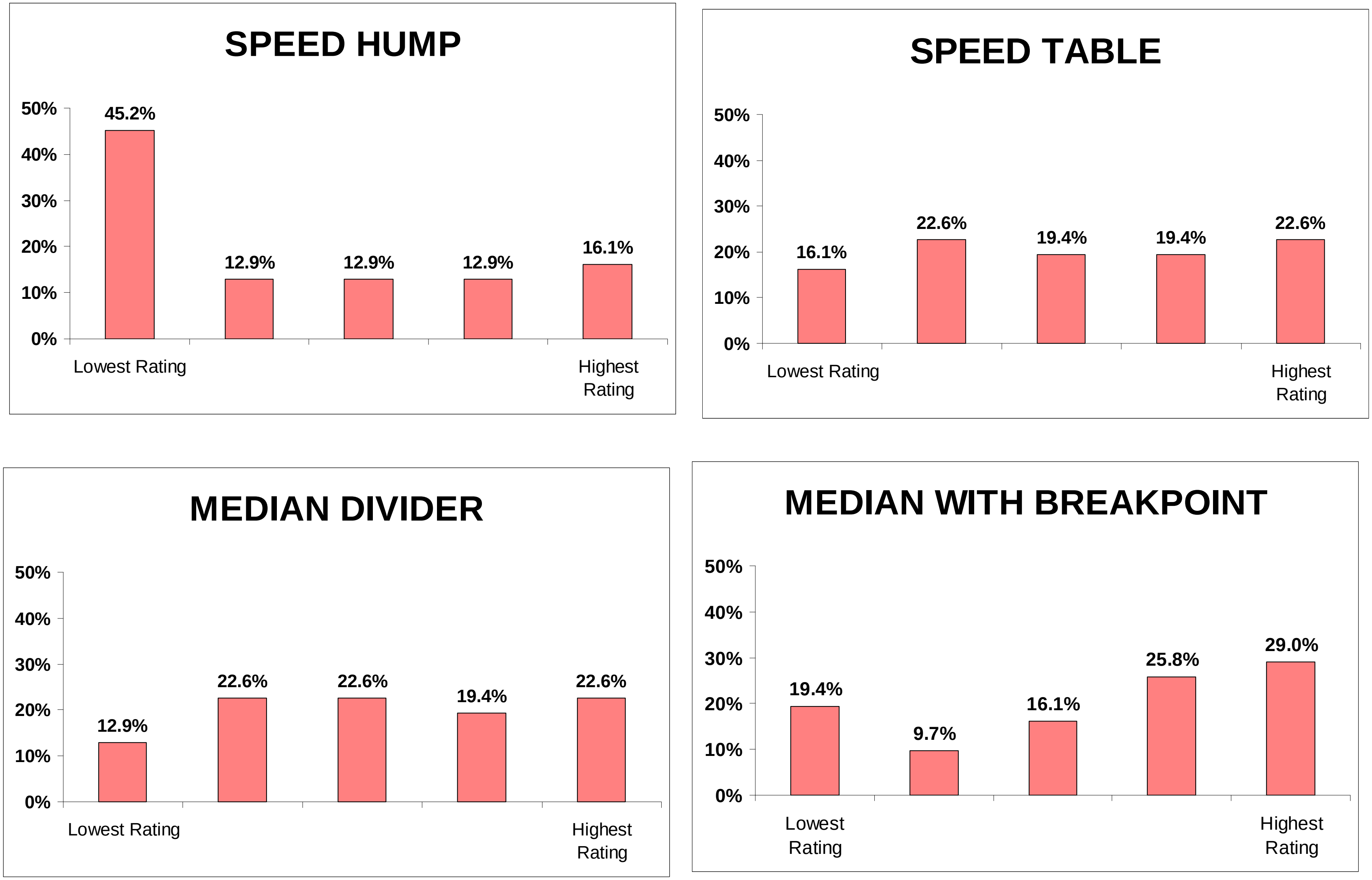

Figure 64. Driver Convenience Rating - Route 67, Fort Lee

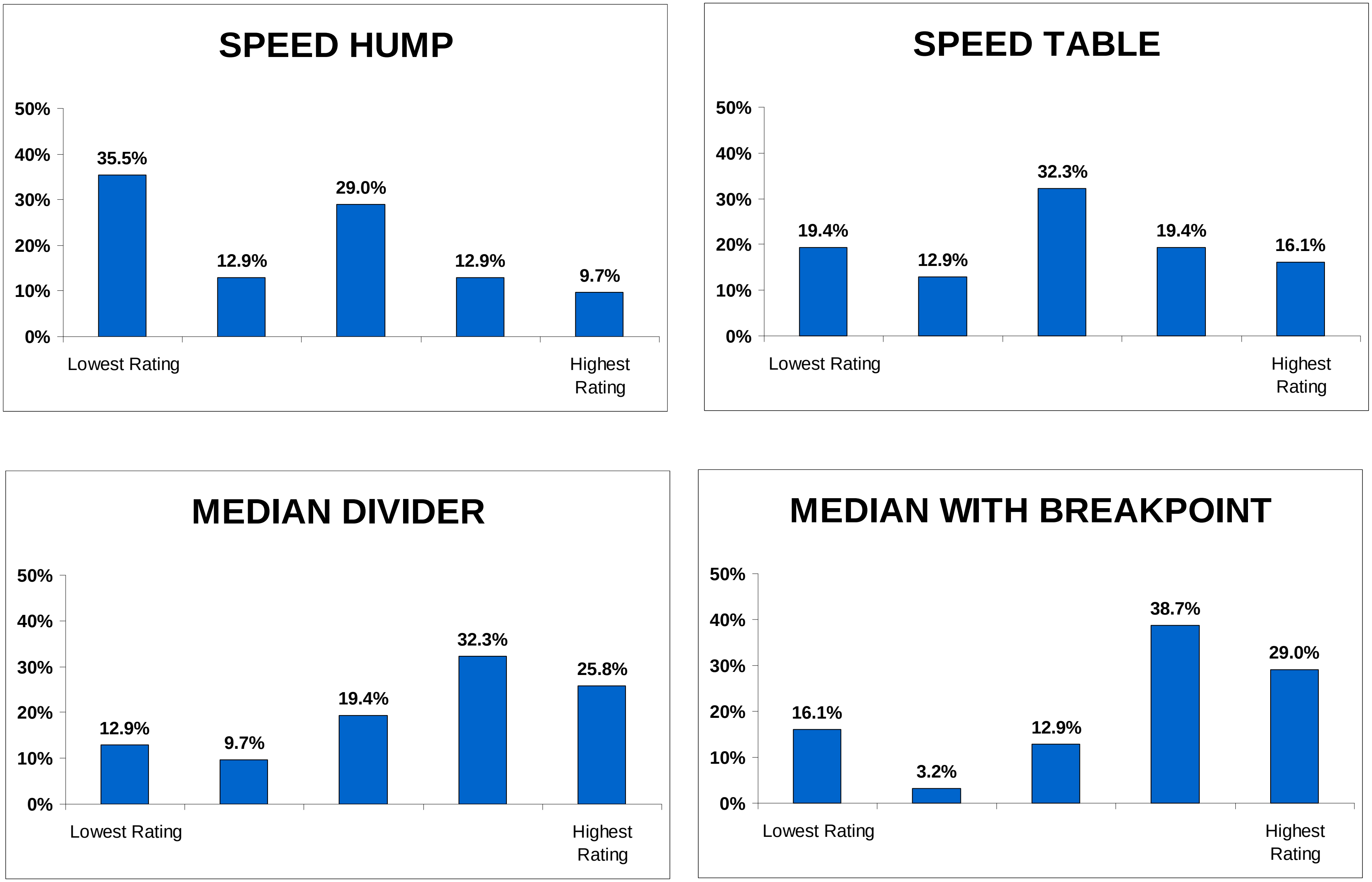

Figure 65. Aesthetic Rating - Route 67, Fort Lee

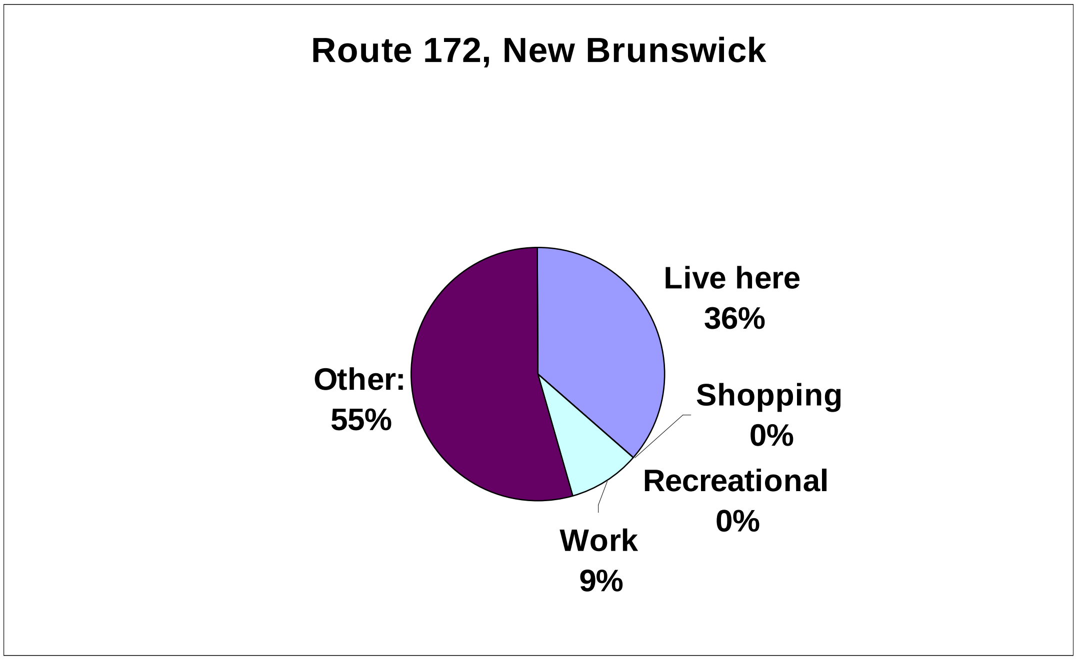

Figure 66. Purpose for Trip – Route 172, New Brunswick

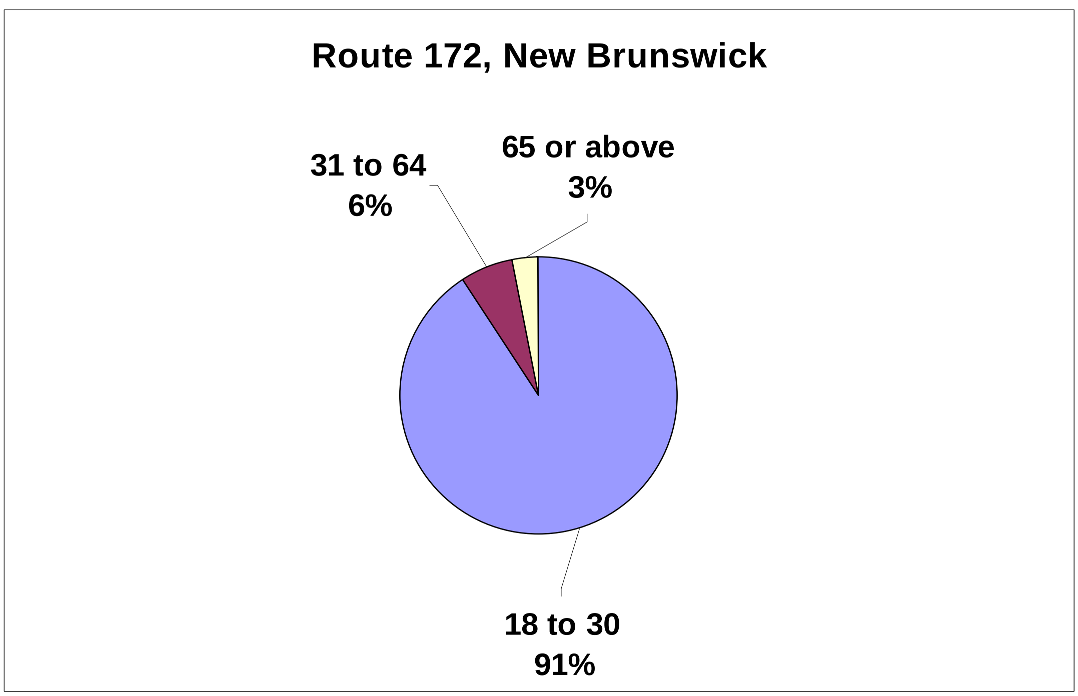

Figure 67. Age of Respondent – Route 172, New Brunswick

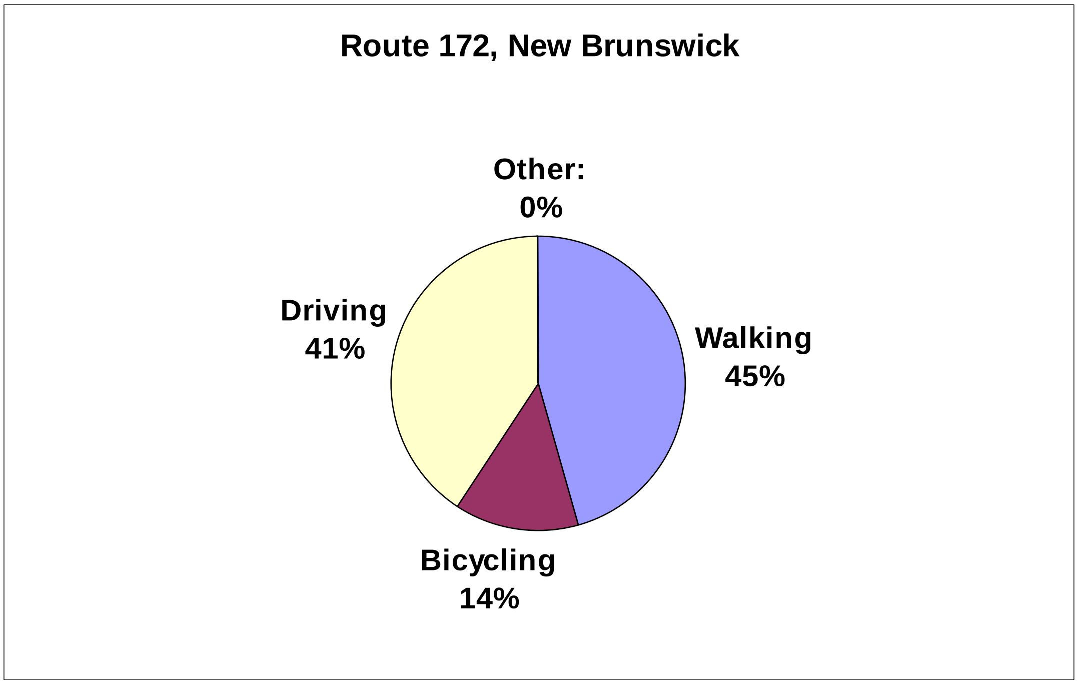

Figure 68. Primary Mode of Transportation – Route 172, New Brunswick

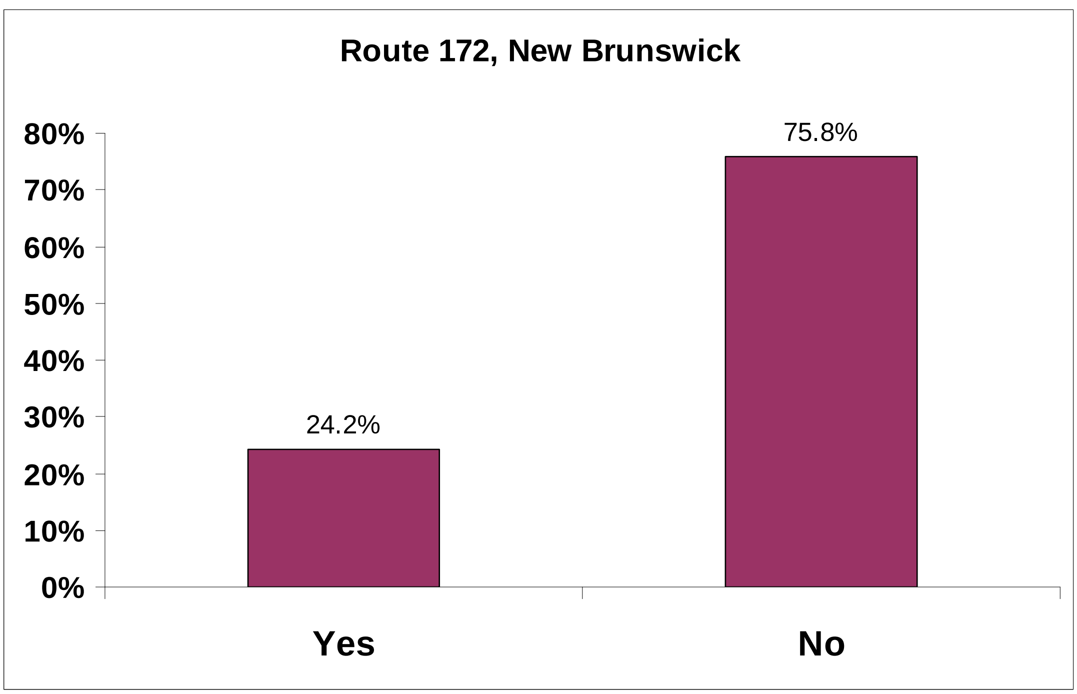

Figure 69. Safety of Roadway – Route 172, New Brunswick

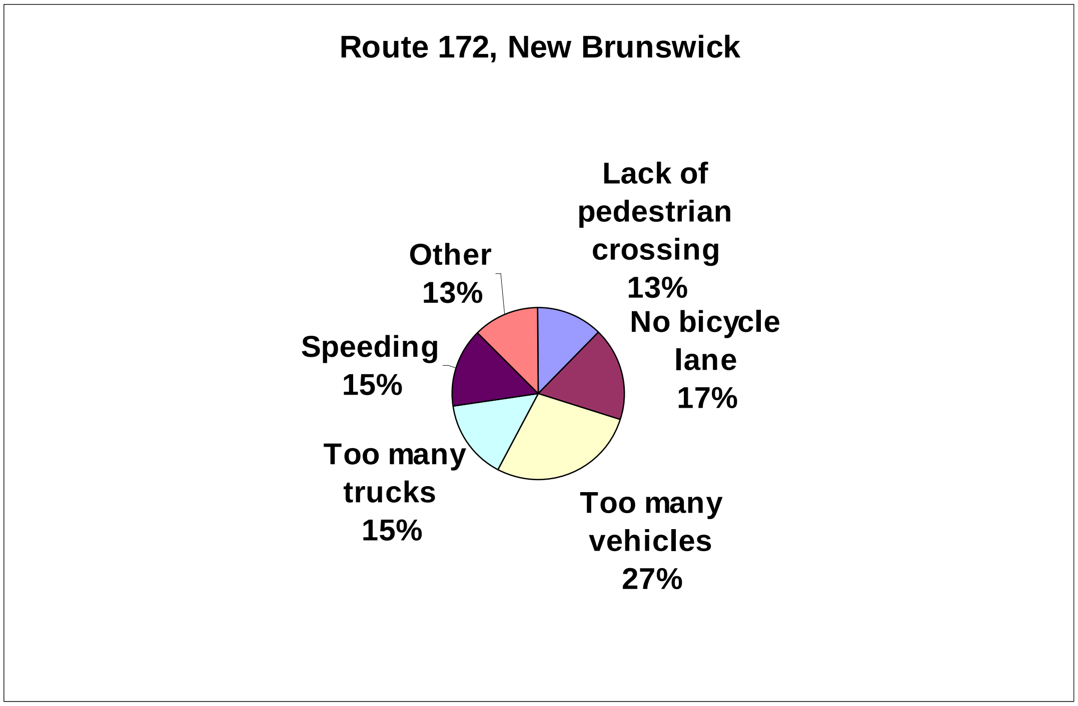

Figure 70. Reasons for Unsafe Roadway – Route 172, New Brunswick

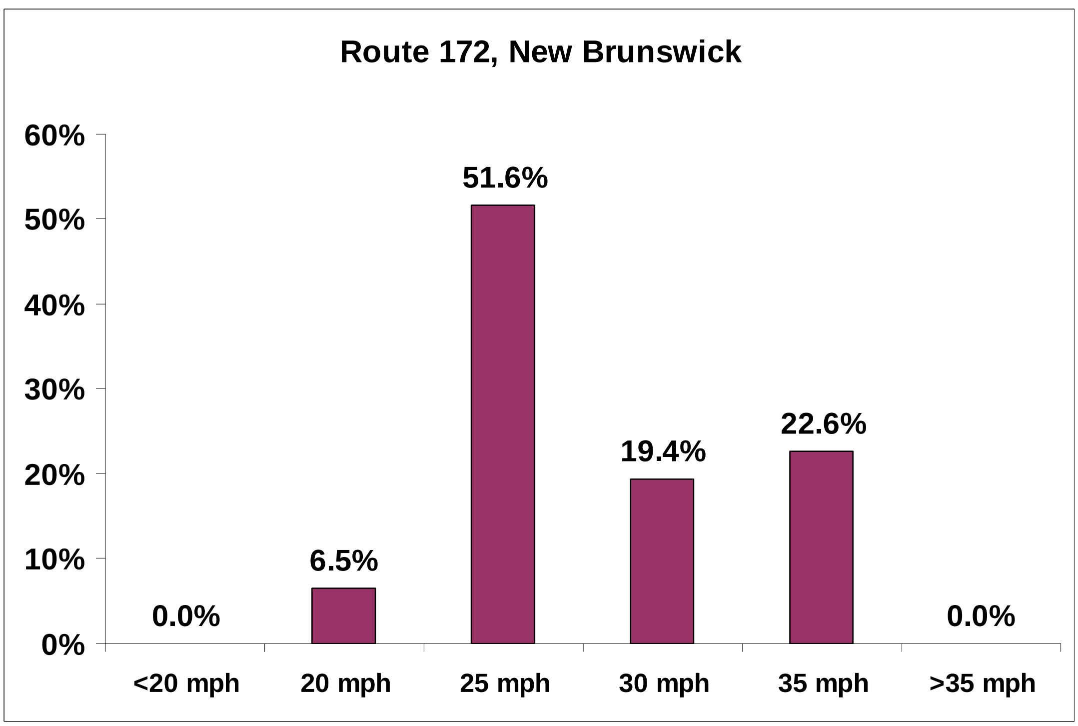

Figure 71. Safe Speed for Roadway – Route 172, New Brunswick

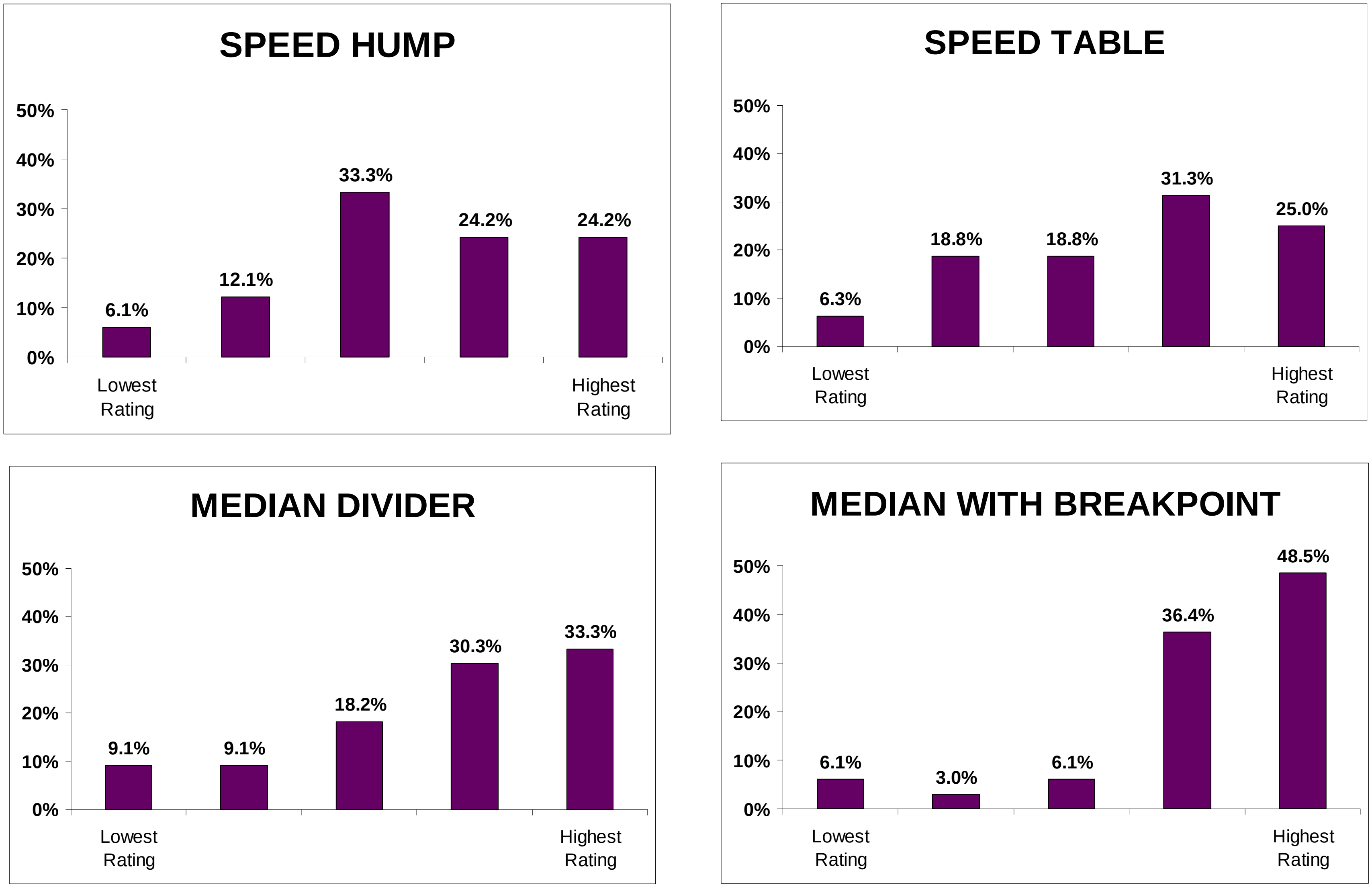

Figure 72. Pedestrian/Bicyclists Safety Rating – Route 172, New Brunswick

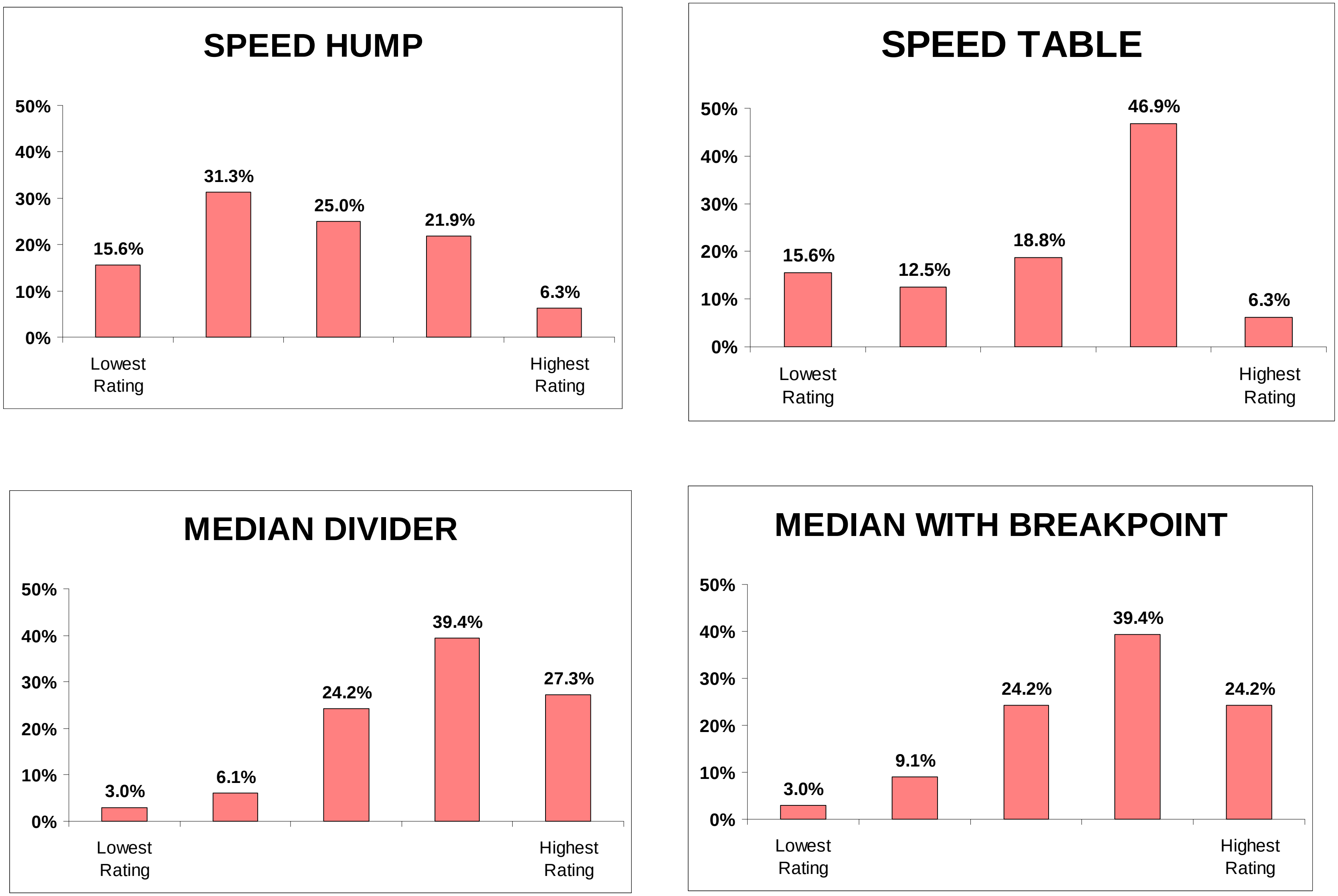

Figure 73. Driver Convenience – Route 172, New Brunswick

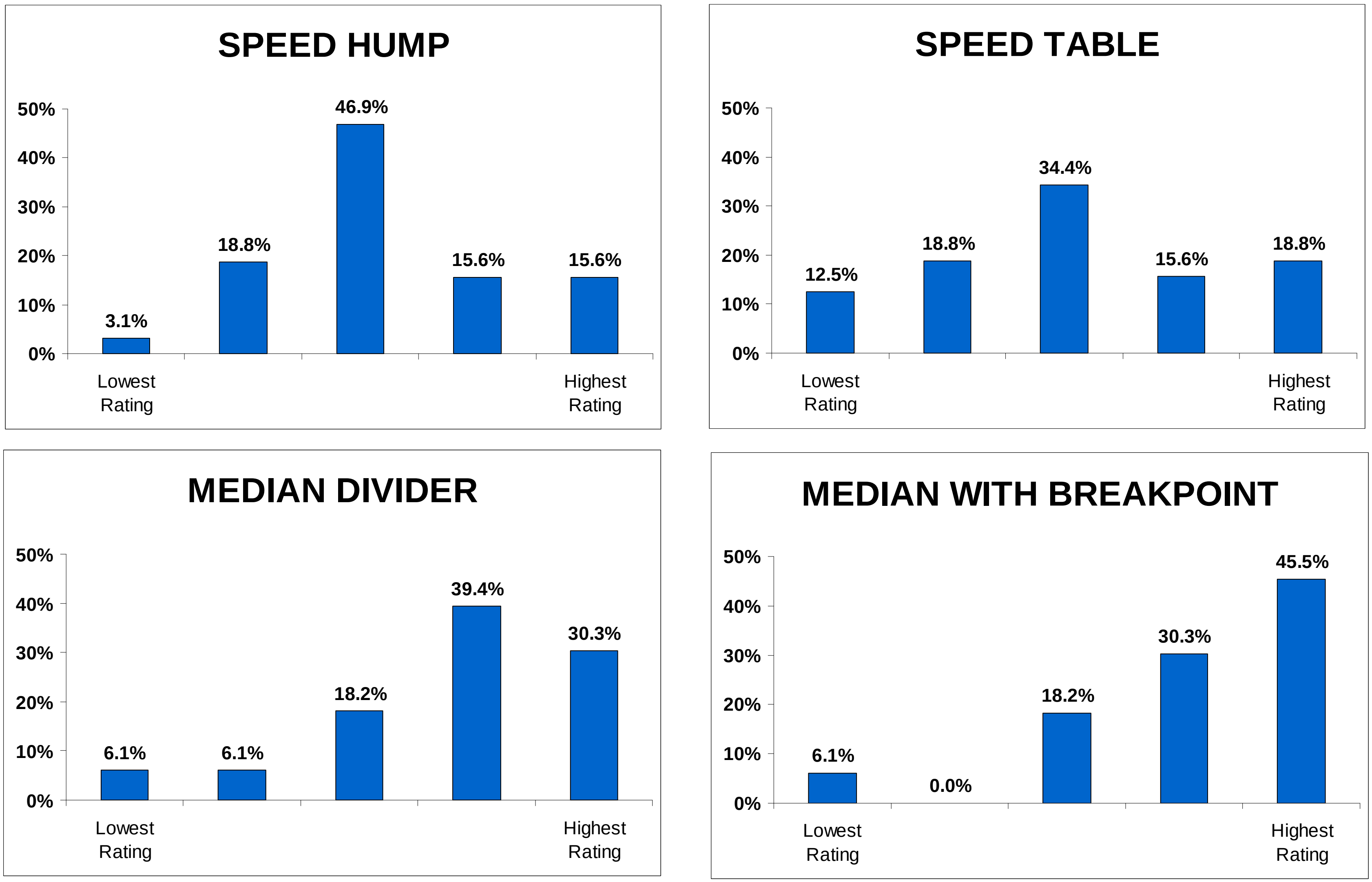

Figure 74. Aesthetic Rating – Route 172, New Brunswick

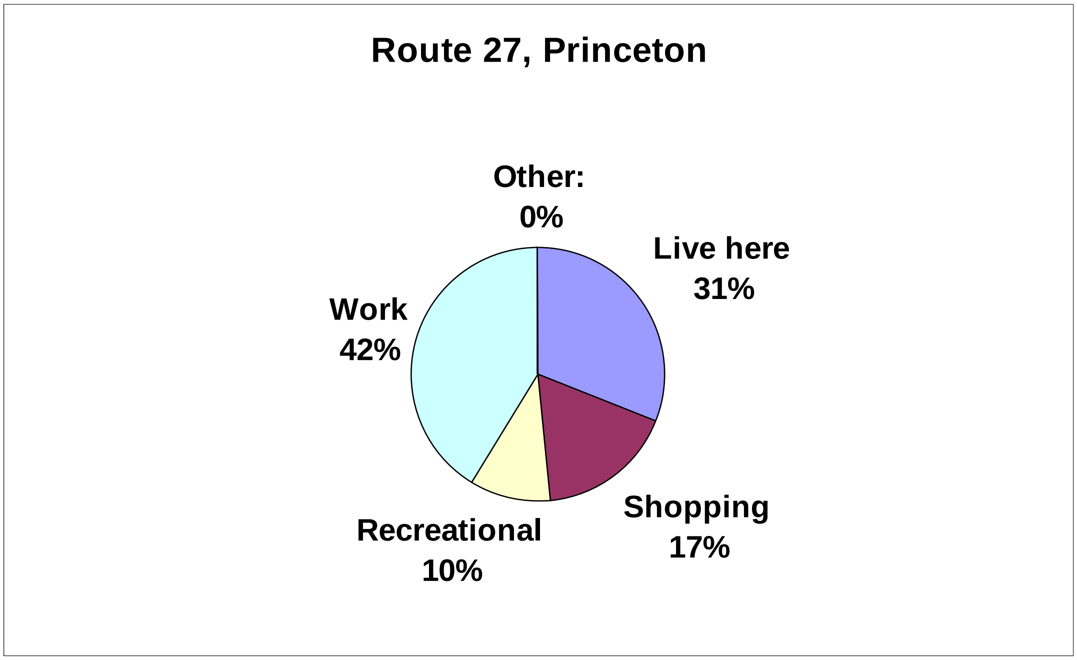

Figure 75. Purpose of Trip – Route 27, Princeton

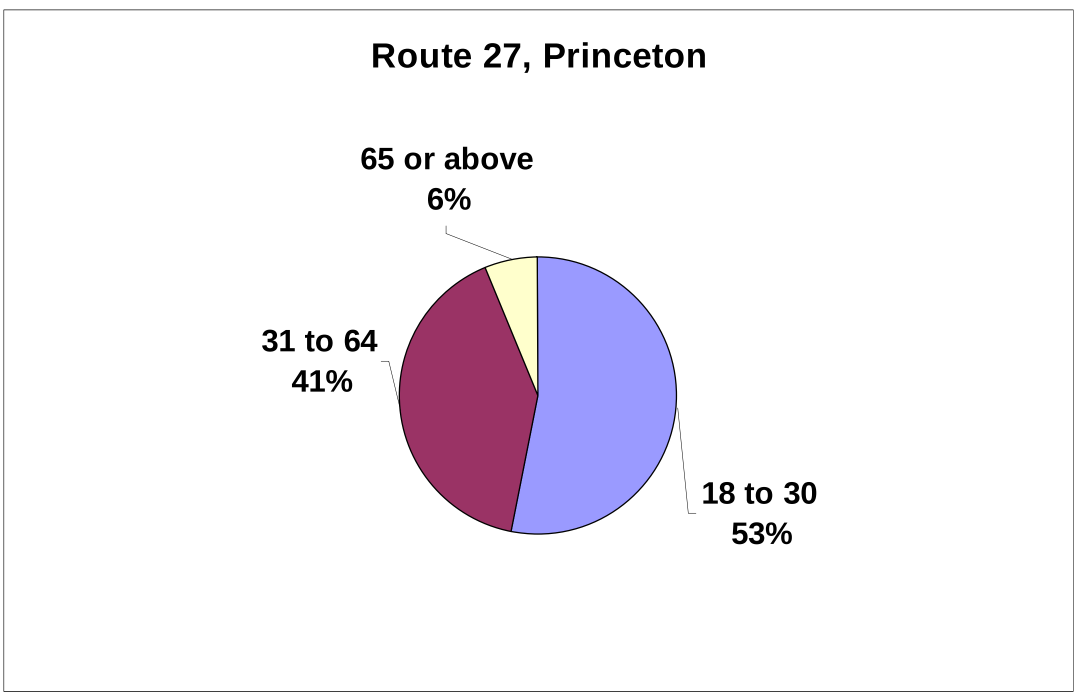

Figure 76. Age of Respondent – Route 27, Princeton

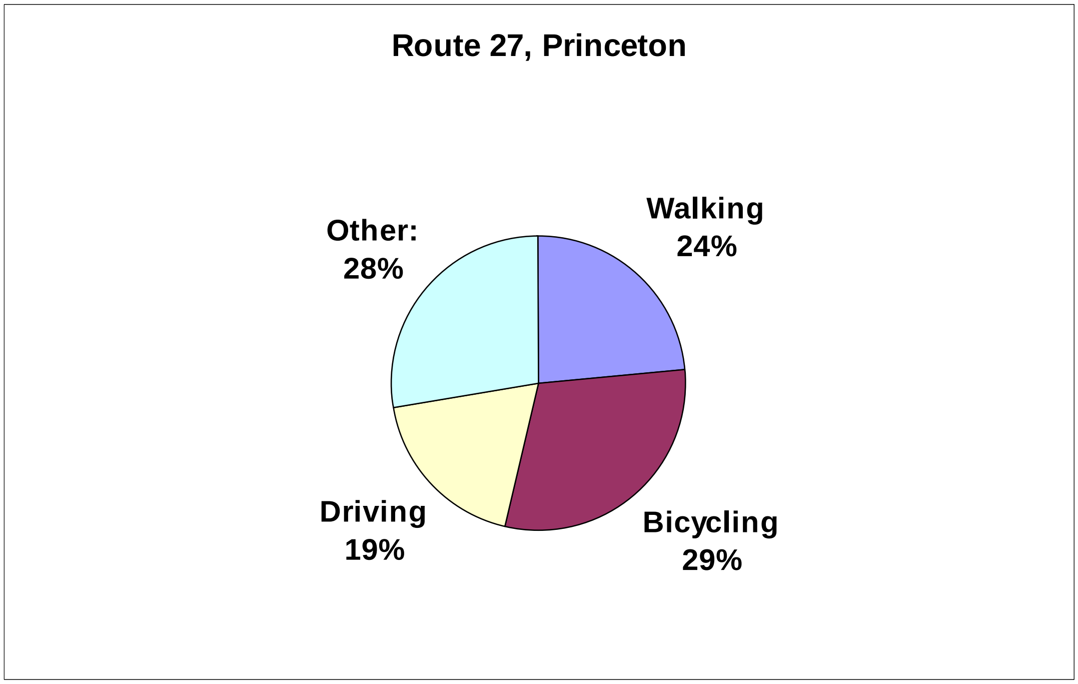

Figure 77. Primary Mode of Transportation – Route 27, Princeton

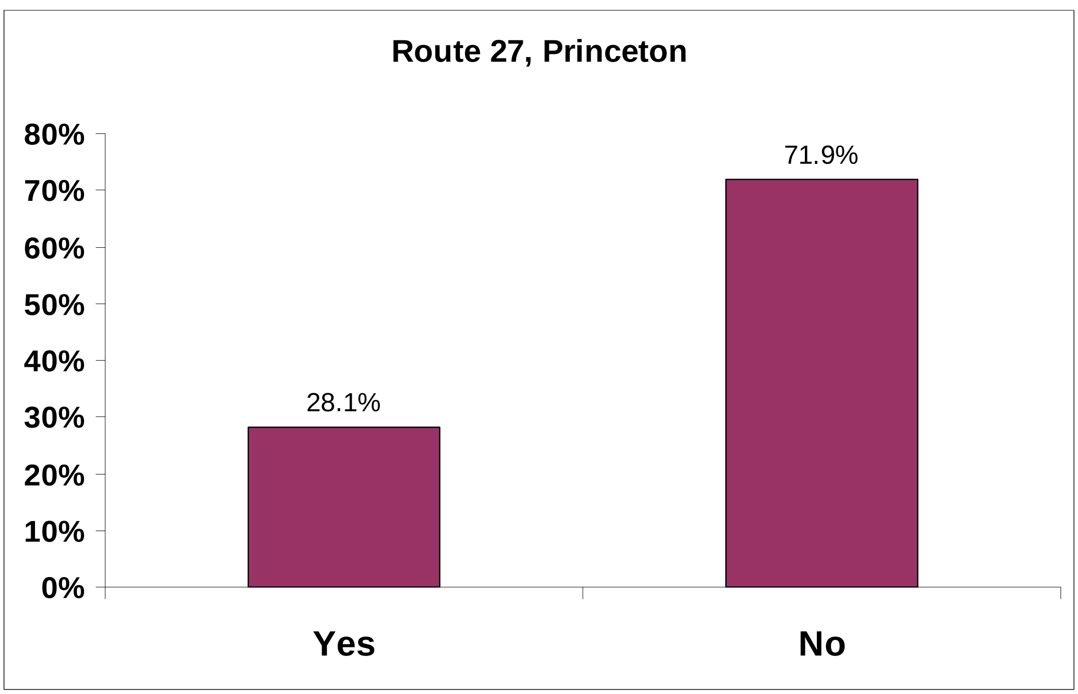

Figure 78. Safety of Roadway – Route 27, Princeton

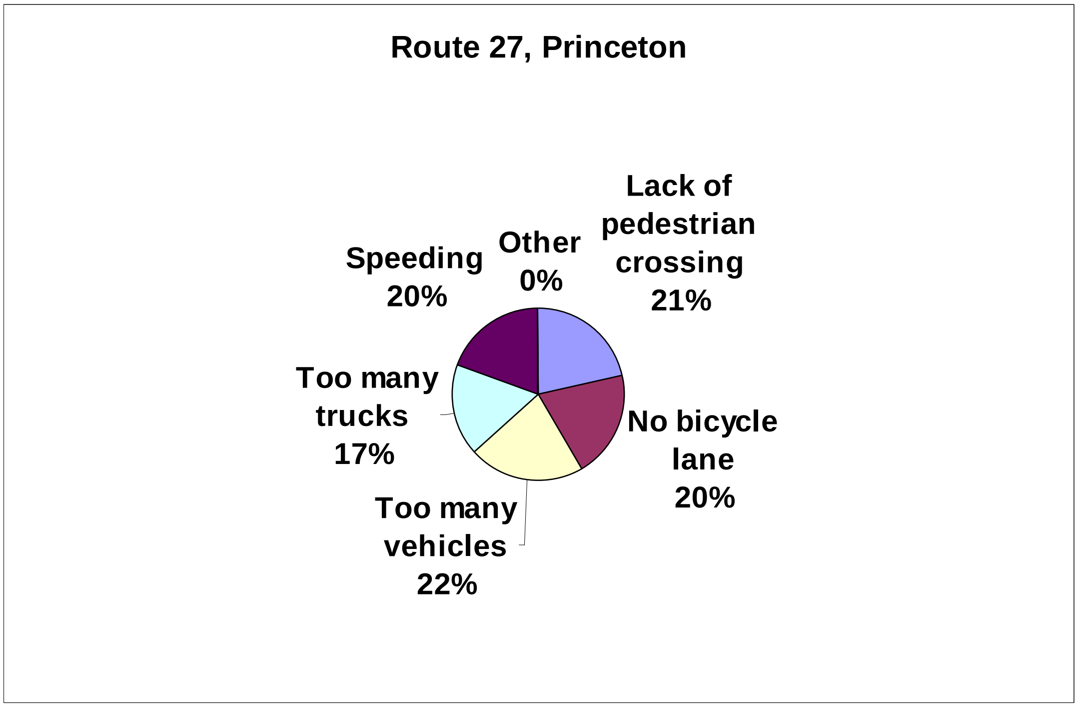

Figure 79. Reasons for Unsafe Roadway – Route 27, Princeton

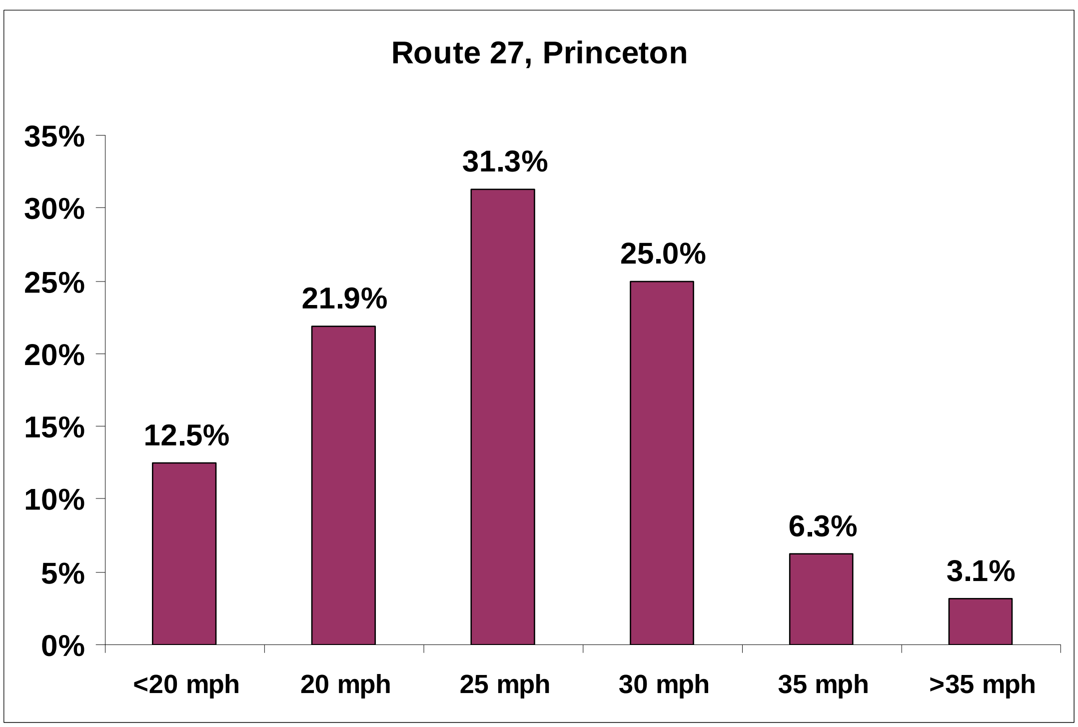

Figure 80. Safe Speed of Roadway – Route 27, Princeton

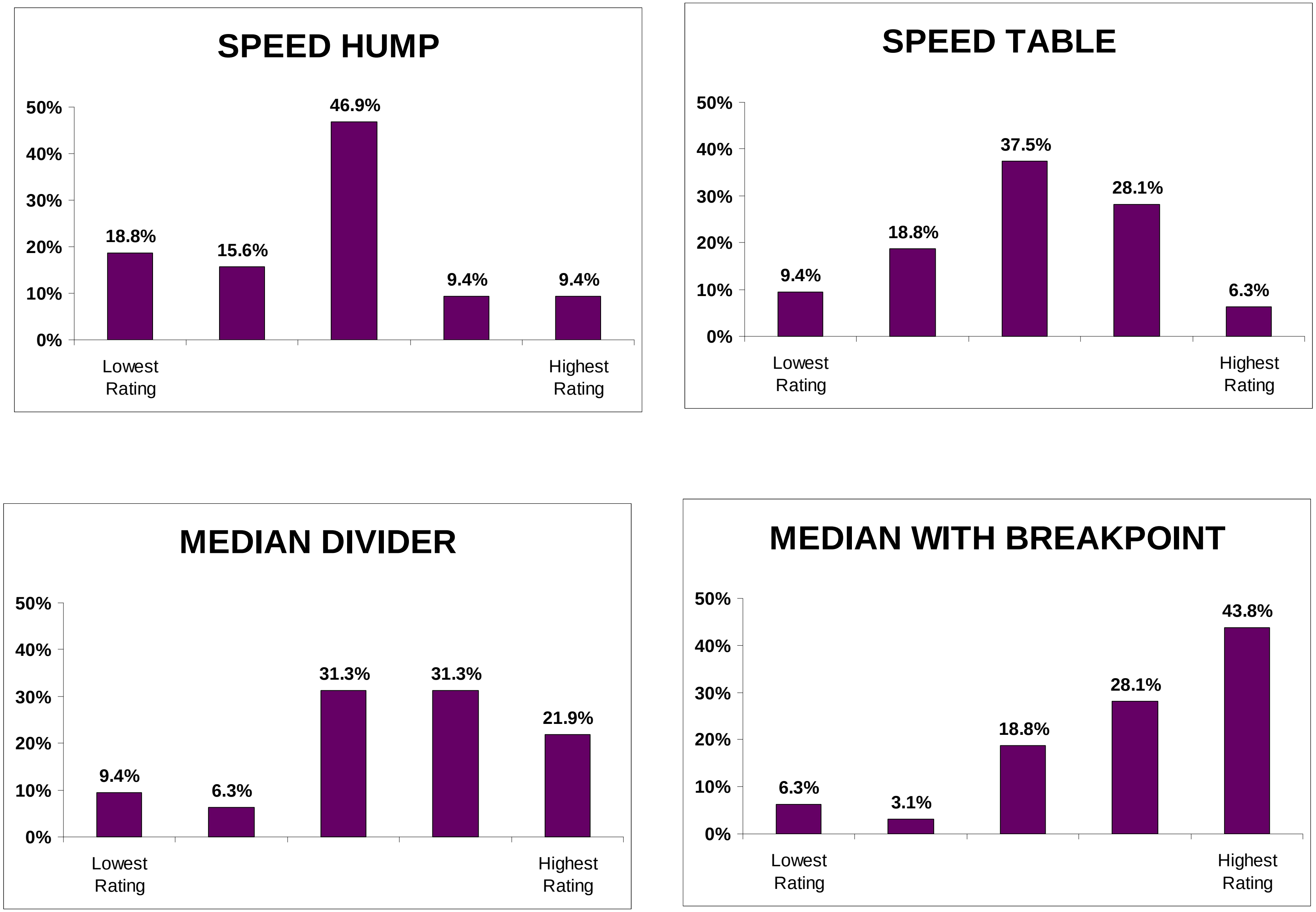

Figure 81. Pedestrian/Safety Rating – Route 27, Princeton

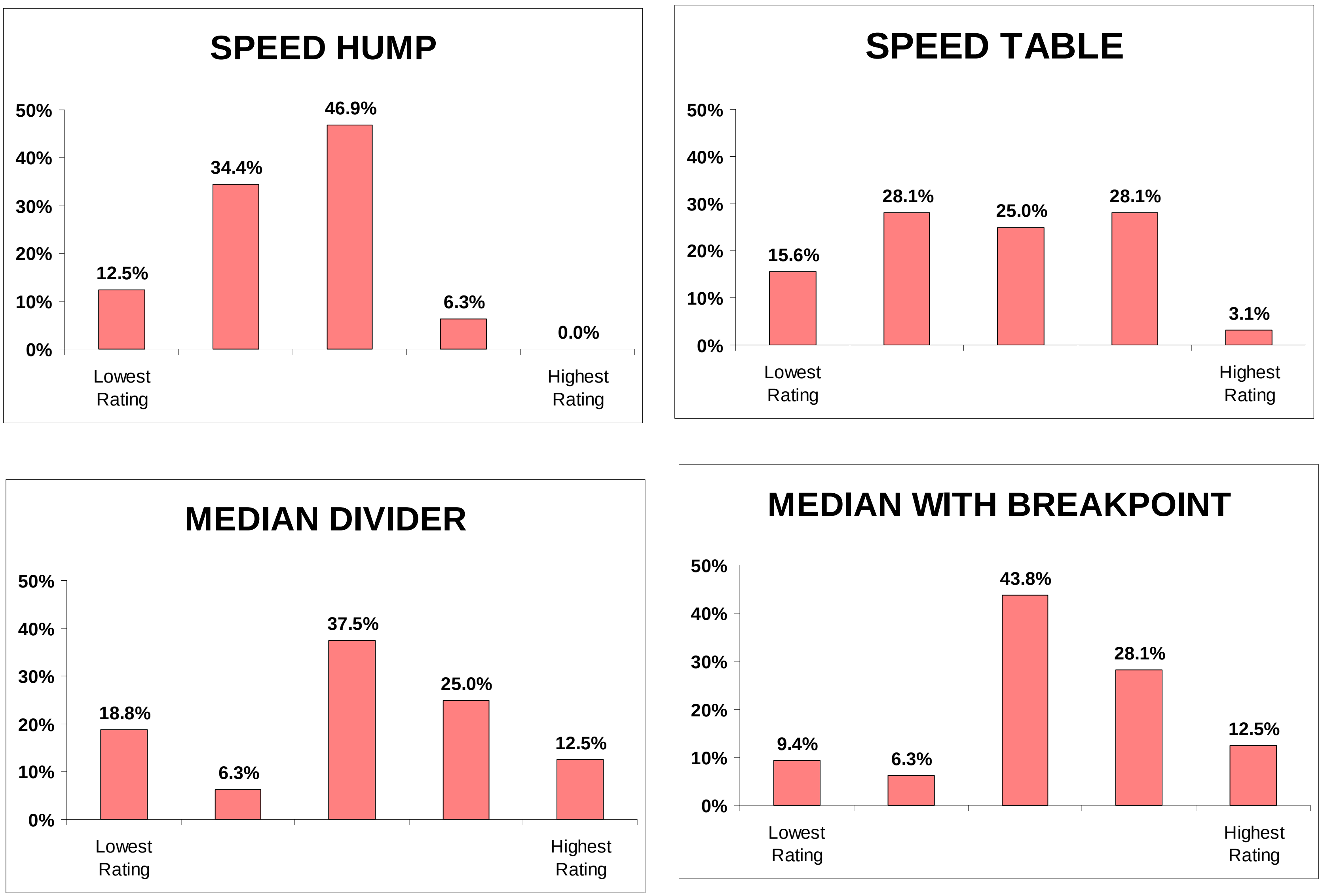

Figure 82. Driver Convenience Rating – Route 27, Princeton

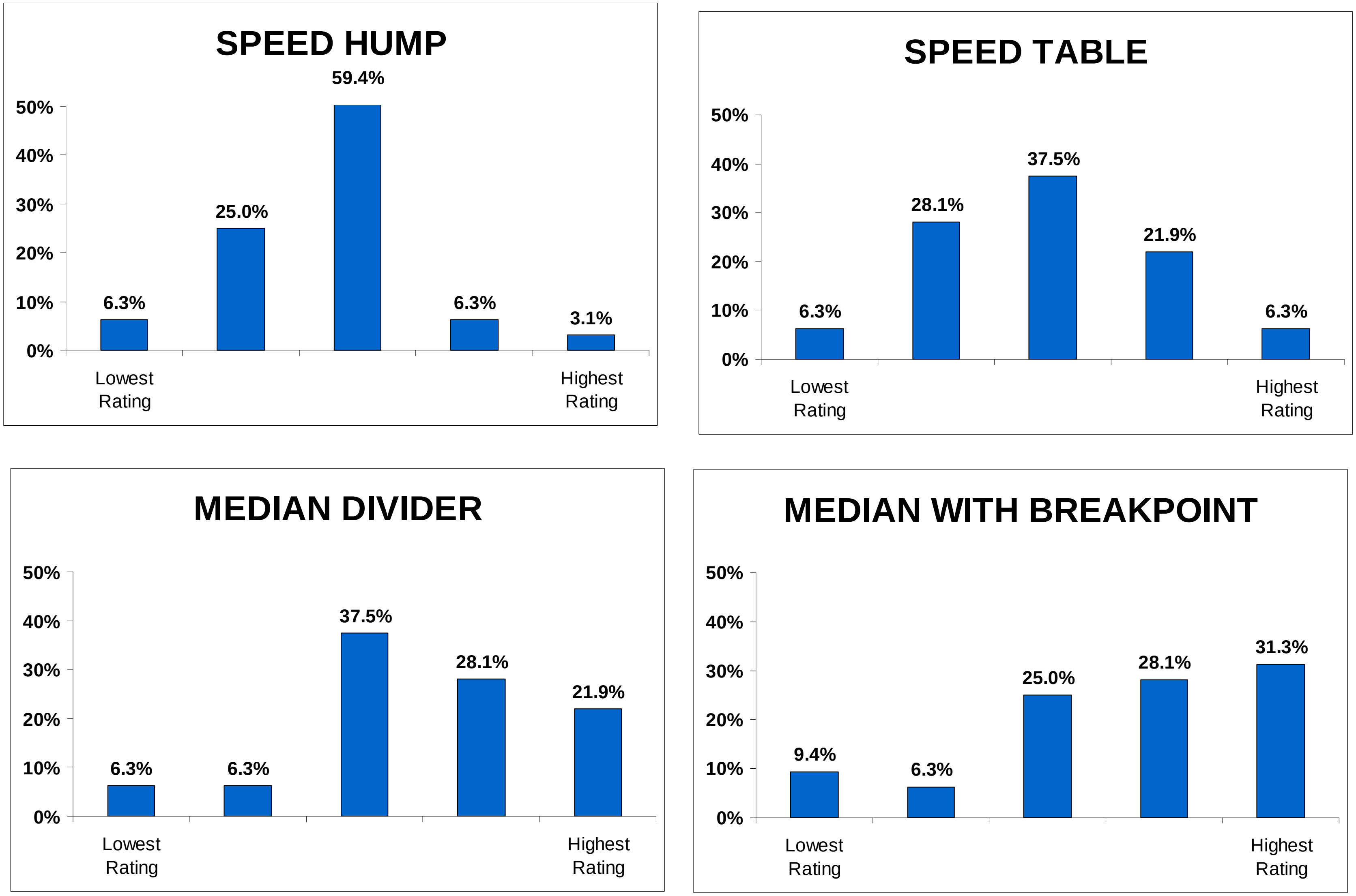

Figure 83. Aesthetic Rating – Route 27, Princeton

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